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National Inventory Report for the German Greenhouse Gas Inventory 1990-2024

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Contact

This report was created as part of the work of the National Coordination Office (Single Entity) for the *National System of Emissions Inventories* (Nationales System Emissionsinventare; NaSE) based at the German Environment Agency (UBA). Contributions for the chapters on agriculture, land use, land-use change and forestry were prepared by the Thünen Institute (TI).

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List of abbreviations

Abbreviation	Explanation
AbfAblV	Ordinance on Environmentally Compatible Storage of Waste from Human Settlements and on Biological Waste Treatment Facilities (Abfallablagerungsverordnung)
ABL	Old federal states (alte Bundesländer)
AGEB	Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen)
AGEE-Stat	Arbeitsgruppe Erneuerbare Energien-Statistik (Working Group on Renewable Energy Statistics)
AK	Working group (Arbeitskreis)
ALH	All other deciduous/broadleaf trees with high life expectancies (NFI tree species group)
ALN	All other deciduous/broadleaf trees with low life expectancies (NFI tree species group)
ANCAT	Abatement of Nuisances from Civil Air Transport
AD	Activity data
ARD	Afforestation, reforestation, deforestation
ARR	Annual Review Report
ATKIS	Official topographic-cartographic information system (Amtliches Topographisch-Kartographisches Informationssystem)
AWMS	Animal Waste Management System
BAFA	Federal Office for Economic Affairs and Export Control (Bundesamt für Wirtschaft und Ausfuhrkontrolle)
BAT	Best Available Technique
BDSI	Association of the German Confectionery Industry (Bundesverband der Deutschen Süßwarenindustrie e.V.)
BDZ	Federal Association of the German Cement Industry (Bundesverband der Deutschen Zementindustrie)
BEF	Biomass expansion factors
BEU	Balance of emissions sources for stationary and mobile combustion processes (Bilanz der Emissionsursachen für stationäre und mobile Verbrennungsprozesse)
BGR	Federal Institute for Geosciences and Raw Materials (Bundesanstalt für Geowissenschaften und Rohstoffe)
BGS	Fuel, gas and electricity industries of blast furnaces, steelworks and rolling mills; and forging plants, press works and hammer mills, including the various other plants (without their own coking plants) publicly connected to such operations
BGW	Federal Association of the German Gas and Water Industry (Bundesverband der deutschen Gas- und Wasserwirtschaft)
BHD	Diameter at breast height (= DBH; tree trunk diameter at a height of 1.30 m above the ground)
BHKW	Combined heat and power (CHP) unit (Blockheizkraftwerk)
BKG	Federal Agency for Cartography and Geodesy (Bundesamt für Kartographie und Geodäsie)
BImSchV	Ordinance on the Implementation of the Federal Immission Control Act (Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes)

Abbreviation	Explanation
BML	cf. BMEL
BMLEH	Federal Ministry of Agriculture, Food and Regional Identity (Bundesministerium für Landwirtschaft, Ernährung und Heimat)
BMUV	Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz)
BMUB	cf. BMU
BMUK	cf. BMU
BMU	cf. BMUV Federal Environment Ministry currently, cf. https://www.bundesumweltministerium.de/impressum
BMEL	Federal Ministry of Food and Agriculture (Bundesministerium für Ernährung und Landwirtschaft)
BMELV	cf. BMEL
BMVEL	cf. BMEL
BMVG	Federal Ministry of Defence (Bundesministerium der Verteidigung)
BMWA	cf. BMWi
BMWE	cf. BMWi
BMWK	Federal Ministry for Economic Affairs and Climate Action (Bundesministerium für Wirtschaft und Klimaschutz)
BMWi	Federal Ministry for Economic Affairs (Bundeswirtschaftsministerium)
BoHE	Main survey on soil use (Bodennutzungshaupterhebung)
BREF	BAT (Best Available Technique) Reference Documents
BSB	Biological oxygen demand (= BOD; Biologischer Sauerstoffbedarf)
BSB_5	Biological oxygen demand within 5 days (BOD5)
BV Kalk	German Lime Association (Bundesverband der Deutschen Kalkindustrie)
BÜK	Soil overview map (Bodenübersichtskarte)
BWI	National Forest Inventory (= NFI Bundeswaldinventar)
BWP	Bundesverband Wärmepumpe e.V. (German Heat Pumps Association)
BZE	Forest Soil Inventory (Bodenzustandserhebung im Wald)
CAPIEL	Coordinating Committee for the Associations of Manufacturers of Industrial Electrical Switchgear and Controlgear in the European Union
CEFIC	European Chemical Industry Council (French name: Conseil Européen des Fédérations de l'Industrie Chimique)
CFC	Chlorofluorocarbons (= Fluorchlorkohlenwasserstoffe (FCKW))
CFI	Continuous Forest Inventory
CH_4	Methane
C_{org}	Organic carbon stored in the soil
CO	Carbon monoxide
CO_2	Carbon dioxide
CORINAIR	Coordination of Information on the Environment, sub-project: Air

Abbreviation	Explanation
CORINE	Coordinated Information on the Environment
CRF	Common Reporting Format
CRT	Common Reporting Table
CSB	Chemical oxygen demand (COD)
CVD	Chemical vapour deposition
D	Germany
DBFZ	German centre for biomass research (Deutsches Biomasseforschungszentrum)
DEHSt	German Emissions Trading Authority (Deutsche Emissionshandelsstelle)
DESTATIS	Federal Statistical Office (official abbreviation: StBA)
DFIU	Franco-German Institute for Environmental Research, at the University of Karlsruhe (Deutsch-Französisches Institut für Umweltforschung an der Universität Karlsruhe)
DG	Landfill gas (Deponie gas)
DGMK	German Association of Oil, Natural Gas and Coal Science (Deutsche Wissenschaftliche Gesellschaft für Erdöl, Erdgas und Kohle e.V.)
DIN	DIN standard (Deutsche Industrienorm)
DIW	German Institute for Economic Research (Deutsches Institut für Wirtschaftsforschung)
DLR	German Aerospace Center (Deutsches Zentrum für Luft- and Raumfahrt)
DME	Dimethyl ether
DMKW	Diesel power stations (Dieselmotorkraftwerke)
D_N	Nitrogen in wastewater
DOC	Degradable organic carbon
DOC_F	Fraction of DOC dissimilated (converted into landfill gas)
DSWF	Forest Fund Database of the former GDR (Datenspeicher Waldfonds)
DTKW	Steam turbine power stations (Dampfturbinenkraftwerke)
DVGW	German Association of the Gas and Water Industry (Deutsche Vereinigung des Gas- und Wasserfachs e.V.)
D7	Tree trunk diameter at a height of 7 m above the ground
EBZ	Energy Balance line in the BEU (Energiebilanzzeile)
EEA	European Environment Agency
EECA	European Electronic Component Manufacturers Association
EEG	Renewable Energy Sources Act (Federal Law Gazette (BGBl) Part I No. 40 of 31 July 2004, pp. 1918 ff)
EF	Emission factor
EI	Emission index = emission factor
E_{KA}	Inhabitant connected to wastewater treatment system
EL	Fuel oil EL (EL = easily liquid)
EM	Emission(s)
EMEP	Cooperative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe

Abbreviation	Explanation
EMEV	Emissions-relevant energy consumption (Emissionsrelevanter Energieverbrauch)
ERT	Expert Review Team
ESIA	European Semiconductor Industry Association
ETS	EU Emissions Trading Scheme
EU	European Union
EU-EHETS	EU Emissions Trading System
EUROCONTROL	European Organisation for the Safety of Air Navigation
EUROSTAT	Statistical Office of the European Communities
EW	Population (Einwohnerzahl)
EXIBA	European Extruded Polystyrene Insulation Board Association
FA	Combustion systems (Feuerungsanlagen)
FAP	Specialised contact person in the NaSe (Fachlicher Ansprechpartner)
FAL	Federal Agricultural Research Institute (as of 2008: cf. TI)
FAO	United Nations Food and Agriculture Organisation
FCKW	Chlorofluorocarbons (CFC)
F gases	Fluorinated greenhouse gases
FHW	District heating stations (Fernheizwerke)
PFC	Perfluorocarbons (PFC)
FKZ	Research project number (Forschungskennzahl)
FNN	Forum Network Technology/Network Operation in the VDE
FPX	Professional polystyrene association (Fachverband Polystyrol-Extruderschaumstoff e.V.)
FV	Responsible expert (Fachverantwortlicher) in the NaSE
FWL	Thermal output from combustion (Feuerungswärmeleistung)
GEREF	GERman Emission Factor Database
GFA	Large combustion systems (Großfeuerungsanlagen)
GG	Total weight (Gesamtgewicht)
GIS	Gas-insulated switching systems
GMBL	Joint Ministerial Gazette (Gemeinsames Ministerialblatt)
GMES	Global Monitoring for Environment and Security
GMKW	Gas-fired power stations (Gasmotorkraftwerke)
GPG	Good Practice Guidance
GSE FM-INT	GMES Services Elements Forest Monitoring: Inputs for national greenhouse gas reporting
GT	Gas turbines
GTKW	Gas turbine power stations
GuD	Gas and steam turbine power stations,
GWP	Global Warming Potential
HFC	Hydrofluorocarbon (HFKW)

Abbreviation	Explanation
HFCKW	Hydrochlorofluorocarbon
HFE	Hydrofluoroether
HFC	Hydrofluorocarbon
Hi	Calorific value (Heizwert)
HK	Key category (Hauptkategorie); is applied to both emissions sources and sinks
HS	High voltage (Hochspannung)
HS-GIS	High voltage and gas-insulated switching systems (Hochspannungs- und Gasisolierte Schaltanlagen)
IAI	International Aluminium Institute
ICE	Intercity Express
ICR	In-country review
IE	Included elsewhere
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IEF	Implied emission factor
IfE	Institute for Energy (Institut für Energetik)
IFEU	Institute for Energy and Environmental Research (Institut für Energie- und Umweltforschung)
IKW	Industrial power stations (Industriekraftwerke)
IMA	Interministerial Working Group (Interministerielle Arbeitsgruppe)
IPCC	Intergovernmental Panel On Climate Change
IS08	Inventory Study 2008 (Inventurstudie 2008)
IVPU	German industry association for rigid polyurethane foam (Industrieverband Polyurethan-Hartschaum)
K	Fuel input for power generation (direct drive)
k.A.	No data (keine Angabe)
KCA	Key category analysis
KP	Kyoto Protocol
KS	Sewage sludge (Klärschlamm)
KTBL	Association for Technology and Structures in Agriculture (Kuratorium für Technik und Bauwesen in der Landwirtschaft)
l	Level (= Level assessment pursuant to IPCC Good Practice Guidance)
LF	Agriculturally used land (landwirtschaftlich genutzte Flächen)
LKW	Truck (Lastkraftwagen)
LTO	Landing/take-off cycle
LUCF	Land Use Change and Forestry
LULUCF	Land Use, Land Use Change and Forestry
MBA	Mechanical-biological waste treatment (Mechanisch-Biologische Abfallbehandlung)
MCF	Methane Conversion Factor

Abbreviation	Explanation
MDI	Metered dose inhaler
MMR	Monitoring Mechanism Regulation 525/2013
MS	Medium voltage (Mittelspannung)
MSW	Municipal solid waste
MVA	Waste incineration plant (Müllverbrennungsanlage)
MW	Megawatt
N	Nitrogen
N_2O	Nitrous oxide
NA	Not applicable
NASA	National Aeronautics and Space Administration
NaSE	German National System of Emissions Inventories (Nationales System Emissionsinventare)
NBL	New German federal states (neue Bundesländer)
NE	Not estimated
NEAT	Non-energy Emission Accounting Tables
NEC	Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain air pollutants
NEV	Non-energy-related consumption (nichtenergetischer Verbrauch)
NF_3	Nitrogen trifluoride
NFR	New Format on Reporting, Nomenclature for Reporting to the UN ECE
NFZ	Commercial vehicles (Nutzfahrzeuge)
NH_3	Ammonia
NIR	National Inventory Report
NID	National Inventory Document
NMVOC	Non-Methane Volatile Organic Compounds
NO	Not occurring
NO	Nitrogen monoxide
NSCR	Non-selective catalytic reduction
OCF	One component foam (installation foam)
ODS	Ozone depleting substances
ORC	Organic Rankine Cycle
OX	Oxidation factor
PAH	Polycyclic aromatic hydrocarbons
PAKXXX	Polycyclic aromatic hydrocarbons
PARTEMIS	Measurement and prediction of emissions of aerosols and gaseous precursors from gas turbine engines
PCDD/F	Polychlorinated dibenzo-dioxins/-furans
PF	Process combustion (Prozessfeuerungen)
PFC	Perfluorocarbons

Abbreviation	Explanation
PFPE	Perfluoropolyethers
PFPMIE	Perfluoropolymethylisopropyl ether
PKW	Passenger car (Personenkraftwagen)
PU	Polyurethane
Py-GAS-EM	Python-based GASeous EMissions (programme for calculation of agricultural emissions)
QC	Quality control
QA	Quality assurance
QSE	Quality System for Emissions Inventories
REA	Flue-gas desulphurising plant (Rauchgasentschwefelungsanlage)
ROE	Oil equivalent (OE; Rohöleinheit)
RSt	Raw steel
RWI	Rheinisch-Westfälisches Institut für Wirtschaftsforschung
S	Fuel input for electricity generation
S	Heating oil, heavy (high viscosity; “Heizöl S”)
S&A report	Synthesis and Assessment Report
SA	Heating oil, heavy (high viscosity; low sulphur content; “Heizöl SA”)
SCR	Selective Catalytic Reduction
SE	Sampling error
SF_6	Sulphur hexafluoride
SKE	Hard coal equivalents (Steinkohleneinheiten)
SNAP	Selected Nomenclature for Air Pollution
SO_2	Sulphur dioxide
StBA	Federal Statistical Office (Statistisches Bundesamt Deutschland)
STEAG	STEAG Aktiengesellschaft (large electricity producer in Germany)
T	Trend (= trend assessment pursuant to IPCC Good Practice Guidance, in the category overview tables)
TA Luft	Technical directive on air quality control; First General Administrative Provision on the Federal Immission Control Act (Clean Air Directive; Technische Anleitung zur Reinhaltung der Luft)
TAN	Total Ammoniacal Nitrogen
TFT	Thin-film transistor
GHG	Greenhouse gas
TI	Johann Heinrich von Thünen Institute
TI-AK	Johann Heinrich von Thünen Institute, Institute of Climate-Smart Agriculture (Institut für Agrarklimaschutz)
TI-WO	Johann Heinrich von Thünen Institute, Institute of Forest Ecosystems (Institute für Waldökosysteme)
TM	Dry matter
TOC	Total Organic Carbon

Abbreviation	Explanation
TREMOD	Traffic Emission Estimation Model
TS	Dry matter (Trockenstoff)
TÜV	Technischer Überwachungsverein (Certifying body for technical and product safety)
TVF	American tonne of usable production (Tonne verwertbare Förderung)
UBA	German Environment Agency
UN ECE	United Nations Economic Commission for Europe
UN FCCC	United Nations Framework Convention on Climate Change
UN	United Nations
UStatG	Environmental Statistics Act (Umweltstatistikgesetz)
VDA	German Association of the Automotive Industry (Verband der Automobilindustrie e.V.)
VDE	Association for Electrical, Electronic & Information Technologies (Verband der Elektrotechnik Elektronik Informationstechnik e.V.)
VDEh	German Iron and Steel Institute (Verein Deutscher Eisenhüttenleute; in 2003, renamed “Stahlinstitut VDEh”)
VDEW	German Association of the Automotive Industry (Verband der Automobilindustrie e.V.)
VDI	Association of German Engineers (Verein Deutscher Ingenieure e.V.)
VDKL	German cold storage and logistics association (Verband Deutscher Kühlhäuser und Kühllogistikunternehmen e.V.)
VDMA	German Engineering Federation (Verband Deutscher Maschinen- und Anlagenbau e.V.)
VDN	Association of German network operators (Verband der Netzbetreiber e.V.)
VDZ	German Cement Works Association (Verein Deutscher Zementwerke e.V.)
VGB	Technical association of operators of large power stations (Technische Vereinigung der Großkraftwerksbetreiber e.V.)
VIK	Association of the energy and power industry (Verband der Industriellen Energie- and Kraftwirtschaft e.V.)
VOC	Volatile Organic Compounds
VRF	Variable refrigerant flow
VS	Volatile Solids
W	Fuel input for heat generation
WS	Portion of a specific wastewater treatment system (e.g. aerobic, anaerobic)
WZ	Industrial sector (Wirtschaftszweig)
XPS	Extruded polystyrene
ZSE	Central System of Emissions (CSE)
ZVEI	German Electrical and Electronic Manufacturers’ Association (Zentralverband Elektrotechnik und Elektronikindustrie e.V.)

Units and sizes

Table 1: Multiplication factors, abbreviations, prefixes and symbols

Multiplication factor	Abbreviation	Prefix/symbol	
		Name	Symbol
1,000,000,000,000,000	1015	Peta	P
1,000,000,000,000	1012	Tera	T
1,000,000,000	109	Giga	G
1,000,000	106	Mega	M
1,000	103	Kilo	k
100	102	hecto	h
0.1	10-1	deci	d
0.01	10-2	centi	c
0.001	10-3	milli	m
0,000.001	10-6	micro	µ

Table 2: Units and abbreviations

Abbreviation	Units
°C	degrees Celsius
a	Year
cal	calorie
g	gram
h	hour
ha	hectare
J	joule
m3	cubic metre
ppm	parts per million
ppb	parts per billion
t	tonne
W	watt

Table 3: Standard conversions

Units	is equivalent to
1 tonne (t)	1 megagram (Mg)
1 kilotonne/thousand tonnes (kt)	1 gigagram (Gg)
1 megatonne/million tonnes (Mt)	1 teragram (Tg)

Reading the introductory information tables

The introductory information tables appear at the beginning of each source category chapter. The tables provide an overview of the relevant source category's importance and of the methods used in connection with it. Global Warming Potentials (GWP) as specified in IPCC Assessment Report 5 (IPCC AR5) are used.

KC	Category	Activity	EM of	1990 (kt CO_2-eq)	Fraction [%]	2021 (kt CO_2-eq)	Fraction [%]	Trend [%] 1990-2024
L/T	1A1c Manufacture of Solid Fuels and Other Energy Industries	All fuels	CO_2	65,289.1	5.1%	8,645.5	1.1%	-86.8%
-/-	1A1c Manufacture of Solid Fuels and Other Energy Industries	All fuels	N_2O	103.0	0.0%	139.8	0.0%	35.7%
-/-	1A1c Manufacture of Solid Fuels and Other Energy Industries	All fuels	CH_4	586.2	0.1%	114.0	0.0%	-80.6%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	NS	CS
CH_4	Tier 2	NS	CS
N_2O	Tier 2	NS	CS
NOX, CO, NMVOC, SO_2			CS

Main category

The upper section of the table shows the lines of the key category analysis that are relevant for the source category, the emissions as an absolute figure (kt CO_2 equivalent) and as a percentage of total emissions in 1990 and in the last report year and the emissions trend between the base year (1990 or 1995 for the F gases) and the last report year. In the German-language version of the NIR/NID, the term "Hauptkategorie" is used synonymously with the term "key category".

L = Key category in terms of emissions level
T = Key category in terms of emissions trend
2 = Key category solely pursuant to Approach 2 analysis (including uncertainties)

Pollutant

The lower section of the table provides information about the methods used, the source of the activity data and the emission factors (EFs) used.

Method used

D = IPCC default
RA = Reference Approach
Tier 1 = IPCC Tier 1
Tier 2 = IPCC Tier 2
Tier 3 = IPCC Tier 3
C = CORINAIR
CS = Country specific
M = Model

Source of the activity data

M = Model
Q = Questionnaires, surveys

PS = Plant-specific data
AS = Associations, business organisations
RS = Regional statistics
NS = National statistics
IS = International statistics

Emission factor (EF)

D = IPCC default
C = CorinAir
CS = Country specific
PS = Plant specific
M = Model

ES SUMMARY

As a Party to the United Nations Framework on Climate Change (UNFCCC), Germany has been obligated since 1994 to prepare, publish and regularly update national emission inventories of greenhouse gases. To deliver on their National Determined Contribution, the EU countries have opted to make use of the joint fulfilment option under the Paris Agreement and the UN Framework Convention on Climate Change. European legislation, most recently EU Regulation 2018/842[1] and its Implementing Regulation 2020/2126[2] has enshrined these emissions targets into law. As a result of the current European regulations, the requirements have become legally binding for Germany.

Pursuant to Decision 24/CP.19, all Parties listed in ANNEX I of the UNFCCC and in accordance with Decision 18/CMA. 1, all countries that have signed the Paris Agreement must prepare and submit a National Inventory Report (NIR), called a National Inventory Document (NID) since 2023, every two years, providing detailed and complete information on the entire process of preparing greenhouse gas inventories. The purpose of these reports is to ensure the transparency, consistency and comparability of inventories and support the independent review process.

Together with the inventory tables, Germany submits a National Inventory Document (NID), which refers to the period covered by the inventory tables and describes the methods and data sources on which the calculations are based. The report and the inventory tables have been prepared pursuant to the UNFCCC guidelines on annual inventories (FCCC/CP/2013/10/Add.3) and in conformance with the 2006 IPCC Guidelines for national Greenhouse Inventories (IPCC, 2006a) and the IPCC Good Practice Guidance (IPCC, 2000).

In Chapters 1 to 10, the **NID** contains all the information relevant to the annual greenhouse gas inventory.

Chapter 1 provides background information about climate change and the greenhouse gas inventories. It then describes the national inventory arrangements that, pursuant to Paragraph 20 of COP decision 24/CP.19, are designed to support and assure compliance with all reporting obligations with respect to atmospheric emissions and removals in sinks. In addition, this chapter describes the basic principles and methods used to calculate the emissions and sinks of the IPCC categories, presents a short summary of key category analysis and describes the Quality System for Emissions Inventories (QSE). The chapter concludes with sections on the uncertainties and completeness analysis.

Chapter 2 provides a general overview of emissions trends of direct and indirect greenhouse gases and removals of carbon dioxide in sinks.

Chapters 3 to 9 present information about the individual source and sink groups. Along with general descriptions and information about the methods used, subchapters in this section also include information about the uncertainties, quality assurance and quality control, recalculations carried out and planned improvements in the relevant source and sink categories.

The inventories, the National System and the Quality System for Emissions Inventories have all been further improved to reflect the results of the reviews that have taken place in recent years.

[1] REGULATION (EU) 2018/842 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 May 2018 on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action to meet commitments under the Paris Agreement and amending Regulation (EU) No 525/2013

[2] COMMISSION IMPLEMENTING DECISION (EU) 2020/2126 of 16 December 2020 on setting out the annual emission allocations of the Member States for the period from 2021 to 2030 pursuant to Regulation (EU) 2018/842 of the European Parliament and of the Council

More detailed information about recalculations and information about the improvements and changes made since the last greenhouse gas inventory is presented in **Chapter 10**.

Annexes 1 through 7, in **Annex 1-7**, contain more detailed descriptions of: key categories, individual source categories, the CO_2 reference approach, completeness, the National System and the Quality System, the CSE emissions database and uncertainties.

More detailed information about specific relevant issues is presented in the literature listed in **Chapter 11**.

The German Environment Agency calculates and compiles the greenhouse gas inventory. Data on emissions and sinks in the land use, land-use change and forestry sector have been provided by the Johann Heinrich von Thünen Institute (TI). The reporting is coordinated by the German Environment Agency (UBA).

ES.1 Background information on greenhouse gas inventories and climate change

ES.1.1 Background information on climate change

Ever since the start of industrialisation, significant transregional and global changes in the composition of the atmosphere have been observed as a consequence of human activities. The Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2023) highlights the ways humans affect the earth's climate. According to the Report, global concentrations of carbon dioxide (CO_2) have increased to 410 parts per million (ppm), while those for methane reached 1,866 parts per billion (ppb) and those for nitrous oxide (N_2O) increased to 332 ppb. Furthermore, a number of brand-new substances – i.e. substances that for all intents and purposes do not occur in nature and are produced almost exclusively by humans – such as chlorofluorocarbons (CFCs), halons, perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3) have entered the atmosphere

ES.1.2 Background information on greenhouse gas inventories

With the Kyoto Protocol's entry into force, in February 2005, the international community became obligated to implement binding targets and instruments for global climate action. In the first commitment period from 2008 to 2012, the European Community (at the time, with 15 Member States) committed to reducing its greenhouse gas emissions by 8% relative to the base year (1990 and 1995[3]). This target was divided up and fulfilled within the EU under a burden-sharing agreement[4] between the participating Member States. With its commitment to reduce emissions by 21% compared to the base year, Germany made a significant contribution to fulfilling the EU target. With a reduction of over 26% by 2012, Germany exceeded that target.

In the second commitment period of the Kyoto Protocol, the European countries committed to reducing their greenhouse gas emissions by 20% by 2020. At the same time, they announced that, under certain conditions, this European contribution could be increased to a 30%[5] reduction relative to 1990. With a 34.3% reduction by 2020, Germany also exceeded that target.

[3] For HFC, PFC and SF_6

[4] Burden-sharing agreement, adopted with Council Decision 2002/358/EC of 25 April 2002 concerning the approval, on behalf of the European Community, of the Kyoto Protocol to the United Nations Framework Convention on Climate Change and the joint fulfilment of commitments thereunder [OJ L 130 of 15 May 2002]

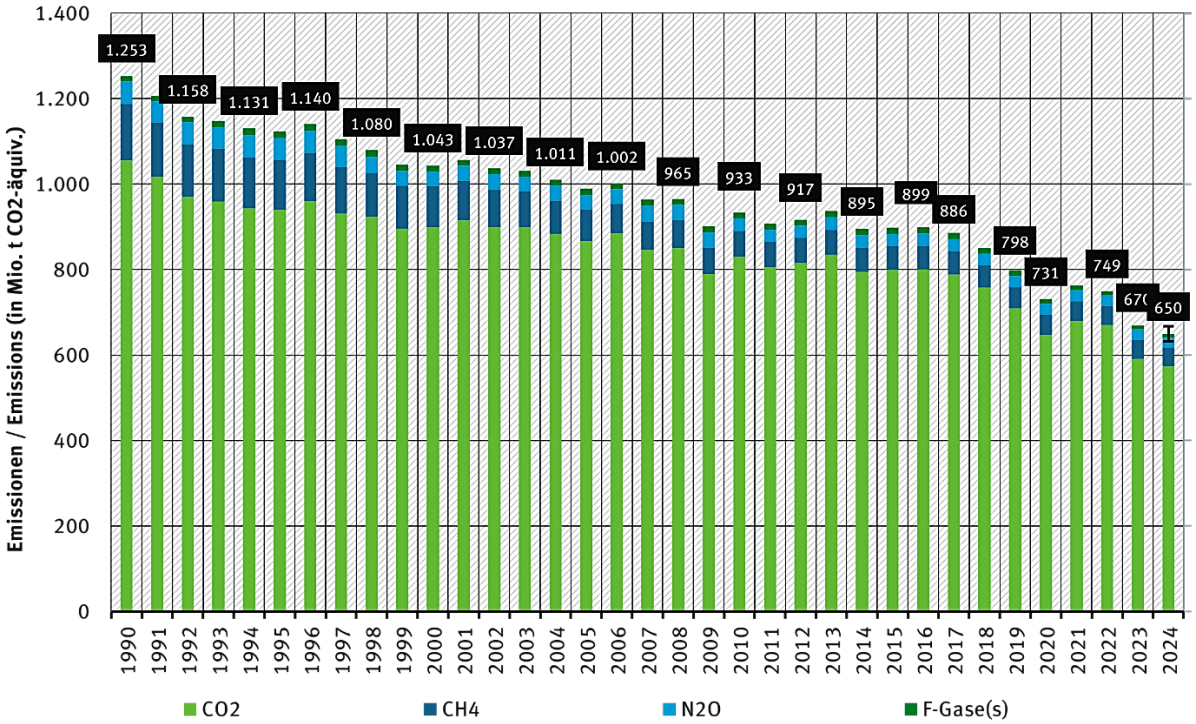
[5] Information on the quantified emission limitation or reduction objectives (QELROs) for the second commitment period under the Kyoto Protocol; SUBMISSION BY DENMARK AND THE EUROPEAN COMMISSION ON BEHALF OF THE EUROPEAN UNION AND ITS MEMBER STATES, Copenhagen, 19 April 2012

With the Paris Agreement, the European Union pledged, as part of its nationally determined contribution (NDC), to reduce its emissions by 40% compared to 1990 levels by 2030 and by between 66.25% and 72.5% by 2035.

ES.2 Summary of emissions of greenhouse gases and their removals in sinks

In the first commitment period from 2008 to 2012, Germany completely fulfilled its obligations under the aforementioned European burden-sharing agreement compared to the base year emissions of 1,232,429.543 Gg (CO_2 equivalents) set in 2007[6] for the first commitment period. Emissions in 2013 rose significantly compared with 2012, mainly due to the cold winter weather in 2013. In the following years, emissions were again considerably lower than their levels in 2013, and they largely stayed in step with economic trends and weather patterns. Since 2017, emissions have exhibited a markedly decreasing trend (cf. Chapter 2.1). In 2021, however, emissions did increase again.

Figure 1: Development of greenhouse gases in Germany since 1990, by greenhouse gases



* without LULUCF; Tier 2 uncertainties without LULUCF (cf. Chapter 1.6.1.2)

Source: own illustration, German Environment Agency

The individual greenhouse gases contributed to this development to varying degrees (cf. Table 4). This is hardly surprising given that, in any given year, the various greenhouse gases account for varying proportions of total emissions (cf. Table 5). Detailed tables are provided in Annex 5.2.

In 2024, with an 88.3% share, carbon dioxide emissions again accounted for the largest share of greenhouse gas emissions. These emissions were largely generated by the stationary and mobile combustion of fossil fuels. As a result of a disproportionately large reduction of other

[6] As a result of the 2007 review of the initial report and 2006 reporting under Article 8 of the Kyoto Protocol, the reference figures for achieving the reduction targets of the Kyoto Protocol have been set, regardless of further possible improvements to the underlying data. Pursuant to its obligations under the Kyoto Protocol and the EU burden-sharing agreement (Council Decision 2002/358/EC), Germany's reduction target is 21%.

greenhouse gas emissions, the relative proportion of total greenhouse gases attributable to CO_2 emissions has increased by 4.2 percentage points since 1990. Methane (CH_4) emissions, caused predominantly by animal husbandry, fuel distribution and landfills, accounted for a 6.8% share in 2024. Emissions of nitrous oxide (N_2O), caused primarily by agriculture, industrial processes and burning of fossil fuels, contributed 3.5% of greenhouse gas releases. Fluorinated greenhouse gases ("F gases") contributed about 1.4% to total emissions. The greenhouse gas NF_3, which is now also being reported, is of negligible importance. Furthermore, the low emissions of that substance are confidential in part, meaning that part of the emissions have to be reported elsewhere. This breakdown of greenhouse gas emissions in Germany is typical for a highly developed and industrialised country.

Information about the relevant trends is provided in Chapter 2, while all detailed tables about the discussion of trends are provided in Annex 5.2.

Table 4: Emissions trends in Germany, by greenhouse gases and categories, in [kt CO_2 equivalents]

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024
CO_2 emissions (without LULUCF)	1,054,796	939,933	898,974	866,910	829,787	798,771	646,683	679,946	670,017	591,373	573,925
Net CO_2 emissions/removals	1,081,618	926,712	897,408	869,065	831,511	796,508	686,158	715,588	719,867	654,005	622,132
CH_4 (without LULUCF)	4,775	4,178	3,469	2,628	2,178	2,024	1,706	1,667	1,628	1,605	1,576
CH_4 (with LULUCF)	5,076	4,468	3,759	2,913	2,481	2,299	1,960	1,963	1,866	1,950	1,881
N_2O (without LULUCF)	197	190	129	131	109	108	96	97	91	91	86
N_2O (with LULUCF)	202	195	133	136	113	112	100	101	95	95	90
F gases sum (CO_2-eq) 1995 base year	12,325	16,023	12,707	13,608	13,683	14,617	11,165	10,499	9,571	9,035	8,867
Total emissions without LULUCF	1,253,128	1,123,404	1,042,998	988,947	933,250	898,606	730,972	762,773	749,266	669,578	649,770
Total Emissions/Removals with LULUCF	1,289,623	1,119,487	1,050,728	1,000,238	944,562	905,194	778,619	807,721	806,865	742,849	707,608
Emission source and sink categories	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2021**	**2022**	**2023**	**2024**
1. Energy	1,044,283	922,715	872,684	835,758	835,758	768,670	612,720	643,676	637,851	561,904	543,295
2. Industry	93,216	94,745	76,592	72,752	72,752	59,880	54,933	56,827	51,446	47,022	47,889
3. Agriculture	74,078	64,880	64,150	60,606	60,606	61,612	57,201	56,360	54,320	55,203	53,308
4. Land-Use Change and Forestry	36,495	-3,917	7,730	11,290	11,290	6,589	47,646	44,949	57,599	73,271	57,839
CO2 (net emissions)	26,822	-13,220	-1,566	2,155	2,155	-2,262	39,475	35,642	49,850	62,632	48,207
N_2O + CH_4	9,673	9,303	9,296	9,136	9,136	8,851	8,171	9,307	7,749	10,638	9,632
5. Waste	41,550	41,065	29,572	19,831	19,831	8,443	6,118	5,909	5,650	5,449	5,277

Table 5: Contributions to emissions trends in Germany, by greenhouse gases and categories, in percent [%]

GHG emission fractions	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024
CO2 emissions (without LULUCF)	84.17	83.67	86.19	87.66	88.91	88.77	88.47	89.14	89.42	88.32	88.33
CH4 (without LULUCF)	10.67	10.41	9.31	7.44	6.54	6.40	6.54	6.12	6.08	6.71	6.79
N2O (without LULUCF)	4.17	4.49	3.28	3.52	3.08	3.25	3.47	3.36	3.22	3.62	3.52
F gases sum	0.98	1.43	1.22	1.38	1.47	1.59	1.53	1.38	1.28	1.35	1.36
GHG emission fractions for categories (without LULUCF)	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2021**	**2022**	**2023**	**2024**
1. Energy	83.33	82.14	83.67	84.51	84.71	85.54	83.82	84.39	85.13	83.92	83.61
2. Industry	7.44	8.43	7.34	7.36	7.11	6.66	7.52	7.45	6.87	7.02	7.37
3. Agriculture	5.91	5.78	6.15	6.13	6.69	6.86	7.83	7.39	7.25	8.24	8.20
5. Waste	3.32	3.66	2.84	2.01	1.49	0.94	0.84	0.77	0.75	0.81	0.81

* Information on the structure of the Common Reporting Format (CRF): http://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch1ri.pdf

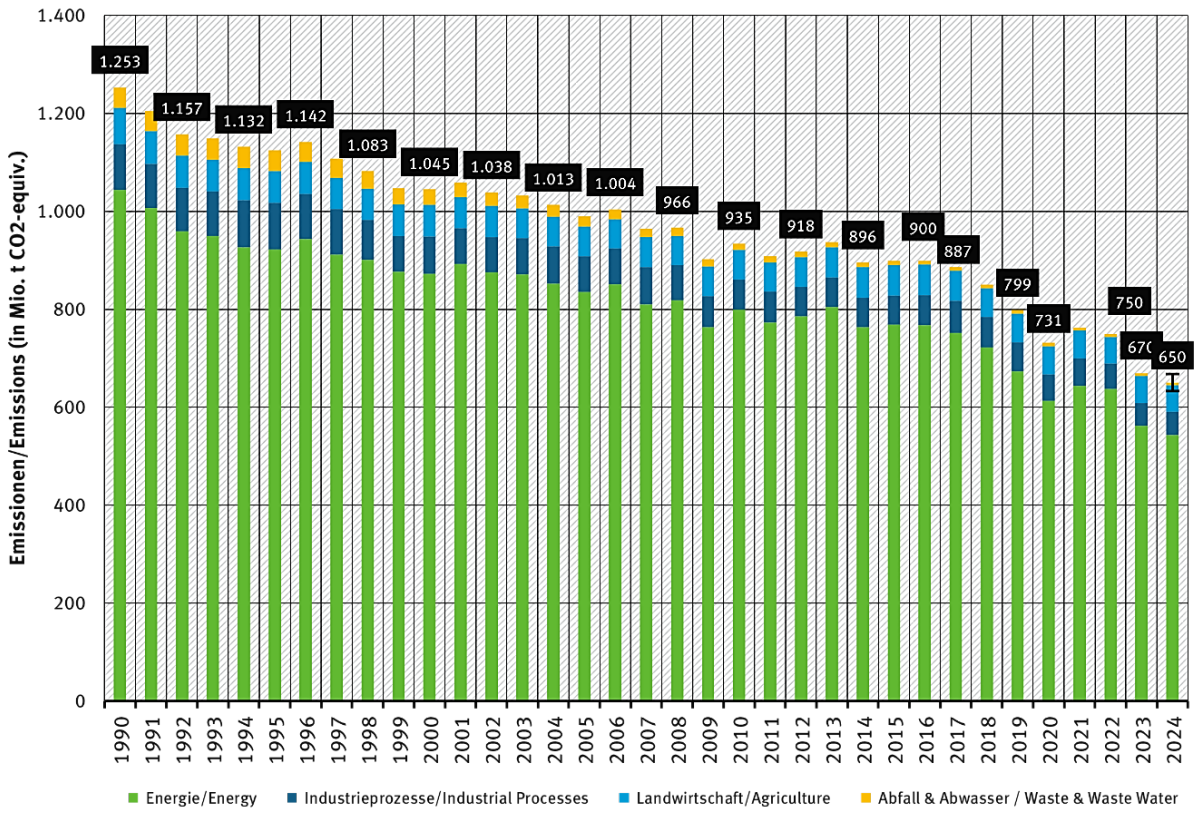
ES.3 Summary of emissions estimates and trends for source and sink groups

Figure 2 shows the contributions of the individual categories to total greenhouse gas emissions. It clearly shows the relatively constant proportions of the individual categories and the absolute dominance of energy-related emissions. Absolute energy-related emissions have continuously decreased over time. Variations affecting this trend are largely temperature-related. Because temperatures – especially in winter – affect heating patterns, they also affect energy consumption for heating, and thus have major impacts on annual trends in energy-related CO_2 emissions.

On the whole, greenhouse gas emissions decreased by 48.1%[7] in 2024. Considerations of the various components involved confirm this trend to varying degrees. The relevant emissions changes for the most important greenhouse gases in terms of quantity were as follows: carbon dioxide (CO_2) -45.6%, methane (CH_4) -67.0% and nitrous oxide (N_2O) -56.3%. The trend for "F" gases, which contribute about 1.9% of greenhouse gas emissions overall, is not quite as uniform. Due to the introduction of new technologies and the use of these substances as substitutes, SF_6 and PFC emissions have decreased since base year 1995, while HFC emissions increased. In total, however, emissions of F gases have decreased by 44.7% since 1995.

Relative to the previous year 2023, total emissions decreased by 3.0%.

Figure 2: Emissions trends in Germany since 1990, by categories



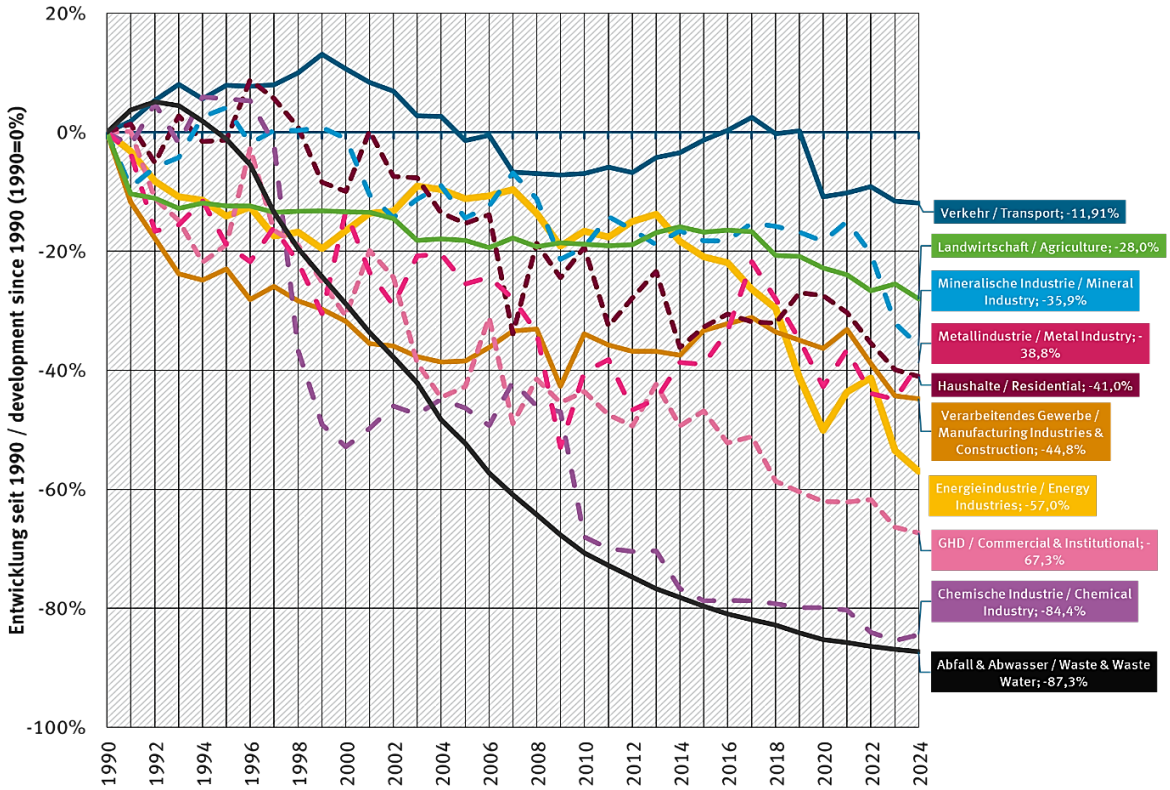
Without LULUCF; Tier 2 uncertainties without LULUCF (cf. Chapter 1.6.1.2)
Source: own illustration, German Environment Agency

Figure 3 shows the relative developments of emissions from the categories since 1990. The most pronounced reductions occurred in the chemical industry and in waste-related emissions.

[7] Alle Angaben ohne Berücksichtigung der Emissionen aus der Kategorie Landnutzung, Landnutzungsänderung & Forstwirtschaft (LULUCF)

Chemical industry emissions were affected especially by emissions reductions in the area of adipic acid production, tied to measures carried out in 1997 and in 2009, and by emissions reductions in solvent and product use, tied primarily to decreases in use of N_2O in anaesthesia. In the waste sector, increased recycling of recyclable materials (Packaging Ordinance) and reuse of materials as compost (Biowaste Ordinance) have led to a sharp reduction in the quantity of waste that is landfilled and therefore to continuous reductions in landfill emissions. The energy industry's emissions have also decreased considerably, especially in recent years. In the residential and commercial/institutional sectors, emissions have been decreasing overall since the mid-1990s, with sharp fluctuations due to weather patterns. A detailed discussion of emissions trends is presented in Chapter 2.

Figure 3: Relative development of greenhouse gas emissions since 1990, by categories



*Emissions from Land Use, Land Use Change and Forestry are reported in detail in the relevant chapter.
Source: own illustration, German Environment Agency

ES.4 Other information about indirect greenhouse gases and precursor substances

Indirect CO_2 emissions from CO and NMVOC are not explicitly calculated in the inventory. They are taken indirectly into account as CO_2, however, based on the specified/used calculation method. Additional information is provided in Chapter 9.

ES.5 Analysis of the key categories

A description of the key categories is provided in Annex 1. The key category analysis was carried out using the two Approach 1 assessments (Level and Trend), Approach 2 and the assessment of qualitative criteria.

ES.6 Improvements

A description of the recalculations and improvements is provided in Chapter 10.

1 Introduction

1.1 Background information on greenhouse gas inventories and climate change

1.1.1 Background information on climate change

Climate change is the change in average weather conditions and extreme events over a long period of time in a specific area or globally.

Climate change may be attributable to the following causes:

1. Changes in geo-astrophysical parameters such as the solar constant, elements of the earth's orbit, etc.
2. Changes in the earth's surface
3. Changes in the energy balance of the earth's surface and atmosphere
4. Changes in the composition of the atmosphere (such as changes in the concentration of greenhouse gases).

Greenhouse gases, including carbon dioxide, nitrous oxide, methane, ozone and other gases (especially water vapour, the most important natural greenhouse gas), have a unique property: they allow the high-energy radiation (primarily in the visible, short-wave range) to pass almost unhindered from the sun to the earth. At the same time, however, they absorb some of the heat radiation (long-wave infrared) rising back up from the warmed Earth. They briefly enter an unstable, higher energy state, after which they return to their original basic state whilst emitting infrared radiation. Heat radiation occurs equally in all spatial directions – in other words, a substantial portion returns to the earth's surface ("thermal back radiation"). For this additional energy to be radiated (which is necessary to maintain the dynamic energy balance between the Earth and the atmosphere), the Earth must have a sufficiently high temperature. This is a simplified description of the greenhouse effect.

Without the naturally occurring greenhouse gases, life on our planet would not be possible. Instead of having an average global temperature of approximately 15°C, the earth would have an average temperature of approximately -18°C. In other words, the natural greenhouse effect protects life on earth.

In spite of being "trace gases", greenhouse gases have considerable impacts. Their increasing concentrations have led to the anthropogenic (human-caused) greenhouse effect, which intensifies the natural greenhouse effect.

The Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2023) unequivocally confirmed that the earth's climate is currently changing: a wide range of changes have occurred throughout the entire climate system since the middle of the last century. The temperature of the lower atmosphere is rising, the oceans are getting warmer, the glaciers are melting, permafrost soils are thawing, ice caps are losing mass and sea levels are continuing to rise.

Extensive observations, expanded models and profound insights into the interdependencies clearly indicate that human activities are the main cause of the climate change currently taking place.

Significant examples of observed climate changes include the following (WMO, 2025):

- The **global mean near-surface temperature** has already risen by 1.55°C compared to the baseline period 1850-1990. Each of the years in the last 10 years, from 2015 to 2024, was one of the 10 warmest years since weather records began.
- In 2024, the **oceans** reached their highest heat content in the 65-year history of recorded climate change. Each of the last eight years set a new record.
- Due to the warming of the world's oceans and the melting of glaciers and ice sheets, the **mean global sea level** reached its highest level since satellite records began in 1993.
- The **extent of Arctic sea ice** in 2024 was the seventh lowest since records began in 1979. The 18 lowest annual minimums all occurred in the last 18 years.

Climate change has extensive impacts on ecological and societal systems, with potentially serious consequences.

In 2015, the international community adopted the Paris Agreement, which aims to prevent dangerous climate change impacts by limiting global warming to considerably less than 2°C – and to 1.5°C if possible – compared to the pre-industrial temperature level (according to (WMO, 2025)), 1.2°C of warming has already occurred). Successfully limiting warming to considerably less than 2°C can be expected only in a scenario with highly ambitious climate policies.

It is still technically and economically possible to limit global warming to 1.5°C by the year 2100 in line with the Paris Agreement. But for this to happen, there needs to be an immediate global turnaround with profound greenhouse gas reductions in all world regions and sectors. Solar and wind energy are now available as highly cost-effective energy sector technologies. Immediate climate action, in conformance with the Paris Agreement, would slow global GDP growth only slightly. And this prediction does not include the climate change-related costs that could be avoided by taking action, nor does it include prevented adaptation costs. However, emissions from existing and currently planned fossil energy infrastructure already exceed the global CO_2 budget for the 1.5°C target.

1.1.2 Background information on greenhouse gas inventories

The world's nations were quick to recognise that the expected temperature changes would pose threats to ecosystems and human civilisation, because the changes would take place relatively quickly, and existing systems would not be able to adapt to the new climate conditions without damage.

The Framework Convention on Climate Change was adopted in 1992 in Rio de Janeiro by nearly all nations of the world. Since 1994, the countries listed in ANNEX I of the Framework Convention on Climate are required to submit annual inventories of greenhouse gases by 15 April of each year to the Secretariat of the Framework Convention. These inventories must include data on emissions and sinks for the base year (1990 for CO_2, N_2O, CH_4; 1995 for HFCs, PFCs, SF_6 and NF_3) and for all years until two years prior to the year of the relevant report (UNFCCC, 2014)).

At the third Conference of the Parties to the UN Framework Convention on Climate Change, held in Kyoto, legally binding obligations on emissions limitations and reductions were defined for the first time for the countries listed in ANNEX I. In the first commitment period under the Kyoto Protocol, industrialised nations were required to reduce their emissions of the six greenhouse gases carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) by an average of 5.2% in the period

2008 to 2012[8]. In the second commitment period of the Kyoto Protocol, the list of relevant gases was expanded to include nitrogen trifluoride (NF_3) and six hydrofluorocarbons (HFC-152, HFC-161, HFC-236cb, HFC-236ea, HFC-245fa, HFC-365mfc) and two perfluorocarbons (c-C_3F_6, $C_{10}F_{18}$).

For the first commitment period, the European Union adopted a target to reduce emissions by 8% relative to the base year. For the second commitment period under the Kyoto Protocol, the European Union committed to reduce its GHG emissions by 20% relative to the base year by 2020. In the European Effort Sharing Decision[9], this target was divided up among the Member States and the European Union. While emissions reductions in those areas of inventories that are subject to emissions trading were implemented at the European level, the Member States were responsible at the national level for emissions reductions in inventory areas not subject to emissions trading. Germany was obligated to reduce its emissions not subject to emissions trading requirements to 451.33 million tonnes of CO_2-equivalents by 2020. This target was achieved. To offset higher emissions from previous years, however, Germany needed to use emission allowances of other EU Member States. The European Union reduced its emissions by 34% relative to the base year, thereby considerably exceeding its target of reducing them by at least 20%.

As of 2021, the European Union's reduction target for the period through 2030, as set forth in its Nationally Determined Contribution (NDC), has been divided under the European Effort Sharing Regulation among the 27 Member States, along with Norway and Iceland. Germany is obligated to reduce its emissions not subject to emissions trading requirements by 50% by the year 2030[10].

The effectiveness and success of the Paris Agreement in reducing global greenhouse gas emissions – like the effectiveness and success of Kyoto Protocol in this regard – depend on two key factors: whether its Parties abide by the rules of the Agreement, make their promised contributions, and set even more ambitious targets; and whether the emissions data used for monitoring compliance are reliable. National reporting and the subsequent international review of emissions inventories therefore play a key role.

1.2 A description of Germany's national circumstances and institutional arrangements

Decision 18/CMA.1 requires all signatories to establish and describe national institutional arrangements for preparation of greenhouse gas inventories. Germany's national institution is its National System for Emissions Reporting (Nationales System Emissionsberichterstattung), which was established in 2011 in line with the provisions of Art. 5.1 KP and has been in place since then. As was the case in the years up to 2020, Germany's national institutional arrangements fulfil the provisions of Article 5.1 of the Kyoto Protocol, the requirements of Decision 18/CMA.1 and the provisions of the European Governance Regulation for the Energy Union and Climate Action[11].

[8] The average reduction, 5.2%, was calculated from the emissions limitations and reductions that the various parties to the Kyoto Protocol entered in the Protocol's Annex B.

[9] Decision No 406/2009/EC of the European Parliament and of the Council of 23 April 2009

[10] REGULATION (EU) 2018/842 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 May 2018 on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action to meet commitments under the Paris Agreement and amending Regulation (EU) No 525/2013

[11] REGULATION (EU) 2018/1999 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018 on the Governance of the Energy Union and Climate Action

National institutionalisation serves to ensure that the inventory is compiled in accordance with the principles of transparency, consistency, comparability, completeness and accuracy. Conformance is achieved by applying the methodological provisions of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, through ongoing quality management and continuous inventory improvement.

At ministerial level, the National System was established in 2007 under the leadership of the then Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) through an agreement between the state secretaries of the ministries involved as a policy paper National Emissions Reporting System" ("Nationales System zur Emissionsberichterstattung") dated 5 June 2007. With the inclusion of the ministries at the time including the Federal Ministry of Food and Agriculture (BMEL), the Federal Ministry of Economics and Technology (BMWi), the Federal Ministry of Transport and Digital Infrastructure (BMVI), the Federal Ministry of the Interior, Building and Community (BMI), the Federal Ministry of Finance (BMF) and the Federal Ministry of Defence (BMVg), all key institutions and organisations capable of contributing high-quality expertise to the preparation of the emission inventories were involved. The policy paper on emissions reporting defines the relevant responsibilities of the various participating federal ministries, and it mandates that the National System be based on existing institutions and data streams.

Furthermore, the relevant resolution sets forth that the involved federal ministries are to undertake suitable activities to close data gaps that fall within their areas of responsibility. Where necessary, this is done by providing existing data or calculations or, if necessary, by ensuring that the necessary data is provided by third parties. In support of the reporting process, the participating ministries established a coordinating committee (cf. Chapter 1.2.1.1). The German Environment Agency (UBA) was charged with carrying out the tasks of the Single National Entity for Germany.

The "National Emissions Reporting System" policy paper of 5 June 2007 is presented in Annex 5.1.1.

Later, further institutionalisation was completed primarily by signing relevant agreements with other federal institutions, industrial associations and individual companies (cf. Chapter 1.2.1.3). In 2013 and 2014, the National System existing at the time was adapted and expanded to meet the requirements of the second commitment period of the Kyoto Protocol.

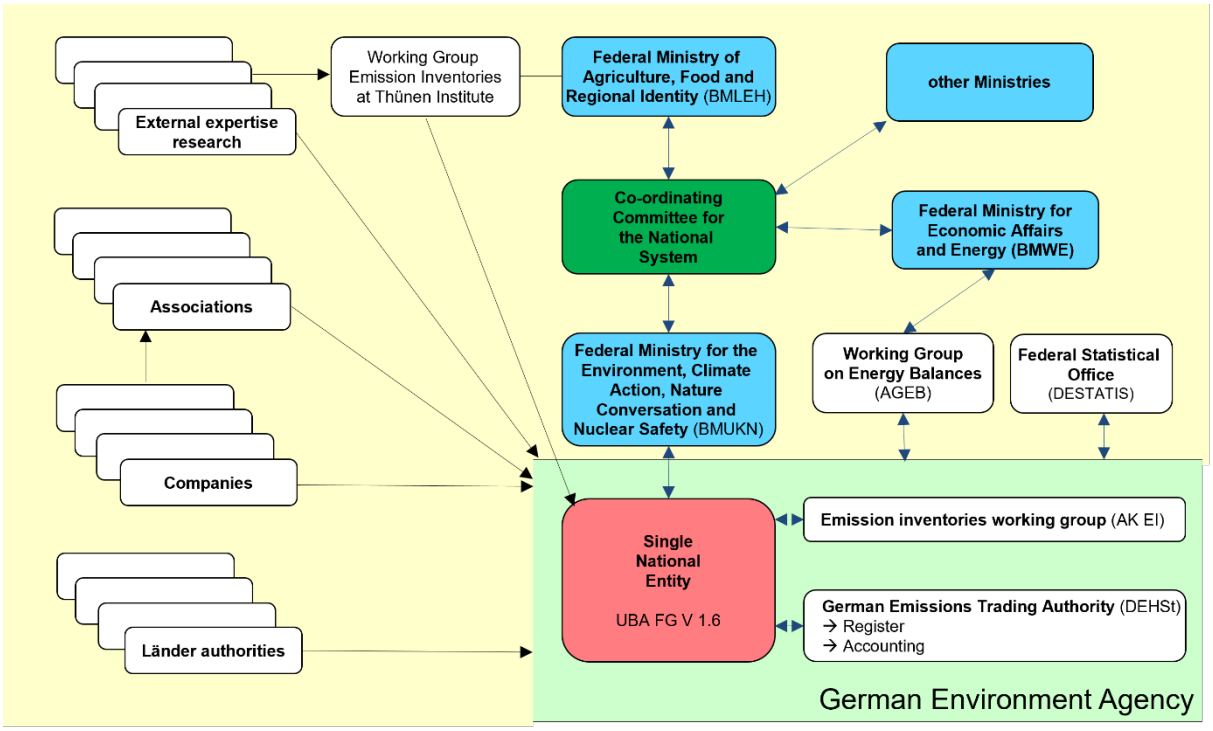
The institutionalisation and functionality of the National System in compliance with requirements have been consistently confirmed by all international reviews to date.

Article 13 of the Paris Agreement emphasises the importance of reporting and makes reporting obligatory for all participating countries. In 2024, Germany therefore submitted its first report in accordance with the reporting rules set out in Decisions 18/CMA.1 and 5/CMA.3 under the Paris Agreement.

The institutionalisation procedures and structures established under the UN Framework Convention on Climate Change and the Kyoto Protocol retain their validity for reporting under the Paris Agreement.

Figure 4 below shows the structure of the three levels of the National System in Germany.

Figure 4: Structure of the National System of Emissions (NaSE)



Source: own illustration, German Environment Agency

1.2.1 National Coordination Committee and Single National Entity

1.2.1.1 The federal National Coordination Committee for greenhouse gas reporting

In its Sec. 2, the state secretaries' resolution of 5 June 2007 provides for the establishment of a National Coordination Committee to be headed up by the Federal Ministry for the Environment, Climate Action, Nature Conservation and Nuclear Safety (BMUKN) which includes representatives of all federal ministries that participate in emissions reporting.

The National Coordination Committee is responsible for supporting the emissions reporting process and clarifying open issues related to institutionalisation. In particular, the Committee carries out consultations with regard to gaps in data streams and settles issues related to responsibilities.

In addition, the National Coordination Committee is responsible for approving publication of the inventories and the National Inventory Report.

The National Coordination Committee met for the first time on 21 December 2007. It meets at least once annually. Between meetings, the participating federal ministries coordinate via electronic communication.

Now, after the second commitment period of the Kyoto Protocol, the National Coordination Committee continues to be an important, established component of the institutionalised arrangements for emissions reporting in Germany.

1.2.1.2 The Single National Entity within the German Environment Agency

The state secretaries' policy paper of 5 June 2007 appointed the German Environment Agency (UBA) to carry out tasks of the Single National Entity for emissions reporting (national coordination agency). Within the Emission Inventories and Climate Action Reporting division has been entrusted with this task. At the level of the German Environment Agency, the Single

National Entity integrates other specialised agencies within the system of national institutional arrangements, and it coordinates the contributions of the other institutions and organisations involved in emissions reporting. For coordination of work within the German Environment Agency, a working group on emissions inventories was established (cf. Chapter 1.2.1.3). For implementation, within the German Environment Agency, of the IPCC guidelines for quality control and assurance, a Quality System of Emissions was established in 2005, through an in-house directive (cf. Chapter 1.2.2.3.1.1).

The Single National Entity's tasks include planning, preparing and archiving of inventories, describing inventories in the inventory reports and carrying out quality control and assurance for all important process steps. The Single National Entity serves as a central point of contact and coordinates and informs all participants in the emissions reporting process. During the period 2003 to 2007, the Single National Entity gave priority to developing new data sources. Since 2008, its focus has been especially on a) improving existing data sources and safeguarding their availability for the long term, and b) maintaining the institutionalisation of data streams. Furthermore, institutions and organisations that need to be integrated within the reporting process have been identified and are now being successively integrated (cf. Chapter 1.2.1.4). In the years 2014 – 2016, its work focused especially on implementation of provisions under the second commitment period of the Kyoto Protocol, and on implementation of the Revised UNFCCC Reporting Guidelines, within the reporting system. Since 2021, its work has been concentrated on implementation of the modalities, procedures and guidelines of the enhanced transparency framework and reporting under the Paris Agreement, as set out in Decision 18/CMA.1. Other important work has had to do with implementing the Quality System for Emissions Inventories.

The Single National Entity has developed two key instruments for carrying out those tasks:

The German Environment Agency's Central System on Emissions (CSE) database is the national, central database for emissions calculation and reporting. It is used for central storage of all information required for emissions calculation (methods, activity data, emission factors). The CSE is the main instrument for documentation and quality assurance at the data level.

Both within and outside of the German Environment Agency, the Quality System for Emissions Inventories (QSE) provides the necessary framework for good inventory practice and the implementation of routine quality assurance. Established within the German Environment Agency in 2005 through an in-house directive 11/2005, it comprises the processes necessary for continually improving the quality of greenhouse gas emissions inventories. The framework it provides includes defined responsibilities and quality objectives related to methods selection, data collection, calculation of emissions and relevant uncertainties and recording of completed quality checks and their results (confirmation that objectives were reached, or, where objectives were not reached, listing of the measures planned for future improvement). Ongoing quality improvement in the framework of the QSE is supported by a database that serves as the repository for all table-based documents emerging from the national QC/QA process (QC/QA plan, checklists, lists of responsibilities, etc.).

The quality control procedures have been developed with the help of external experts, taking special account of the German Environment Agency's work structures, general guidelines for quality assurance and the *IPCC Good Practice Guidance*. For the second commitment period, the quality control procedures have been brought into line with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Since 2008, the QSE has been extended to the entire national system by involving other authorities, institutions and inventory experts in quality management through the specification

of minimum requirements for data documentation, QC/QA and archiving. In addition, the procedure is designed to enable other organisations to develop their own internal quality assurance systems on the basis of their existing structures. The QSE is described in detail in Chapter 1.2.2.3.

1.2.1.3 Working Group on Emissions Inventories, in the German Environment Agency

The Single National Entity receives essential input for the inventories – particularly with regard to emission factors – from other working units of the German Environment Agency and the Thünen Institutes involved in compiling the inventories. In addition, associations, companies and other independent organisations are integrated into the reporting system to supply data primarily by the German Environment Agency's specialised units that are responsible for the specific issues involved in each case.

In 2003, a Working Group on Emissions Inventories was set up to coordinate relevant work within the German Environment Agency; since then, it has liaised with all of the experts who are involved in inventory preparation.

The Single National Entity convenes meetings of the working group at least once a year. In addition, relevant members of the working group meet as necessary to discuss specific issues and to make any necessary in-house arrangements.

In addition to the working group's events, the necessary information is also provided through an intranet service offered by the National Coordination Office for Emissions Reporting and a newsletter on the Central Emissions System (ZSE) database produced by the National Coordination Office.

1.2.1.4 Cooperation by the Single National Entity with other federal institutions and with non-governmental organisations in the framework of reporting

As described above, the "National System" principles paper on emissions reporting of 5 June 2007 defines the responsibilities of the participating federal ministries with respect to all source and sink groups.

For some of the data streams moving to the Single National Entity from other federal institutions, special agreements have been concluded between a) the relevant institution in the case in question and b) the Single National Entity.

In 2009, for example, a statutory provision was introduced for the provision of data by the Federal Statistical Office for emissions reporting within the framework of an omnibus act (3rd SME Relief Act, MEG 3) for, among other things, the Energy Statistics Act (EnStatG), which was incorporated into Section 13 (2) following the amendment of the EnStatG in 2017. The provisions under the MEG 3 make it possible to supply data for emissions reporting from energy, environmental and production statistics that are subject to statistical confidentiality. On that basis, on 13 January 2010 an administrative agreement between the German Environment Agency and the Federal Statistical Office came into force that specifies data deliveries for emissions reporting purposes. The agreement provides for annual reviews of the German Environment Agency's data requirements. In addition, a process of close direct exchanges between the Single National Entity and the Federal Statistical Office, regarding issues of emissions reporting, has been institutionalised.

The "National Emissions Reporting System" policy paper assigns responsibility for the areas of agriculture and LULUCF to the Federal Ministry of Food and Agriculture (BMLEH). The BMLEH has commissioned its agencies to carry out the tasks necessary for emissions reporting. That commissioning took place through a directive of 29 August 2007 to the (then) Federal

Agricultural Research Centre (FAL). As a result of a restructuring of the FAL as of 1 August 2008, the tasks are now carried out by the Thünen Institute (TI). The relevant work includes all tasks in the agriculture and forestry sectors that are necessary for the preparation of the annual emissions inventories, including the writing of the relevant reports. The TI sends the data and report to the Single National Entity. With a concept (BMELV, 2016) that names and specifies all processes and actors, and the actors' roles, the BMLEH and TI codified the procedures for preparation of emissions and carbon inventories for source and sink categories 3 and 4 (agriculture and forestry), and for KP-LULUCF (Art. 3.3. and 3.4 KP), and including a quality assurance concept.

In addition, on 13 February 2008, the TI concluded an agreement with the Federal Statistical Office on provision of emissions data on the basis of agricultural statistics. A research and development agreement between the TI and the Association for Technology and Structures in Agriculture (KTBL) has been in place since 7 July 2009. That agreement specifies the supporting work that the KTBL is to carry out for emissions reporting.

Furthermore, a working group on emissions reporting has been established within the TI, to serve as liaison to the Single National Entity within the German Environment Agency. That working group also has responsibility for planning and QC/QA for categories CRF 3 and CRF 4.

Responsibility for coordination of the Working Group on Emissions Reporting lies with the TI's Institute of Climate-Smart Agriculture (TI-AK). Responsibility for reporting on agriculture and LULUC lies with the same institute, while responsibility for reporting on forests pursuant to the Convention and Kyoto Protocol Arts. 3.3 and 3.4 lies with the TI's Institute of Forest Ecosystems. As of the second commitment period of the Kyoto Protocol, the Thünen Institute of Wood Research (TI-HF) has responsibility for reporting on emissions from harvested wood products (HWPs).

The working group on emissions reporting is integrated into the TI through direct (cross-ministerial) integration of the working group into the Single National Entity's communication structures. The working group at the TI is also part of the working group on emissions inventories (Arbeitskreis Emissionsinventare – AKEI) within the German Environment Agency, and it is fully integrated within the Single National Entity's Quality System for Emission Inventories (QSE).

The involvement of trade associations, companies and other independent organisations is primarily carried out by the specialist units of German Environment Agency divisions I, III and V, which are responsible for specific issues. The Single National Entity supports the departments in discussion of reporting requirements and in determination of requirements for data sharing by associations. The data flows are continually reviewed by the Single National Entity and, where necessary, are updated and safeguarded by suitable agreements between the Single National Entity and associations/business enterprises.

The Working Group on Energy Balances (AGEB) is contractually obligated to provide Energy Balances through the Federal Ministry for Economic Affairs and Energy (BMWE). Use of a coordinated schedule ensures that a provisional Energy Balance for the last report year is prepared on time, and is transmitted to the German Environment Agency, by 1 September of each year, for purposes of inventory preparation. The final Energy Balance is transmitted by 15 February of year x+2. The current agreement will end in 2025, with the preparation of the final Energy Balance for 2022. In 2019, and beginning with the 2018 provisional Energy Balance, responsibility for provision of data on renewable energies passed to the Working Group on Renewable Energy Statistics (Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat).

On 29 August 2024, the German Environment Agency was designated as the national contact point for the EU Commission within the framework of the EU Methane Regulation (EU, 2024a). One key function is to use individual companies' emissions reports for international emissions reporting. This regulation requires companies in the oil and gas industry (the entire supply chain up to the end consumer) as well as operators of active surface mines and those responsible for decommissioned and abandoned underground coal mines to report regularly on the quantification and measurement of methane emissions at source. The data will be published in a transparency database on the European Commission's website on 5 February 2026, in accordance with Article 30 of the Regulation. For significant parts of categories 1.B.1 and 1.B.2, these data were used in the 2026 national reporting or – if incomplete or not sufficient to meet UNFCCC requirements – used for verification purposes.

In 2008, a sample agreement was prepared for inclusion of non-governmental organisations within the National System. That agreement is used to involve stakeholders, under binding terms, within preparation of inventories. The sample agreement is adapted to the various data suppliers' own requirements and needs as is necessary. In July 2009, the Federal Ministry for Economic Affairs (BMWi) and the German Environment Agency concluded an agreement, with the German Chemical Industry Association (VCI) and German producers, on data provision in the categories Ammonia (2.B.1) and Nitric acid (2.B.2). In early summer 2014, that agreement was adapted to the requirements applying under the Revised UNFCCC Reporting Guidelines and the 2006 IPCC Guidelines. In addition, in 2009 agreements on data provision were reached with producers of adipic acid (2.B.3) located in Germany. Furthermore, an association agreement was concluded with the VDD industry association for bitumen paper and bitumen roof sheeting in the category Bitumen for roof sheeting (2.D.3.c). Since 2009, data for the aforementioned categories for emissions reporting have been provided on the basis of these agreements. In 2021, cooperation agreements were concluded with both soda ash producers (for all three production facilities in Germany). At the German Environment Agency (UBA), the reported data on production quantities are combined, and used in time series formats (for the period as of 2013).

In June 2011, the Single National Entity, acting with the support of the responsible ministry, the Federal Ministry for Economic Affairs and Energy, entered into a cooperation agreement with the Wirtschaftsvereinigung Stahl German steel industry association. That agreement had become necessary because the Federal Statistical Office had discontinued its data collection and publication activities for Fachserie 4 Reihe 8.1 (iron and steel statistics) as of 31 December 2009, due to the expiration of the legal basis (Raw Materials Statistics Act (Gesetz zur Neuordnung der Statistiken der Rohstoff- und Produktionswirtschaft einzelner Wirtschaftszweige (Rohstoffstatistikgesetz – RohstoffStatG; Act for reordering of the statistics on raw materials and production in individual economic sectors)). This considerably reduced the availability of the bases for calculations in that area, and it created a significant gap in the data streams. The new cooperation agreement closed that gap. The agreement assures data provision by both member companies of the association and by non-member companies.

A relevant voluntary commitment of semiconductor manufacturers with production sites in Germany, a commitment that served as the basis for data provision for category 2.F.6, expired on 31 December 2010. In August 2012, the Single National Entity acted to close the resulting potential data gap by entering into a cooperation agreement with the Electronic Components and Systems (ECS) division of the German Electrical and Electronic Manufacturers' Association (ZVEI) to ensure the supply of data for category 2.E.1 on a long-term basis.

These agreements provide a reliable long-term framework for data provision, and they have had the effect of considerably improving data quality in the relevant categories.

1.2.2 Inventory preparation

As the overview in Chapter 1.2.2.4 shows, inventory preparation functions in accordance with a regular, annual scheme. The processes for preparation of greenhouse gas inventories, preparation of National Inventory Reports and implementation of quality control and quality assurance measures are very closely linked.

At the same time, the upstream processes for inventory preparation (cf. Chapter 1.2.2.1.1), including definition of bases for calculation (cf. Chapter 1.2.2.2.1), and data collection, processing and storage (cf. Chapter 1.2.2.2), remain distinct from those for quality control and quality assurance (cf. Chapter 1.2.2.3).

1.2.2.1 Greenhouse gas inventory

1.2.2.1.1 Preliminary/upstream processes

Apart from the sub-processes for emissions reporting, as outlined in Figure 8, certain upstream (preliminary) processes are carried out – in each case, between a pair of emissions reporting cycles.

The following sub-processes are considered preliminary/upstream processes:

- Continuous review and assurance of data streams from data suppliers to the German Environment Agency by improving institutionalisation of the National System;
- Implementation of improvements in inventory planning and inventory preparation;
- Identification of key categories (using Approach 1 pursuant to Chapter 4.3.1, Vol. 1 of the IPCC GL 2006);
- Calculation and aggregation of emissions uncertainties using Monte Carlo simulation (pursuant to Approach 1 or Approach 2 in accordance with the *IPCC Good Practice Guidance*);
- Expanded identification of key categories using Monte Carlo simulation (using Approach 2 pursuant to Chapter 4.3.2, Vol. 1 of the IPCC GL 2006).

1.2.2.1.1.1 Improvement of the national institutional arrangements

As a result of the manner in which reporting has been institutionalised, reporting builds on existing data streams, and it provides for suitable measures to assure long-term data provision where such assurance is lacking (cf. Chapter 1.2.1). Consequently, data streams continually have to be reviewed between pairs of reporting cycles.

Where voluntary commitments expire, discussions have to be carried out with the relevant data suppliers in order to secure the commitments' renewal or their conversion into cooperation agreements. Where continued data provision is not assured, relevant commitments or cooperation agreements have to be obtained. In cases of any doubt, relevant legal provisions about data provision have to be reviewed and implemented.

Existing agreements have to be adapted as necessary to new circumstances and reporting requirements (for example, to changes in reporting procedures). Such efforts help assure the consistent high quality of the National System and the inventory preparation process.

1.2.2.1.1.2 Implementation of improvements in inventory planning and preparation

The quality system helps to assure the high quality of the inventory, and it supports the continual improvement of the inventory and of inventory planning. In each case, and as possible,

the following are implemented in the next reporting cycle: a) improvement requirements that have emerged from past quality control and quality assurance; b) results of past reviews; and c) planned improvements listed in the NID.

A detailed description of the quality control and quality assurance procedures is provided in Chapter 1.2.2.3. The improvements achieved for the present report are described in the relevant category chapters.

1.2.2.1.1.3 Determination of key categories (pursuant to Tier 1)

In order to be able to focus the many and detailed activities and capacities required for inventory preparation and improvement on the principal categories of the inventory, the IPCC has introduced the definition of a "key category". Key categories are source/sink categories that play an especially prominent role in the national inventory because their emissions/removals have a significant influence on the total emissions of direct greenhouse gases – because of their absolute quantities, because of their contribution to the emissions trend over time, because of their uncertainties, or because they have been assessed by an expert as an important category.

The Single National Entity identifies key categories once per year, prior to the emissions reporting process. Whereas in the reporting framework results are reported for year x, they cannot be taken specifically into account until inventory preparation for the year x+1. A category's designation as a key category helps decide what calculation method (Tier approach) must be used for the category and, as a result, how detailed emissions modelling for the category must be. In addition, the key category selection process is used to identify any categories to which priority must be given in inventory improvement.

The 2000 *IPCC Good Practice Guidance* (Vol. 1, Chapter 4) specifies the methods – "Approaches" – to be applied in identifying key categories. These methods identify the relevant key categories with the help of analysis of the inventory for one year with regard to emissions levels for individual categories (Tier 1 level assessment), time series analysis of inventory data (Tier 1 trend assessment) and detailed analysis of inventory data with error evaluation (Tier 2 level and trend assessment with consideration of uncertainties).

The key categories have been defined by applying the two Approach 1 procedures, Level (for the base year and for the last year reported) and Trend (for the last year reported, as compared to the base year), to German greenhouse gas emissions. According to the IPCC requirements, analyses have taken account of both emissions from sources and removals of greenhouse gases in sinks.

1.2.2.1.1.4 Calculation and aggregation of emissions uncertainties

Uncertainties are a fundamental part of emission inventories. Determining them should lead to a quantitative expression of the accuracy of emission inventories. While uncertainties are determined when data is collected and thus are part of the "data collection" section of the emissions reporting process, they can be aggregated only after an inventory – or the emissions-reporting cycle – has been completed.

When calculating and aggregating uncertainties, the uncertainties of activity rates and emission factors, which were generally estimated by experts at the lowest level of the categories in the ZSE, are converted into uncertainties of emissions and aggregated. Uncertainties are aggregated once per year at the end of the report preparation cycle for the current report year.

To determine the uncertainties, the individual uncertainties were estimated, wherever possible to date, by experts of the relevant units in the German Environment Agency and external institutions.

1.2.2.1.1.5 Expanded identification of the key categories

Aggregated uncertainties serve as a basis for expanded identification of key categories (Tier 2 key categories identification).

1.2.2.2 Data collection, processing and storage

1.2.2.2.1 Definition of bases for calculation

The selection, review and, where necessary, modification of the calculation methods used to determine emissions has an impact on the entire emissions reporting process. For this reason, the main process "definition of the bases for calculation" must begin with review of the suitability of the methods to be used. The 2006 *IPCC Guidelines* provide decision trees to help determine which methods are to be used for the various categories. This also depends on whether the group in question is a key category or not. Any use of different – country-specific – methods, instead of the prescribed methods, must be justified in the NID. In each case, why the method in question is equivalent or better must be provided, along with clear documentation.

Another factor that is critical to the success of the overall process is the selection, review and (where necessary) modification of data sources, since the quality of results of all downstream processes (data preparation, calculation, reporting) cannot be better than that of the primary data used. Data sources can relate to the activity data, emission factors or emissions of a specific category. In many cases, the data sources used have been relied on for a number of years. It can become necessary to select new data sources – for example, as a result of required changes in methods, the loss of an existing data source, the need for additional data or the results quality checks of previously used data sources.

The suitability of a given data source depends on various criteria. These include:

- Long-term availability,
- Institutionalisation of data provision,
- Good documentation,
- Implementation of quality assurance and control measures by the persons/organisations providing data,
- Identification of uncertainties,
- Representative nature of the data in question and
- Completeness of the expected data.

In each case, it is important that the reasons for choosing a particular data source be documented and, where the data source has significant deficits, that suitable measures for improving the data be planned.

Efforts are made to give quality control, quality assurance and documentation requirements to data suppliers; this is particularly relevant where research projects are awarded since the German Environment Agency, as the customer, can exert considerable influence on the contractor in such cases.

1.2.2.2.2 Data collection

Data collection and documentation take place under the responsibility of the relevant experts. One way of collecting data is to evaluate official statistics, association statistics, studies, periodicals and research projects. Research projects can include research projects carried out by

the Agency itself or third-party research projects. Data may also be collected through the use of personal information and through data exchanged between the Federal Government and the federal states. The bottom line is that work results obtained by other means are often reused for the purposes of emissions reporting.

Data collection comprises the following steps:

5. Definition of requirements,
6. Determination of the category-specific quality criteria for the data,
7. Request for data from data providers (carried out by the relevant experts' group) and
8. Receipt of data

Requests for inventory input are sent by the National Single Entity (national coordination agency) to the responsible experts. In each instance, the relevant specialised subject area supervisor is notified about the request. A master file, specifying the structure for this input, is provided for NID preparation. The requirements for subsequent data input are provided in the CSE (ZSE) specifications (direct entry or completion of the import format). Reporting requirements (including QC/QA measures), along with the results of all inventory reviews, the category-specific data set for each category and the current results of the key category identification are all communicated to the responsible experts through informational events held by the German Environment Agency's Working Group on Emissions Inventories, the German Environment Agency's intranet and share-point sites for emissions reporting and through an electronic inventory description (cf. Chapter 1.2.2.3.1.5). On this basis, the responsible experts define requirements for data sources and calculation methods.

The requirements influence the upstream process of defining the bases for calculation (review and selection of methods and data sources) – a process which always takes place when requirements have not yet been fulfilled or have changed.

Before any third parties begin with data collection – after the requirements for data sources and methods have been defined – the category-specific quality criteria for such third-party data should be defined, in order to support the QC process at the data level. At present, this step is optional, since in most categories the available data offer little opportunity for selection and differentiation, because not enough data sources are available.

If the data is requested by the person responsible for the subject matter from third parties, the scope expected by the data provider, the requirements for data quality and data documentation should be specified. Upon receipt of the data, they are checked for completeness, compliance with quality criteria and currentness. Data validation is carried out by the relevant expert.

1.2.2.2.3 Data preparation and emissions calculation

The process of data preparation and emissions calculation comprises the following steps:

- Data entry,
- Data preparation (model formation, disaggregation, aggregation)
- Calculation of emissions,
- Preparation of report sections (texts) and
- Approval by the relevant experts

Much of the data import, entry and processing (processing of data, and emissions calculation) takes place in the CSE. This considerably enhances transparency and consistency, and makes it

possible to automate general data level quality control measures in the CSE (such as review of orders of magnitude and completeness, etc.). In these cases, it makes sense to supplement certain quality control measures with manual procedures. In order to validate the calculation results of complex models, cross-checks with simplified assumptions should be carried out outside the CSE for verification purposes.

After completing the checks and consultations where necessary, the emissions are calculated in the CSE using an automated procedure based on the following principle:
activity data x emission factor = emission.

Once upstream calculation pathways are set up within the CSE, these calculations can be initiated automatically and the results incorporated in the emission calculation.

Once the time series for activity data, emission factors, uncertainties and emissions are completed, the report sections are prepared. As a result, the term “data” is understood in a broad sense. In addition to number data, time series, etc., it also includes contextual information such as the sources for time series, and descriptions of calculation methods. It also refers to the preparation of report sections for the NID and documentation of recalculations.

In each case, the relevant expert responsible for QC is responsible for approving texts and calculation results before they are used by the Single National Entity. This is usually done by sending the completed QC/QA checklists to the Single National Entity and obtaining their approval.

1.2.2.2.4 Report preparation

Report preparation includes the following steps:

- Aggregation of emissions data for the report formats: this includes exporting JSON files for the ETF Inventory Reporting Tool from the CSE, importing JSON files into the ETF Inventory Reporting Tool, creating data tables for the NFR and aggregating emission data for the national trend tables.
- Compilation of submitted report texts to create a report draft (NID) and editing of the complete NID,
- Internal review of the draft (national trend tables and NID) by the German Environment Agency, followed by approval,
- Submission to the BMUKN for ministerial coordination with final approval by the Coordination Committee and finally
- Submission to the UNFCCC Secretariat, the European Commission and the UNECE Secretariat and
- final archiving

Following complete preparation of data, report sections and QC/QA checklists by the responsible experts and their submission to the Single National Entity, they are reviewed by category-specific, specialised contact persons at the Single National Entity on the basis of a QC checklist. The results of this review are then provided to the relevant responsible experts to enable these experts to revise their contributions (if necessary, after consultation).

Before emissions data can be transferred to the report formats for the Framework Convention on Climate Change (CRT = *Common Reporting Tables*) and the UNECE Geneva Convention on Long-range Transboundary Air Pollution (NFR = *New Format on Reporting*), emissions data from CSE time series (in the data collection format) must be aggregated into the CRT/NFR category report formats This is accomplished through a hierarchical classification in the CSE, a process that is described in detail for the various key categories in Annex 3. Where nothing has changed from the previous year, the aggregations are carried out automatically.

After calculation aggregation, activity data and emissions are imported into the *ETF Inventory Reporting Tool* via export to JSON files where the IPCC's CRT report tables are automatically generated. However, quality control is still necessary to ensure that the values and *implied emission factors* calculated by the *ETF Inventory Reporting Tool* are consistent between the emissions inventory and the CRF reporter tables. Furthermore, suitable explanatory remarks have to be provided for any recalculations and *notation keys*.

In parallel with this, the report coordinator compiles the reviewed report texts to create the draft of the NID.

The German Environment Agency (UBA)'s internal review and approval of the completed report tables and the NID, as well as the inventory plan to be included in future, takes place through co-signing as part of the internal coordination process at UBA. Everything is then submitted to the BMUKN for the second approval phase as part of interministerial coordination. In a final step, the Coordination Committee approves the report tables and the NID for submission to the UNFCCC Secretariat.

The data tables and the corresponding NID are securely archived in the inventory description (cf. also Chapter 1.2.2.3.1.5). The content of the CSE database used for calculation purposes is also archived.

1.2.2.3 Procedures for quality assurance and quality control (QA/QC), and detailed review of greenhouse gas inventories

1.2.2.3.1 The Quality System for Emissions Inventories

The QSE takes into account the requirements of the *2006 IPCC Guidelines (Vol. 1, Chapter 6)*, the national circumstances in Germany and the internal structures and processes of the reporting institution, the UBA. The QSE's procedures are flexible enough to be able to routinely incorporate future changes in requirements. The QSE's scope of application comprises the entire emissions reporting process.

The QSE covers all participants of the NaSE. Within the German Environment Agency, the QSE is binding thanks to the agency's in-house directive (UBA-Hausanordnung) 11/2005. Details on whether the QSE is binding for other NaSE participants are provided in Annex 5.1.1.

1.2.2.3.1.1 Directive 11/2005 of the German Environment Agency

In 2005, the German Environment Agency established a Quality System for Emissions Inventories (QSE) internally through in-house directive (Hausanordnung) 11/2005. The QSE provides the necessary framework for compliance with good inventory practice and implementation of routine quality assurance. The QSE conforms to the provisions of the 2006 *IPCC Guidelines (Vol. 1, Chapter 6)*, and has been adapted to the national circumstances in Germany and to the internal structures and procedures of the German Environment Agency (UBA), the reporting institution. The in-house directive (Hausanordnung 11/2005) issues binding provisions on competencies within the Agency, lists deadlines for the various inventory preparation steps and describes the necessary measures for quality control/quality assurance.

The directive has fulfilled requirements, pursuant to Paragraph 20 of the *Reporting Guidelines* (24/CP.19), for specification of relevant procedures and, pursuant to Paragraph 23 (a), for definition of specific responsibilities at the Agency level.

1.2.2.3.1.2 Minimum requirements for a quality control and assurance system

The requirements for the quality control and quality assurance system (QC/QA system) and for quality control and quality assurance measures are defined primarily by Chapter 6 of the 2006 *IPCC Guidelines (Vol. 1)*.

In 2007, the German Environment Agency derived "General minimum requirements pertaining to a quality control and quality assurance system for GHG emissions reporting" ("Allgemeine Mindestanforderungen an die Qualitätskontrolle und Qualitätssicherung bei der Treibhausgasemissionsberichterstattung") from the previously applicable *Good Practice Guidance* (Chapter 8) (cf. Annex 5.1.2). External National System participants then adopted the minimum requirements after representatives of the participating federal ministries approved them in the framework of the National Coordination Committee for the National System of Emissions Inventories (cf. Annex 5.1.1).

Further information regarding the German Environment Agency's necessary organisational measures for implementing these requirements is provided in the following chapters and in a complementary section in Annex 5.1.2.1.11.

1.2.2.3.1.3 Organisation structure for establishing the Quality System for Emissions Inventories

As part of the QSE, a concept for the organisational structure was developed that defines binding responsibilities for the implementation of the necessary QK and QS measures for the UBA. The defined roles and responsibilities are intended to ensure effective information exchange and the implementation of QC and QA in compliance with requirements (see table below).

Table 6: QSE - Roles and responsibilities

Role	Task	Responsible
Responsible expert at the operational level (FV)	• Preparation of parts of the National Inventory Document (NID) • Data collection and data entry in the CSE, and calculation in accordance with the selected/prescribed methods • Implementation of systematic QC measures in the NID, CSE and inventory description • Implementation of verification measures • Archiving of all category-specific inventory information (inventory description and decentralised documentation) • If necessary (for category-specific QC): Definition of category-specific quality targets and the criteria for their achievement, in consultation with the QC section representative, the expert responsible and the QC/QA coordinator (QSEK). • Review, preparation and response to review results • Active participation in review processes. This includes giving presentations, providing explanations and being available for questions (before and during the process and in any follow-up). • Initiation and development (specifications) of R&D projects and providing expert support	All staff appointed by the head (FGL) on a category-specific basis
QC/QA section representative for the specific area (QKV)	• Implementation of systematic measures for assuring the quality of the data and report sections delivered to the Single National Entity • Approval of data and report sections • Verification that the necessary inventory work, quality controls, documentation, and archiving have been completed • Definition of responsibilities for emissions reporting in specialised fields and provision of the necessary time resources • Provision of support for review processes, and participation in them	All responsible heads
Specialised contact person (category-specific) in the SNE (FAP)	Category-specific support for responsible experts (FV) and QC/QA section representatives (QKV); support/guidance of FV/QKV in: • Implementation of international requirements • Provision of expertise for data and report texts	Staff of the Single National Entity (SNE) that are appointed on a

Role	Task	Responsible
	• Quality control/quality assurance: ➢ Preparation of missing parts of the National Inventory Document (NID) ➢ Collection and entry of any data missing in the CSE and calculation in accordance with the selected/prescribed methods ➢ Verification that the necessary inventory work, quality controls, documentation, and archiving have been completed ➢ Implementation of systematic QC/QA measures in the NID, CSE and inventory description ➢ Archiving of any missing category-specific inventory information (inventory description and decentralised documentation) • Initiation of and support for R&D projects • Performance of all work using the CRT reporter and quality control • Assumption of tasks of unavailable responsible experts (FV) and vacant positions • Review, preparation and response to (as necessary) review results • Support for, participation in and performance of (as necessary) FV tasks for review processes • Performance of cross-category tasks • If necessary (for category-specific QC): Definition of category-specific quality objectives and the criteria for their achievement in consultation with the QC section representative, the specialised contact person (FAP) and the QC/QA coordinator (QSEK).	category-specific basis
Report coordinator (NIRK)	• Coordination of text contributions • Compilation of the NID from the various contributions • Overarching QC and QA for the NID and some cross-checking with the CRF	An appointed staff member of the Single National Entity (SNE)
CSE coordinator (ZSEK)	• Overarching QC and QA for data entry and calculation for the inventory • Verification of the integrity of databases and reporting tables (Common Reporting Tables (CRT)) • Emissions reporting and data aggregation into report formats • Support for specialised unit in the event of questions relating to the Central System of Emissions (CSE) and to the reporting tables • Identification of uncertainties (with Approach 2), using Monte Carlo simulation	An appointed staff member of the Single National Entity (SNE)
QSE coordinator (QSEK)	• Overarching QC and QA throughout the entire reporting process • Maintenance and further development of the QSE • Maintenance and update of the QC and QA plans, QC checklists and QSE manual • Responsibility for maintaining and updating the inventory plan and improvement plan • If necessary (for category-specific QC): Definition of category-specific quality objectives and the criteria for their achievement in consultation with the responsible expert at the operational level (FV), the QC section representative and the specialised contact person (FAP).	An appointed staff member of the Single National Entity (SNE)

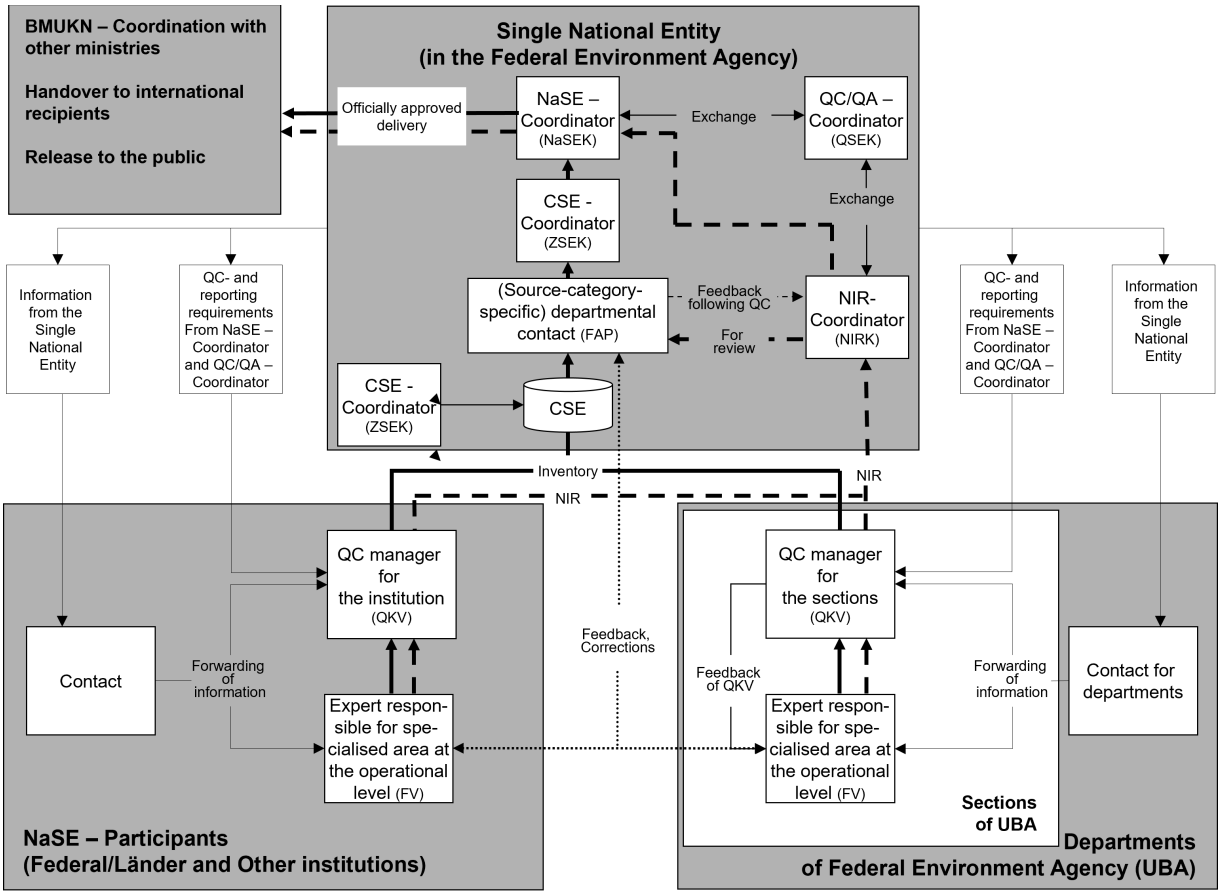
In very rare exceptional cases, the German Environment Agency (UBA) is unable to fill the position of the responsible expert at the operational level (FV) for a particular category. In such cases, the Single National Entity assumes complete responsibility for the QSE role system which provides the roles of the responsible expert (FV), specialised contact person (FAP) and QC/QA section representative (QKV) – with a different person for each role.

Only in cases where a category is of extremely low relevance in terms of its contribution to total emissions is this role concept simplified due to resource constraints. In such cases, the Single National Entity assumes the roles of the FV and the QKV. In return, external quality assurance is carried out at regular intervals for the relevant source categories. The situation and procedure described is currently not being applied.

1.2.2.3.1.4 The operational structure of the Quality System for Emissions Inventories

Procedures for QC/QA measures in the QSE follow the emissions reporting process described in Chapter 1.2.2.4. Quality management is directly linked to the various steps in the inventory process. Suitable quality control measures were assigned to each step in the process of creating the inventory, and these measures were assigned to the individual actors (cf. figure below).

Figure 5: QSE - Roles, responsibilities and workflow



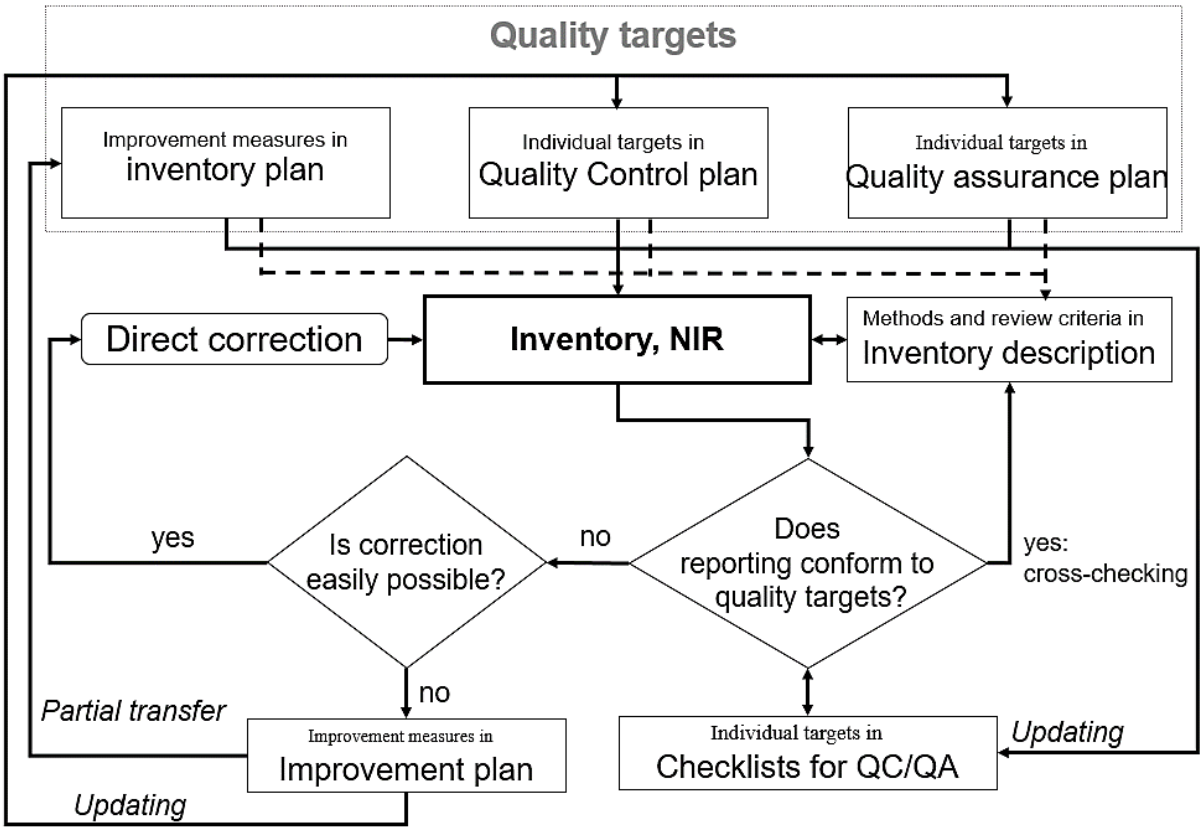
Source: own illustration, German Environment Agency

The quality checks to be carried out in accordance with paragraph 25 (f) of the *Reporting Guidelines* (24/CP.19) are provided to the FV, QKV, FAP and NIRK (cf. Table 6) in the form of quality checklists together with the data request and are completed in the course of the preparatory work.

1.2.2.3.1.5 Performance of QC/QA measures, and control and documentation of these measures within the Quality System for Emissions Inventories

The requirements for the implementation, description and documentation of QC/QA measures, as formulated for the minimum requirements for a QC/QA system (cf. Annex 5.1.2.1) are largely fulfilled in conjunction with production of the respective inventory contributions. A concept was developed for the QSE that presents the measures in an integrated form, tailored to specific target groups and tasks. The individual components are shown in Table 6 (in a slightly simplified form of the inventory plan and the quality control plan; cf. also Chapter 1.5.1.1) Figure 6.

Figure 6: Control and documentation of QC/QA measures



Source: own illustration, German Environment Agency

A general description of the quality objectives is provided in the QSE handbook and is based on the 2006 *IPCC Guidelines (Vol. 1, Chapter 6)*. In addition, individual operational objectives for quality control and quality assurance must be derived for each category from a comparison of the requirements set out in the 2006 IPCC Guidelines, the results of the independent inventory review, the areas for improvement reported in the NID and the actual inventory.

Pursuant to the 2006 *IPCC Guidelines* (Vol. 1, Chapter 6) and Paragraph 19 of the *Reporting Guidelines* (24/CP.19), the necessary QC/QA measures for emissions reporting are to be summarised in a QC/QA plan. The primary function of a QK/QS plan is to organise, plan and monitor these measures. To manage the implementation and monitoring of measures to achieve quality objectives transparently and effectively, they are specified in the quality control plan (QC plan) and quality assurance plan (QA plan) by role and category. Quality objectives can focus on the inventory, the reporting process or the QSE itself. The quality assurance plan also includes the scheduling of quality assurance measures, which are carried out both internally and, for the most part, by independent external third parties. Both plans are essentially sets of specifications.

As to their structure, the QC and QS plans are combined with the checklists for quality control and quality assurance, which are used to review and document successful implementation of QC/QA. In this context, quality checks are actually defined not as checks but as quality objectives (*data quality objectives* pursuant to 2006 IPCC GL, Vol. 1, Chapter 6.5); in each case, either compliance with the objectives must be validated or non-compliance explained. The QC/QA checklists must be completed by the participants in the NaSE[12] in parallel with the inventory

[12] These include responsible experts (FV), specialised contact persons (Fachliche Ansprechpartner – FAP), QC/QA section representatives (QKV – quality control managers) and the coordinator for the national inventory report (Koordinator für den Nationalen Inventar Report – NIRK).

preparation process and facilitate immediate improvements. Where improvements cannot be carried out immediately, they are still useful in providing important information about the quality of the inventory's underlying data, methods and texts. The first time the German Environment Agency carried out systematic QC/QA using checklists and in cooperation with the NaSE participants was for the 2006 report. Since then, the checklists for general quality control are completed every report year and for all reported categories – i.e. both for key categories and for categories that are not key categories. Since the 2007 report, the checklists have been used in electronic form. Also as of the 2007 report, the general QC checks (formerly, Tier 1 checks) have been expanded to include a number of category-specific QC checks (formerly, Tier 2 checks), for key categories. For the 2008, 2009 and 2010 reports, the checklists for the experts involved in the various specialised areas and for specialised contact persons were comprehensively revised. The revision aimed to further enhance the clarity, practical usefulness and transparent structure of the checklists. To ensure the success of the improvements, a selection of the persons affected was involved in the revision. No requirements related to content have changed as a result. Since then, the checklists are reviewed annually for any need for any necessary updates and revised or supplemented as required. Like the checklists, the QC and QA plan is continually further developed. With the 2013 reporting, the previously category-specific checklists of the QKV were converted to a single overarching checklist per QKV for the first time. This was done primarily to improve/simplify the clarity of the QM/QM process for management staff and for reasons of resource efficiency.

The 2015 reporting ensured that the general checklists met the revised requirements of the *2006 IPCC Guidelines (Vol. 1, Chapter 6).* Missing requirements have been added.

Both plans and the QK/QS checklists are instruments for verifying compliance with international requirements and enable inventory quality to be monitored by initiating quality assurance measures in accordance with Paragraph 13 of the *Guidelines for National Systems*.

In the improvement plan, all identified possibilities for improvement (as identified in checklists, NID information on planned improvements, audit results (if applicable) and other required improvements), and any issues brought up by independent inventory reviews, were collected and stored with possible corrective measures. The Single National Entity categorises the corrective measures, prioritises them and, in consultation with the relevant experts, usually incorporates them in full into the inventory plan. They are assigned deadlines and responsibilities in the inventory plan. As an annex to the NID, the inventory plan undergoes a coordination and approval process. It is thus a binding set of specifications for improvements to be carried out in the coming report year.

The Single National Entity also maintains an inventory description as a central document for the various categories. The description covers all key aspects of inventory preparation. All category-specific work relevant to the creation of the inventory must be documented here. The inventory description consists of a server-based folder (directory) system that is available both on mobile devices and on the workstations of those involved in emissions reporting. The obligation to prepare the described documentation was introduced in the German Environment Agency through an in-house directive (cf. Chapter 1.2.2.3.1.1). It provides the basis for archiving inventory information pursuant to the provisions of Paragraph 27 (a) of the *Reporting Guidelines* (24/CP.19).

- For a range of different reasons, the documentation concept provides for an archive that is mainly, but not exclusively, centralised. The decisive factors in this decision were the extensive and partially decentralised database used to calculate the German inventory.

- In addition, external parties hold some of the responsibility for the data
- and confidentiality aspects that, for legal reasons, prevent the transfer of individual data for the purpose of archiving at a central location.

The inventory description contains information on the locations of documents that are not centrally stored.

1.2.2.3.1.6 The QSE handbook

The international requirements for quality assurance and quality control measures in emissions reporting are specified for the National System of Emissions Inventories (NaSE) in Germany in the "Handbook for quality control and quality assurance in preparation of emissions inventories and reporting under the UN Framework Convention on Climate and EU Decision 525/2013/EC" ("Handbuch zur Qualitätskontrolle und Qualitätssicherung bei der Erstellung von Emissionsinventaren und der Berichterstattung unter der Klimarahmenkonvention der Vereinten Nationen sowie der EU Entscheidung 525/2013/EG"). This document is binding for the German Environment Agency and describes the Quality System for Emissions Inventories (QSE).

The QSE handbook entered into force through an in-house directive of the German Environment Agency (cf. Chapter 1.2.2.3.1.1). It was published, along with its associated documents on the German Environment Agency's intranet.

1.2.2.3.1.7 Support for the UNFCCC review

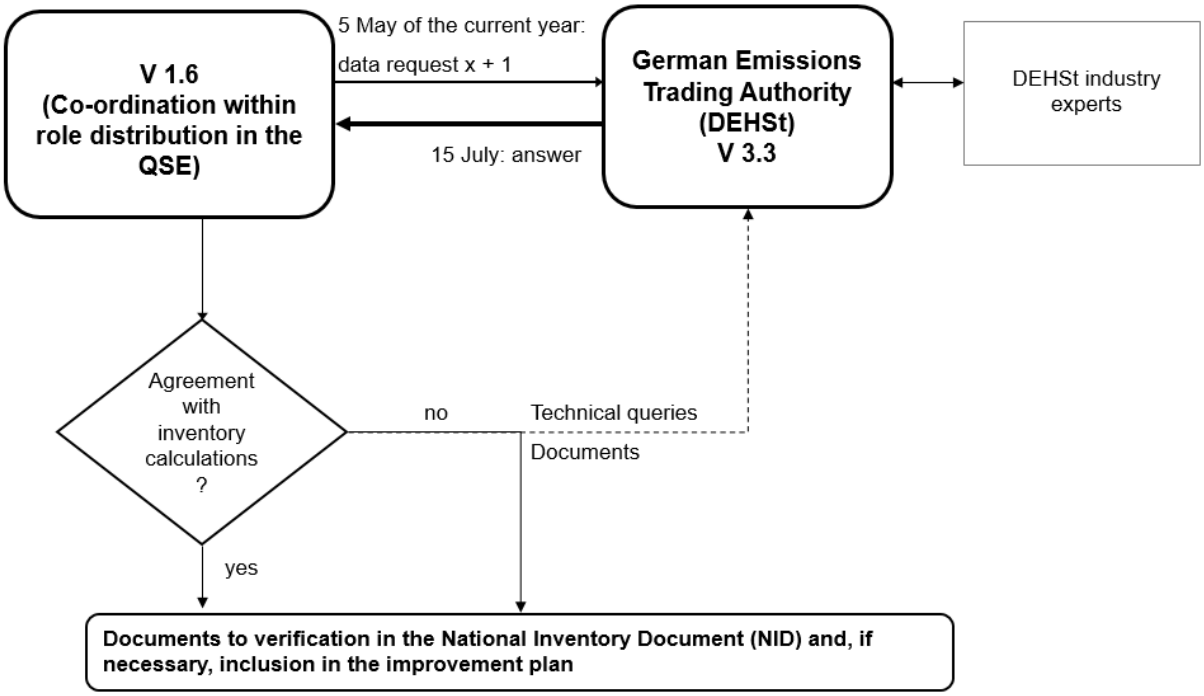
In addition to the German Environment Agency's own quality control and assurance measures, the UNFCCC review provides important impetus for inventory improvement. Consequently, it is in the Single National Entity's own interest to fulfil the requirements for provision of archived inventory information for the review process (pursuant to Paragraph 27 (b) of the *Reporting Guidelines* (24/CP.19)) and to answer questions raised by expert review teams (pursuant to Paragraph 27 (c) of the *Reporting Guidelines* (24/CP.19)). These aspects were given appropriate priority in the design of the QSE.

1.2.2.3.1.8 Use of EU ETS monitoring data for improvement of GHG emissions inventories

Monitoring data from European emissions trading will be used to improve the quality of annual national emissions inventories for categories that include installations subject to reporting obligations under the CO2 Emissions Trading Scheme (ETS).

Comparisons have confirmed the usefulness of this method for verifying individual categories and identifying data gaps. For regular use, a formalised procedure with defined deadlines and procedures was agreed for annual data exchange. For details of data use in QC/QA, cf. also Chapter 1.5.2.1.

Figure 7: Procedure for annual inventory verification using ETS monitoring data



Source: own illustration, German Environment Agency

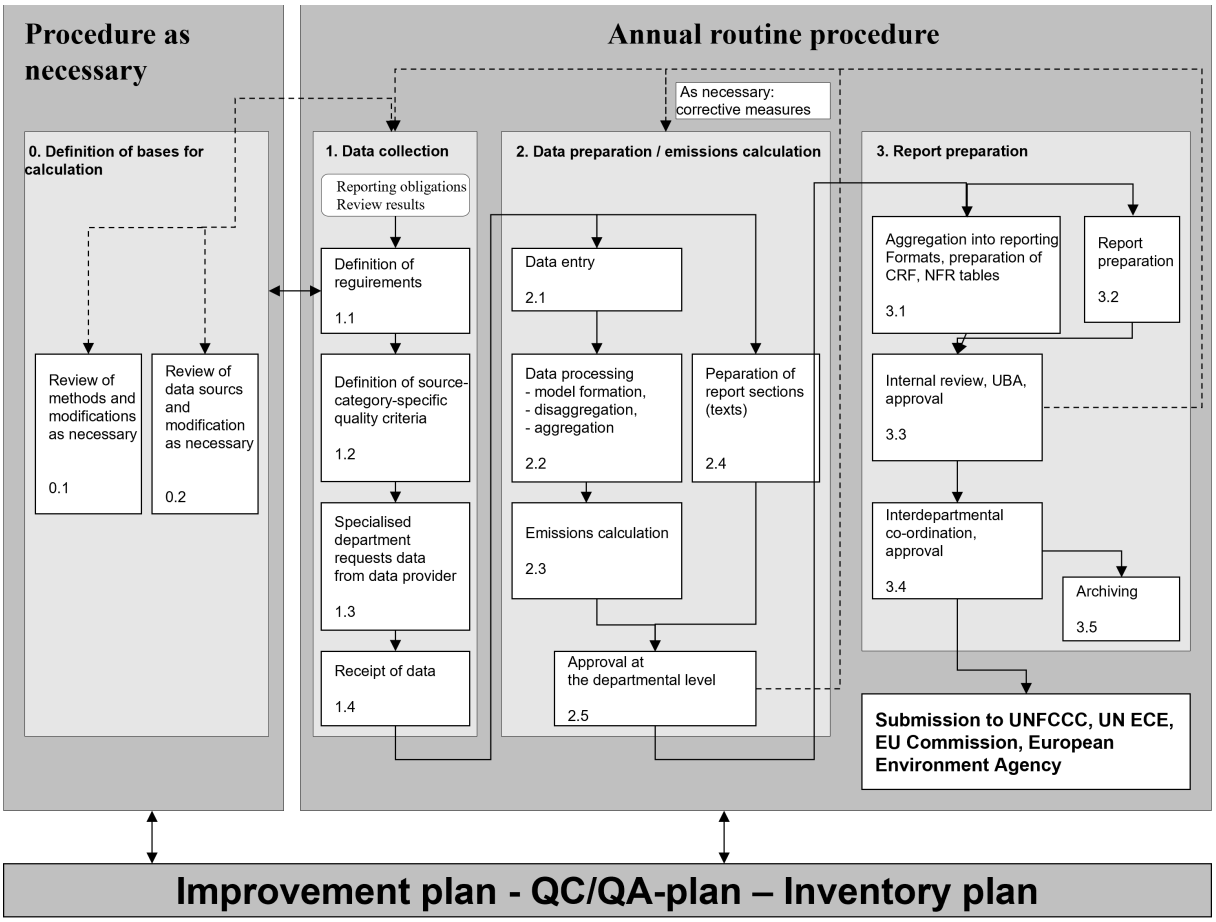
1.2.2.4 Overview of inventory preparation and management

The emissions reporting process is a regular, annual process. Since it is a decentralised process and carried out by different persons, it can vary for different parts of the inventory. Prior to the introduction of the QSE (in 2005), this process was intensively studied and analysed. As a result, the QSE differentiates the following main processes in the overall emissions reporting process that are described in detail in Chapter 1.2.2.2:

- Definition of the bases for calculation,
- Data collection,
- Data preparation and emissions calculation and
- Report creation.

These main processes are broken down into sub-processes according to the following figure.

Figure 8: Overview of the emissions reporting process



Source: own illustration, German Environment Agency

It has been shown that the sequence of the inventory planning and creation process can influence the quality of the inventories. In other words, the sequence of the process is not irrelevant for inventory quality. That is one of the reasons why the inventory preparation process is closely tied to quality assurance and control measures. Suitable QC/QA measures have thus been assigned to each sub-process to ensure that quality assurance not only ensures the quality of inventory data in its final form, but also safeguards the quality on the pathways leading to that final form. This also allows periodic internal evaluations of the inventory preparation process pursuant to paragraph 26 of the *Reporting Guidelines* (24/CP.19).

The process, including QC/QA measures, fulfils the requirements of Paragraph 21 (b) of the *Reporting Guidelines* (24/CP.19) with regard to inventory preparation.

The sequence of inventory preparation is described in detail in Chapter 1.2.2.

1.2.3 Archiving of information

In general, archiving of information used in inventory preparation, including related results and any required explanations, is carried out on the basis of the “inventory description.” Extensive information about the inventory description is provided in Chapter 1.2.2.3.1.5. At the end of each reporting cycle, the inventory description is archived using publicly available software (.zip) and moved to a separate server drive. Read access to the archive is possible at any time.
In addition, the text modules provided by responsible experts, along with the associated QSE QC/QS checklists, are approved and archived in a separate electronic process management

system of the German Environment Agency (UBA) by the responsible expert (FV), specialised contact person (FAP) and QC/QA section representative (cf. Table 3: QSE – Roles and responsibilities of the QSE, Chapter 1.2.2.3.1.3).

1.2.4 Procedure for the official review and approval of the inventory

The official review and approval of the inventory takes place in Germany, in a procedure carried out in addition to the activities conducted in the QSE framework (cf. Chapter 1.2.2.3). The procedure is a two-stage procedure conducted at the level of the German Environment Agency and the participating ministries of the Federal Government (Chapter 1.2.4.1).

An annually recurring schedule (Chapter 1.2.4.1) is established that covers the entire process for inventory preparation, review and approval; for submission to the UNFCCC; and for final inventory review.

1.2.4.1 Procedure for internal review within UBA and binding schedule for the creation of emissions inventories

The binding schedule for preparation of emissions inventories and the NID is communicated to all internal and external stakeholders on the UBA's intranet site and through publication in the NID. The following dates may vary by 1-2 days depending on the calendar and differ for deliveries of final energy data for the inventories to ensure broad consistency with energy reporting to EUROSTAT and the IEA:

15 May	The German Environment Agency's national coordination agency (Single National Entity) asks the responsible experts to submit data and report texts
31 July	Provision of energy data of the Working Group on Energy Balances (AGEB), the statistical data of the Federal Statistical Office and the data provided under agreements with associations and companies, where this data serve as the basis for further calculations
by 1 September	Provision of complete inventory data from the UBA and external NaSE institutions
as of 2 September	Validation/discussion of the provision of data by responsible experts and quality managers, taking account of review results
30 September	Provision of energy data for stationary installations Time series inventories from 2003-2024 to CSE
by 1 October	Initial emissions calculations and preparation of national trend tables; final editing by the Single National Entity within the German Environment Agency
as of 1 October	Validation/discussion of provision of energy data for stationary installations by responsible experts and quality managers, taking account of review results
6 November	In-house consultations at the German Environment Agency
as of 17 November	Final quality assurance by the QSE/CSE/NID coordinator
25 November	Report of the Single National Entity to the BMUKN to initiate interministerial coordination for the emissions data and the National Inventory Report
by 20 December	Approval through interministerial coordination (initiated by the BMUKN)

as of 2 January	Final editing by the German Environment Agency's national coordination agency (Single National Entity)
15 January	Report (CRT and certain parts of the NID) is submitted to the European Commission (as part of the CO_2 Monitoring Mechanism) and to the European Environment Agency
15 March	Report (corrected CRT and complete NID) is submitted to the European Commission (as part of the CO_2 Monitoring Mechanism) and to the European Environment Agency
15 April	Report is submitted to the FCCC Secretariat
May	Initial check by the FCCC Secretariat

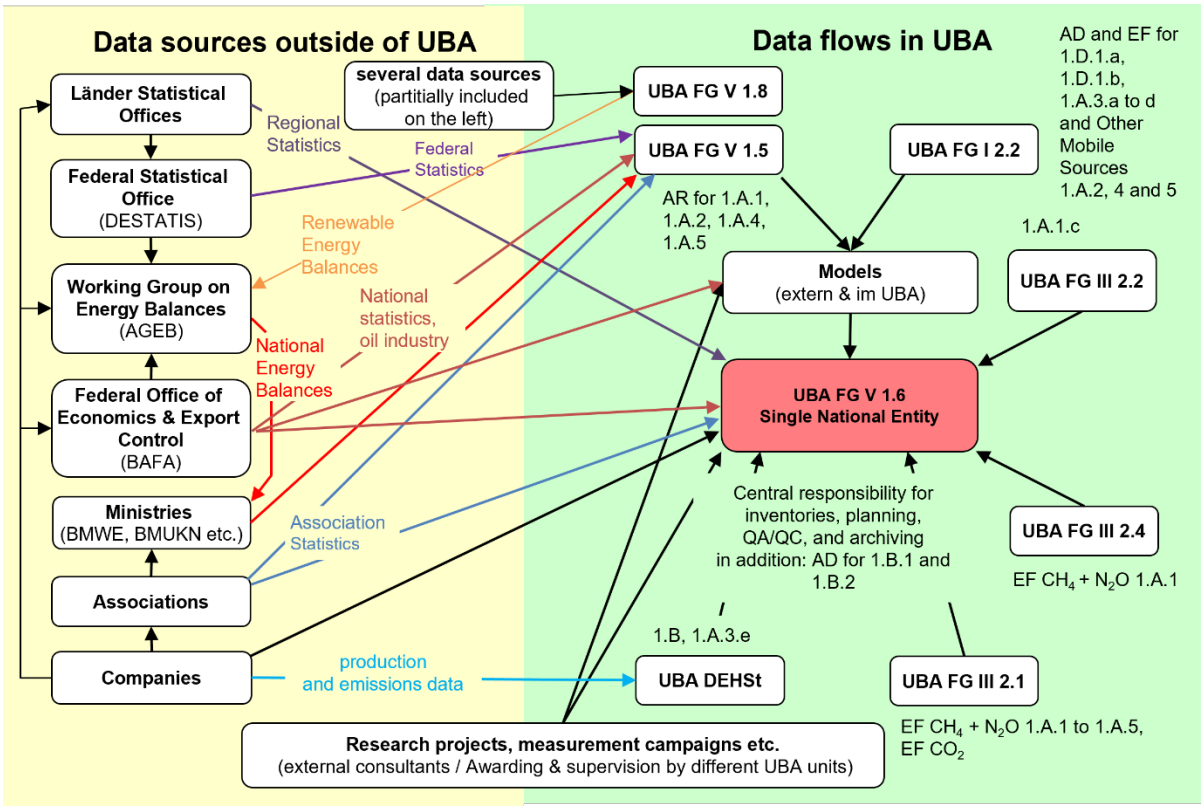
September - Inventory review by the UN FCCC Secretariat

1.3 General description of the methods and data sources used

1.3.1 Sources of data

1.3.1.1 Energy

Figure 9: Responsibilities and data flow for the calculation of greenhouse gas emissions in the energy sector



Source: own illustration, German Environment Agency

The central data source for determination of activity data for category 1.A is the "Energy Balance of the Federal Republic of Germany" ("Energiebilanzen der Bundesrepublik Deutschland"; hereinafter referred to as: the "Energy Balance"), which is published by the Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen – AGEB) and is based, for the most part, on official statistics of the Federal Statistical Office. For the area of renewable energies, the AGEB receives Energy Balance data from the Working Group on Renewable Energy Statistics

(Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat)). The Energy Balance provides an overview of the interdependencies within Germany's energy sector and allows for a breakdown by energy source as well as by their production, conversion and use.

Since 2007, the AGEB has been commissioned, for preparation of Energy Balances, by the Federal Ministry for Economic Affairs and Energy. As part of multi-year contracts, the AGEB has been contractually required to apply the National System of Emissions' minimum requirements for quality assurance. Since 2012, the AGEB has submitted quality reports for the Energy Balance (cf. Annex 6.4.1) and prepared an "Energy Data Action Plan for inventory improvement" ("Energiedaten Inventarverbesserung"; cf. Annex 6.5). Since 2023, AGEB has been producing revisions in the time series for energy balances every two years. Recalculations resulting from this process have now been made for the first time for the 2024 report.

The Federal Statistical Office (Statistisches Bundesamt) is the most important data source for the determination of activity data and the preparation of Energy Balances. For purposes of inventory preparation, the Federal Statistical Office's Fachserie 4 (Reihe 4.1.1 and Reihe 6.4) is used[13]. As of 2018, the data, which provide a detailed breakdown of the manufacturing sector, remain available within the Federal Statistical Office's Genesis database for about one year. To support further data differentiation and clarification of details, the Federal Statistical Office provides special evaluations. For preparation of waste data balances, the Federal Statistical Office makes use of energy statistics and the Statistical Report on Waste Management (Statistischer Bericht Abfallentsorgung), which is published every two years (Statistisches Bundesamt, 2022b).

Since 2022, the Federal Statistical Office makes near-final energy data for the previous year – extrapolated on the basis of existing survey data, using an imputation procedure – available in August of the current year. Based on these data, the AGEB can create a considerably improved preliminary Energy Balance for inventory preparation. The use of these data allows for a high degree of consistency with the energy reporting to EUROSTAT and the IEA.

For the iron and steel sector, data from the German steel industry association (Wirtschaftsvereinigung Stahl) have been used since the 2012 report Wirtschaftsvereinigung Stahl (2025). These data replace, among other things, the "BGS form" (Fuel, gas and electricity industries of blast furnaces, steelworks and rolling mills; and forging plants, press works and hammer mills, including the various other plants (without their own coking plants) locally connected to such operations), a section of the "Fachserie 4, Reihe 8.1," publication of which was discontinued as of 31 December 2009, as well as the monthly production volumes published by the association.

The series Statistik der Kohlenwirtschaft ("Coal industry statistics"), especially its annual publication "Der Kohlenbergbau in der Energiewirtschaft der Bundesrepublik Deutschland" ("Coal mining in the energy sector of the Federal Republic of Germany"), is used as an additional data source. The special evaluations provided by the Bundesverband Braunkohle (Debriv, 2025) are also used for differentiation of the different types of raw lignite coal that are burned. Furthermore, DEBRIV provides the necessary data for calculation of fuel inputs for lignite drying.

Another data source consists of the "Petroleum Data" ("Mineralöl-Zahlen") of the Wirtschaftsverband Fuels & Energie (*en2x*; Fuels and energy industry association), which include data on petroleum production and consumption in Germany, broken down by various

[13] Finding an overview: https://www.destatis.de/DE/Service/Bibliothek/_publikationen-fachserienliste-4.html#149352

production, conversion and use sectors. These statistical data, which are a key basis for the National Energy Balance, are published within just a few months after they have been collected.

The quantities of secondary fuels used for energy generation (listed under CRF 1.A.2) are taken from the Energy Balance, the annual report of the German Pulp and Paper Association (Verband der Papierindustrie) and from reports of the German Cement Works Association (Verband der Zementindustrie – VDZ) and the German lime-industry association (BV Kalk).

Another important data source is the Emissions Trading System (ETS). It keeps highly detailed, plant-specific data that are also used for the inventory. Emissions trading data is used especially in areas that are not covered by national statistics:

- fuel-related CO_2 emission factors for stationary combustion systems,
- fuel inputs for natural gas compressors,
- emissions from coke burn-off in catalyst regeneration, and in calcining, in refineries, and
- fugitive emissions in coking plants.

For collection of transport emissions data (1.A.3), Official Petroleum Data (amtliche Mineralöldaten) of the Federal Office for Economic Affairs and Export Control (BAFA) are used, in addition to Energy Balance data and the Petroleum Data (Mineralöl-Zahlen) of the association *en2x*.

For air transport, in addition to the aforementioned sources, the following sources for consumption data are used: the fuel consumption and emissions are broken down into national and international flights on the basis of data on real aircraft movements. These data are collected and made available by the Federal Statistical Office and further processed in the TREMOD AV model, a separate module of the TREMOD ("Transport Emission Estimation Model") database. Fuel consumption and emissions are also broken down into the flight phases LTO cycle (Landing and Take Off; movements below an elevation of 3,000 feet) and cruise (movements above 3,000 feet); this is also based on the aircraft movement data collected by the Federal Statistical Office.

Country-specific consumption and emissions data provided by Eurocontrol are used solely for verification purposes.

Road transport emissions are calculated primarily with the TREMOD model. For the calculations performed here, extensive basic data from generally accessible statistics and special studies are used, coordinated and supplemented. A precise description of the data sources for emission factors is provided by the "Handbook of road-traffic emission factors" ("Handbuch Emissionsfaktoren des Straßenverkehrs") (HBEFA, Version 4.1).

TREMOD is also used for modelling emissions from fuel combustion in railway vehicles and inland waterway vessels. The emissions from the combustion of coal and coke caused by historic steam railways are calculated outside of TREMOD on the basis of operator information.

The specific consumption and emissions of ship transport departing from German seaports are calculated within a model developed by the Federal Maritime and Hydrographic Agency (BSH). For this area, the breakdown of fuel consumption and emissions into domestic and international transport is based on data derived, among other things, from the ships' AIS messages.

Data on emissions of other mobile sources (in 1.A.4 and 1.A.5) are also collected from figures of the Working Group on Energy Balances (AGEB), of the Federal Office for Economic Affairs and Export Control (BAFA) and of the Association of the German Petroleum Industry (MWV).

Military transports (1.A.5.b) have a special status in this regard; the consumption data for such transports, which as of 1995 are no longer listed in the Energy Balances, are obtained directly from BAFA statistics.

Due to a lack of reliable figures on consumption of biofuels by mobile sources in the construction, agricultural and forestry sectors and by the residential and military sectors, the relevant annual quantities are calculated on the basis of the official admixture quotas.

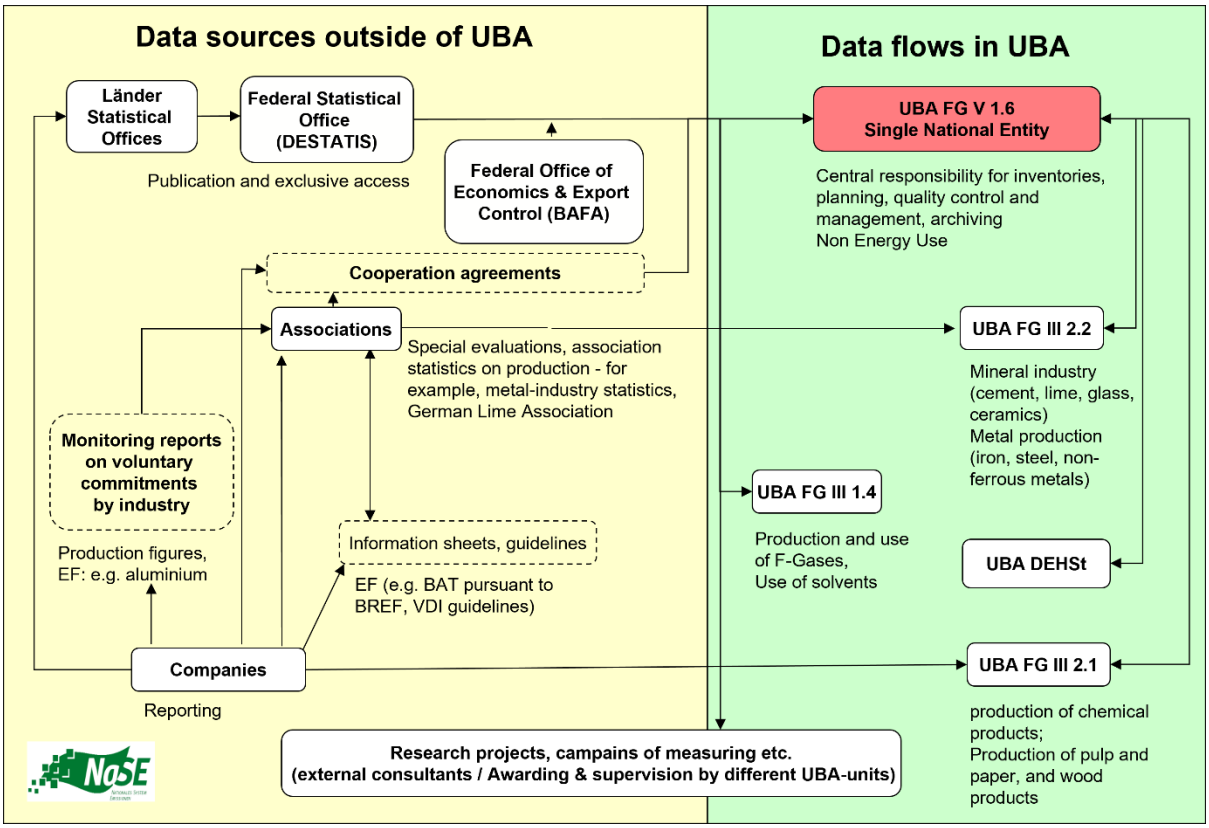
Data on the subcategories in category 1.B.1 are obtained from publications of the Statistik der Kohlenwirtschaft coal sector statistics association, of the DEBRIV Federal German association of lignite-producing companies and their affiliated organisations and of the engineering services company Deutsche Montan Technologie GmbH (DMT).

Data for categories in category 1.B.2 are taken from publications of the following organisations: Federal Statistical Office; the industry association Wirtschaftsverband Fuels und Energie e. V. (en2x); the German Society for Petroleum and Coal Science and Technology (DGMK); the Federal association of the natural gas, oil and geothermal energy industry (BVEG); the German Technical and Scientific Association for Gas and Water (DVGW), the Federal association of the German gas and water industry (Bundesverband der deutschen Gas- und Wasserwirtschaft – BDEW; gas statistics) and the German Emissions Trading Authority (DEHSt). They are also obtained from monitoring reports of the Federal Network Agency (Bundesnetzagentur) and the Bundeskartellamt (Federal cartel office) and from surveys of operators in the area of gas transport. Also, information in line with the EU Methane Regulation (EU) 2024/1787 is incorporated into the compilation of the inventory.

1.3.1.2 Industrial processes

Activity data for the mineral industry are obtained primarily from association statistics. Data for the cement industry (2.A.1) are obtained from the German Cement Works Association (VDZ), in cooperation with the German Emissions Trading Authority (DEHSt). The figures for lime and dolomite lime production (2.A.2) are collected by the German Lime Association (BVK) on a per-plant basis and then provided annually in aggregated form. Glass production figures (2.A.3) are taken from the regularly published annual reports of the Federal glass industry association (Bundesverband Glasindustrie), with relevant auxiliary figures on glass recycling taken from other statistics. Production trends in the ceramics industry (2.A.4.a) are determined using official statistics and conversion factors from an expert project. Figures for soda ash use (2.A.4.b) are determined by the German Environment Agency in a balance sheet calculation.

Figure 10: Responsibilities and data flow for calculation of greenhouse gas emissions from industrial processes



Source: own illustration, German Environment Agency

A range of different sources are used to determine emission factors for the mineral industry. The emission factor used for the calculation of emissions from cement clinker production (2.A.1) is based on a calculation of the German Cement Works Association (VDZ) carried out by aggregating plant-specific data. CO_2 emissions from lime production (2.A.2) and from soda ash use (2.A.4.b) are calculated using stoichiometric factors. The CO_2 emission factors for various types of glass (2.A.3) have been derived by responsible experts from the glass composition data, while CO_2 emission factors for the ceramics industry (2.A.4.a) have been derived by German Environment Agency experts from analyses of ETS data.

The activity data for category 2.B Chemical industry are determined from data of the Federal Statistical Office (FS 4, R 3.1) and directly from figures of industry associations and producers. Some of these data are confidential. The relevant emission factors have been determined by experts in the German Environment Agency in research projects or by the producers. Until 2008, activity data for 2.B.1 Ammonia production and 2.B.2 Nitric acid production were collected by the Federal Statistical Office. Since 2009, data for ammonia and nitric acid production have been collected by the producers themselves – plant-specifically, on the basis of an agreement with the chemical industry and for the entire time series as of 1990. These data are forwarded to the association, which aggregates and submits them, in anonymised form, to the German Environment Agency. For this purpose, in addition to determining the activity data, the producers determine the emissions for 2.B.1 and the emission factors for 2.B.2. Until the mid-1990s, plant-specific activity data were supplied for 2.B.3 Adipic acid production. The default emission factor for N_2O was applied to this data. Plant operators now supply emissions data directly to the German Environment Agency on a confidential basis. For adipic acid production, an agreement from 2009 ensures that data will be supplied in the long term. In 2.B.4, only N_2O

emissions from caprolactam production play a significant role. These emissions are below the applicable threshold value, however, and are thus not reported. Since there is only one calcium carbide (2.B.5) producer in Germany, the relevant data are confidential. The German Environment Agency obtains these data directly from the producer. The CO_2 emissions from titanium dioxide production are not reported, because they lie below the applicable threshold (2.B.6). The total amounts of soda ash produced in Germany (2.B.7) are determined by the Federal Statistical Office, with the most recent data coming directly from the two producers (through a cooperation agreement). The emission factors for soda ash production are derived from the ETS monitoring data of the German Emissions Trading Authority (DEHSt). The activity data for the production of the products listed under 2.B.8 Petrochemicals and carbon black production are obtained from statistics of the Federal Statistical Office. Some of the data are subject to confidentiality. The emission factors have been obtained from experts' assessments, research projects and default figures in the IPCC Guidelines. For carbon black production, the CO_2 emissions data reported within the ETS framework are used. The activity data up to the year 2021 are determined using the default EF. Since 2022, UBA has been obtaining the emissions data directly from the two operators. In the area of production of halocarbons and SF_6 (2.B.9), data are obtained from producers' figures and surveys of producers. For the most part, activity data are researched in research projects, directly in accordance with the inventory's requirements. In some cases, producers supply only emissions data. Only small numbers of companies are involved in the various sub-source categories, and thus data in these areas are confidential. Under 2.B.10 Other, emissions of precursor substances from production of sulphuric acid and fertilisers are reported. The activity data are obtained from information provided by producers and from data of the Federal Statistical Office. The emission factors are obtained from experts' estimates and research projects. N_2O emissions from the production of 1,12-dodecanedioic acid (DDS) also fall within the category (2.B.10). The relevant data are provided by the sole producer of DDS. For reasons of confidentiality, the emissions are reported in 2.B.3.

The activity data for the metal industry (2.C) are provided by the Federal Statistical Office, by the relevant associations (Steel Institute VDEh, Wirtschaftsvereinigung Metalle (metals industry association) and Gesamtverband der Aluminiumindustrie (aluminium industry association) and by sellers of industrial gases. The emission factors for the metals industry (2.C) are normally calculated by experts in the German Environment Agency; in some cases, emission factors are provided by industrial associations or IPCC default values are used.

One exception in this regard is the category ferroalloys where activity data from statistics of the UK Geological Survey are used, while the relevant emission factors are taken from the results of a research project (in some cases, IPCC default values are also used).

In category 2.D Non-energy-related products from fuels and solvents, the activity data have been taken from published surveys of the Federal Statistical Office and of other federal authorities (for production and foreign trade statistics, and for petroleum statistics) and of relevant associations (the VDD industry association for bitumen paper and bitumen roof sheeting; the German asphalt industry association (Deutscher Asphaltverband – DAV)). The activity data are supplemented with industry statistics and information supplied by experts.

The emission factors are obtained from various sources. The emission factors for paraffin wax use (2.D.2), for example, are calculated with the help of IPCC default values. The emission factors for lubricant use (2.D.1) have been determined in a research project (pursuant to the 2006 IPCC Guidelines, NMVOC emissions are to be given only as CO_2 equivalents). The emission factors for the production and laying of bitumen paper and bitumen roof sheeting (2.D.3) and for the

production of asphalt for road paving (2.D.3) refer only to NMVOC, and they have been taken from research reports.

Emission factors, along with other parameters that are included in the calculation of emissions from solvent use, are taken from national studies, experts' opinions and research projects directly commissioned by the German Environment Agency; in some cases, they are also based on information provided by experts in the context of dialogues with industry.

More detailed information on emission factors is presented in the descriptions of methods for the various categories.

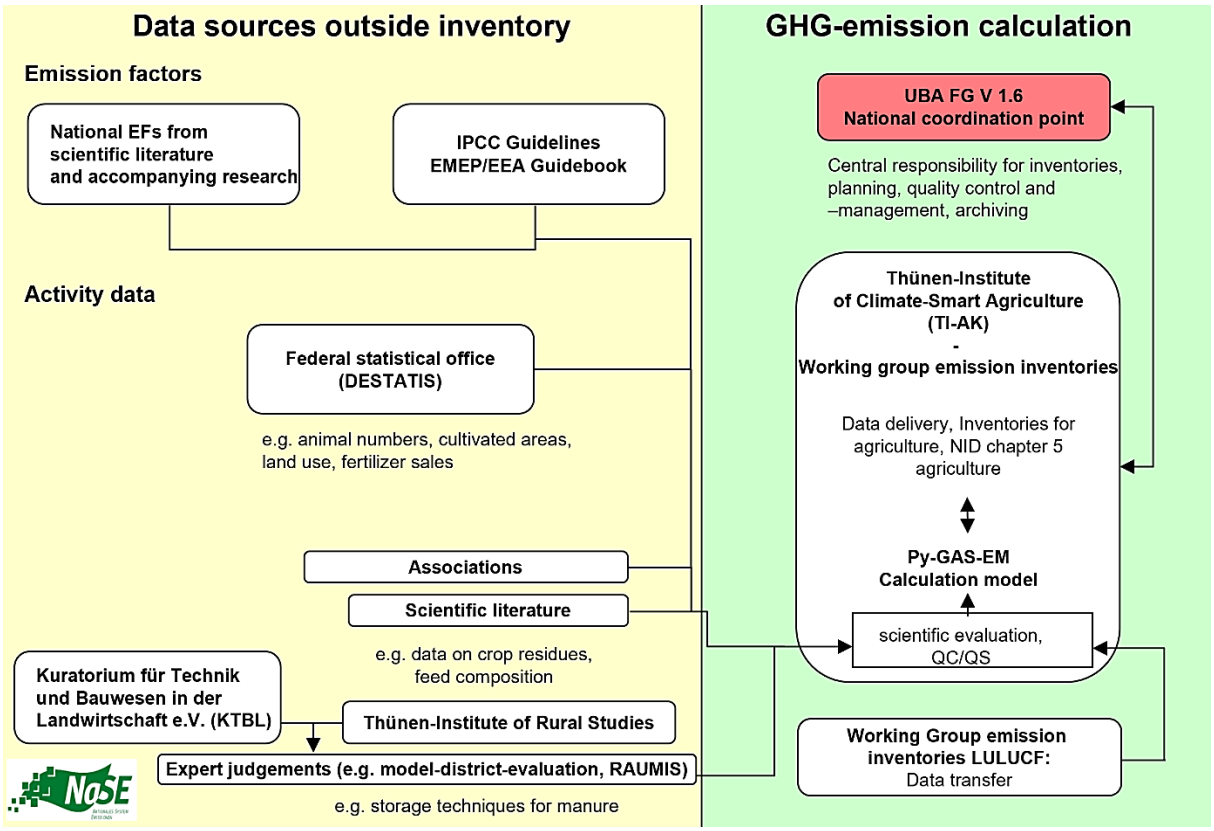
The activity data for the electronics industry (2.E), for product use as substitutes for ODS (2.F) and for other product production and use (2.G) have been determined from information provided by producers and associations, from surveys of the Federal Statistical Office and other federal authorities and with the help of calculation models. In individual cases, producers provide emissions data directly. The data are classified into several subcategories. Product use as ODS substitutes is also subdivided into production, use and disposal emissions. In these categories as well, the data in some areas are subject to confidentiality requirements.

Emission factors for fluorinated greenhouse gases are obtained in part from national and international fact sheets and directives or from surveys of experts; where necessary, IPCC default values are used.

In the area of 2.H.1 Other production: Pulp and paper production, data from the production report of the German Pulp and Paper Association (Verband Deutscher Papierfabriken – VDP) are used. In the area of 2.H.2 Other production: Food and beverages, data of the Federal Food Industry Association (Bundesvereinigung der Deutschen Ernährungsindustrie; BVE), of the Federal Statistical Office (Statistisches Bundesamt) and of the Federal Ministry of Food and Agriculture (BMEL) are used. The emission factors have been obtained from a research project that was completed in 2008.

1.3.1.3 Agriculture

Figure 11: Responsibilities and data flow for calculation of greenhouse gas emissions from agriculture



Source: own illustration, German Environment Agency

Emissions calculations for category 3 (Agriculture) are carried out by the Thünen Institute (TI). The Federal Ministry for the Environment, Climate Action, Nature Conservation and Nuclear Safety (BMUKN) and the Federal Ministry of Food and Agriculture (BMEL) initiated a project for calculation of agricultural emissions in Germany. In it, the former Federal Agricultural Research Institute (FAL) developed a modular model for relevant spreadsheet calculation (GASeous Emissions (GAS-EM)) Dämmgen et al. (2002), and Rösemann et al. (2025); (Vos et al., 2026). For purposes of the 2022 submission, this model was implemented in the Python programming language (Py-GAS-EM).

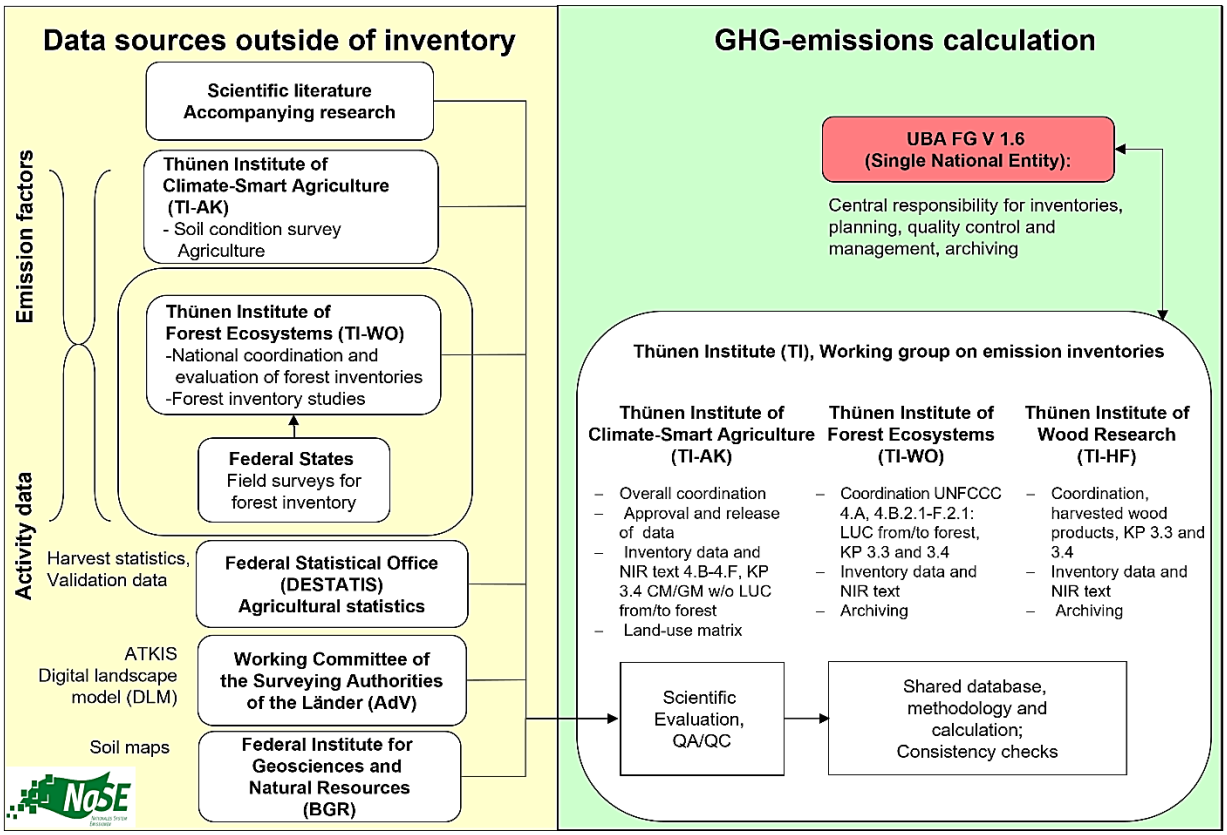
Agricultural statistics of the Federal Statistical Office are another important data source for the calculation of agricultural emissions. Animal statistics have been obtained from the Federal Statistical Office (Statistisches Bundesamt, FS 3, R 4); other Fachserien (technical series) provide data on the amounts of fertiliser sold and agricultural land under cultivation. In some areas, these data are supplemented by figures from the literature (for example, crop residues and feed data). Additional data are available from experts' assessments (for example, an evaluation of model districts with regard to techniques for storing farm fertilisers).

In many areas, calculations for the agriculture sector are based on highly differentiated activity data obtained from national data sources. The activity data are combined, depending on the emission sources involved, either with national emission factors or with the standard emission factors of the 2006 IPCC Guidelines, of the 2019 IPCC refinements of the 2006 IPCC guidelines

and of the EMEP/EEA guidebook of the United Nations Economic Commission for Europe (UNECE).

1.3.1.4 Land-use change and forestry

Figure 12: Data flow for the calculation of greenhouse gas emissions from land-use change and forestry (LULUCF) and KP-LULUCF



Source: own illustration, German Environment Agency

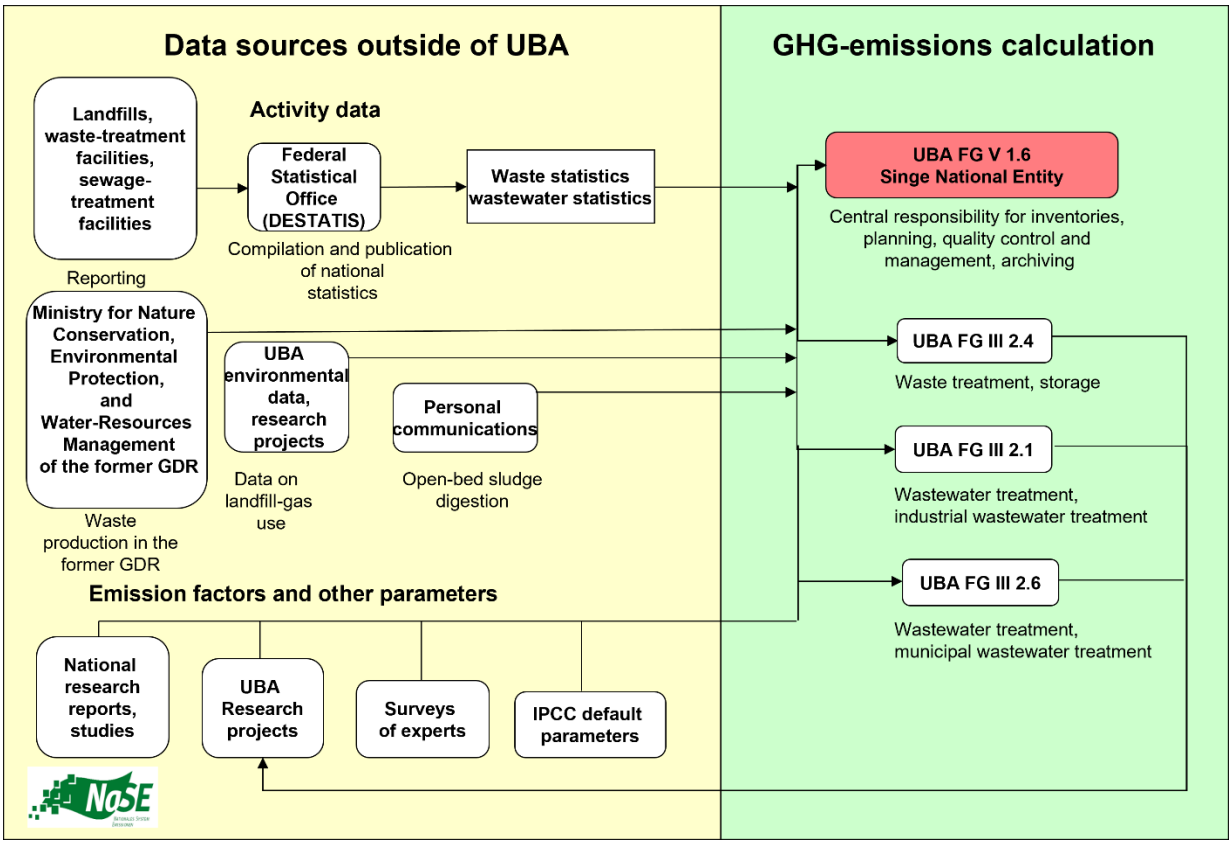
In the 2012 submission, a consistent, unified method was introduced for taking account of land-use changes in the LULUC sector and the forestry sector. The method expands the existing sample-based system for determining forest areas, and land-use changes to and from forest land, for all land-use categories and change types. As a result, the method for creating the land use matrix was adjusted and expanded, and the practice of emission calculation at sample points was introduced.

Soil carbon stocks are estimated using soil maps and soil profile data (both differentiated to show usages) and data from Forest Soil Inventories and Agricultural Soil Inventories (BZE), while use change-related changes in these stocks are estimated on the basis of changes in the mean stocks per land use category.

Changes in biomass carbon stocks are estimated on the basis of harvest statistics, the main survey on soil use (Bodennutzungshaupterhebung), the National Forest Inventory (NFI) and specific factors that are provided in scientific literature and used in conjunction with area data.

1.3.1.5 Waste and wastewater

Figure 13: Data flow for the calculation of greenhouse gas emissions from waste and wastewater



Source: own illustration, German Environment Agency

German Environment Agency Section FG III 2.4 Waste technology, waste technology transfer is responsible for selecting the methods, parameters and data for calculating emissions from the waste sector.

Activity data in the waste sector are drawn mainly from published data of the Federal Statistical Office. The section on waste provides precise information on what statistical sources were used. The Federal Statistical Office has not published any data on amounts of waste produced in the former GDR. An official source of the former GDR's ministry for nature conservation, environmental protection and water resources management was used here. The calculations on landfill gas use are based on data of the Federal Statistical Office. The database for landfill gas use was updated as part of the 2010 In-Country Review. Statistical data on gas collection at landfills in the aftercare phase have been collected since 2012.

The emission factors and other parameters that are included in the calculation of emissions from waste landfilling, mechanical-biological waste treatment and composting and digestion were taken from national studies and research reports conducted/prepared in research projects commissioned directly by the German Environment Agency. IPCC default parameters were also used for this purpose. Selected experts were also consulted regarding a few of the relevant parameters (for example, half-life selection). The relevant chapter documents in detail which parameters originate from which sources.

The German Environment Agency's Section for General Aspects, Chemical Industry, Combustion Plants (III 2.1) is responsible for selecting the methods, parameters and data for calculating

emissions from the industrial wastewater/sewage sludge handling sector (5.D.2). The German Environment Agency's Section III 2.6 Waste Water Treatment Research, Waste Water Management is responsible for selecting the methods, parameters and data for calculating emissions from the "municipal wastewater handling sector" (wastewater and sewage sludge) (5.D.1).

Activity data in the wastewater sector are drawn mainly from published data of the Federal Statistical Office. The section on wastewater provides detailed information on what statistical sources were used.

The emission factors and other parameters that are included in the calculation of emissions from wastewater treatment were taken from national studies and research projects commissioned directly by the German Environment Agency. IPCC default parameters are also used.

1.3.2 Methods

The methods used for the individual categories are outlined in the overview tables for the various categories and in the CRT reporting tables Summary 3. In addition, detailed descriptions are provided in the relevant category chapters.

A distinction is made between calculations made with *country-specific* ("CS") methods and calculations made, in the various categories, with IPCC calculation methods of varying degrees of detail (of varying "*Tiers*")[14]. The manner in which a calculation is assigned to the various IPCC methods depends on the category's share (expressed as equivalent emissions) of total emissions. This assignment is made using the *key category analysis* tool (cf. Chapter 1.4 in this regard).

NMVOC emissions from solvent use, converted into indirect CO_2, are calculated on the basis of a product consumption approach pursuant to the 2006 *IPCC Guidelines*. A similar procedure is used in the area of lubricant use.

1.4 Brief description of key categories

For identification of key categories, both Approach 1 procedures – *"Level"* (looking at the base year and the most recent year) and *"Trend"* (looking at the most recent year versus the base year) – were used.

In addition, the Approach 2 procedure was implemented.

In accordance with the IPCC specifications for Approach 1, not only were emissions from sources taken into account, but also the absorption of greenhouse gases in sinks. The analyses were first carried out solely for emissions from the sources listed in Annex 1 of the UN Framework Convention on Climate Change and then, in a second step, the sinks were included.

All specified key categories result either from level analysis or from trend assessment, or from the Approach 2 key category analysis on the basis of current uncertainties determination. No new key categories were added as a result of assessment of qualitative aspects (explanations are provided in Annex 1).

As a result, for the current report, Approach 1 identified 50 categories as key categories out of a total of 173 source and sink categories studied. 36 of these were identified as key categories as a result of the trend and level analyses. In addition, 8 categories were identified as key categories

[14] Tier 1 refers to the simpler calculation methods that can be used with fewer input data, while Tier 2 and Tier 3 require more detailed input data and thus usually lead to more accurate results.

solely by trend analysis, and 6 categories were so identified solely by level analysis. Approach 2 identified 16 additional key categories (cf. Table 9).

Ultimately, 66 key categories were defined as a result. These are summarised in Table 7.

Table 7: Number of categories and key categories

Category		**173**	
			Key categories
by Level	Level & Trend	Trend	
6	36	8	**50 (Approach 1)**
			+16 (Approach 2)
			66 (total)

Table 8 provides an overview of the results of the key category analysis based on Approach 1. Table 9 shows the additional key categories identified using the Approach 2 analysis. Annex 1) of this report provides detailed explanations of the key category analysis that was carried out.

There have been only minor changes compared to the results determined last year. The number of key categories pursuant to the Approach 1 analysis has increased to 50.

The following key categories have been added.

- *N_2O 1.A.1.a Public Electricity and Heat Production*
- *CO_2 4.E Settlements*

The following key categories have been eliminated:

- *CH_4 4.B Cropland*

Germany uses all recommended approaches for identifying and evaluating categories. The 2006 *IPCC Guidelines* ((IPCC, 2006a): Vol. 1, Chapter 4.3) mandate that 95% of emissions from sources/removals in sinks be classified as key categories. The key categories that Germany has identified comprise emission-causing activities that account for about 98% of the total inventory. This high percentage results from Germany's practice of identifying key categories by combining the results of all analysis procedures and evaluations.

A comparison of the key category analysis carried out by the CRF Tool and Germany's key category analysis has found that the two analyses differ only slightly. There are slight differences in approach: in the energy sector, Germany distinguishes between subcategories, while the CRF Tool differentiates between fuel types. The resulting number of key categories is virtually the same in both analyses, however.

Table 8: Key categories for Germany pursuant to Approach 1, with GWP from IPCC AR5

			Level						Trend		
IPCC Categories	**Activity**	**Emissions of**	**Base year**	**Base year +LULUCF**	**1990**	**1990 +LULUCF**	**2024**	**2024 +LULUCF**	**2024**	**2024 +LULUCF**	**KCA decision**
1 A 1 a, Public Electricity and Heat Production	fossil fuels	CO_2	•	•	•	•	•	•	•	•	L/T
1 A 1 a, Public Electricity and Heat Production		CH_4	-	-	-	-	•	•	•	•	L/T
1 A 1 b, Petroleum Refining	fossil fuels	CO_2	•	•	•	•	•	•	•	•	L/T
1 A 1 c, Manufacture of Solid Fuels and Other Energy Industries	fossil fuels	CO_2	•	•	•	•	•	•	•	•	L/T
1 A 2 a, Iron and Steel	fossil fuels	CO_2	•	•	•	•	•	•	•	•	L/T
1 A 2 b, Non-ferrous metals	fossil fuels	CO_2	-	-	-	-	•	-	-	-	L/-
1 A 2 e, Food Processing, Beverages and Tobacco	fossil fuels	CO_2	-	-	-	-	-	-	•	-	-/T
1 A 2 f, Non-metallic minerals	fossil fuels	CO_2	•	•	•	•	•	•	-	-	L/-
1 A 2 g, Other Manufacturing Industries and Construction	fossil fuels	CO_2	•	•	•	•	•	•	•	•	L/T
1 A 3 b, Road transport	fossil fuels	CO_2	•	•	•	•	•	•	•	•	L/T
1 A 3 c, Rail Transport	fossil fuels	CO_2	•	•	•	•	-	-	•	•	L/T
1 A 3 d, National Shipping	fossil fuels	CO_2	•	•	-	-	-	-	-	-	L/-
1 A 4 a, Commercial/Institutional	fossil fuels	CO_2	•	•	•	•	•	•	•	•	L/T
1 A 4 a, Commercial/Institutional		CH_4	-	-	-	-	-	-	•	-	-/T
1 A 4 b, Residential	fossil fuels	CO_2	•	•	•	•	•	•	•	•	L/T
1 A 4 c, Agriculture/Forestry/Fishing	fossil fuels	CO_2	•	•	•	•	•	•	•	•	L/T
1 A 5, Military	fossil fuels	CO_2	•	•	•	•	-	-	•	•	L/T
1 B 1, Solid Fuels		CH_4	•	•	•	•	-	-	•	•	L/T
1 B 2 b, Fugitive Emissions from Natural Gas		CH_4	•	•	•	•	•	•	•	•	L/T
2 A 1, Cement Production		CO_2	•	•	•	•	•	•	•	•	L/T
2 A 2, Lime Production		CO_2	•	•	•	•	•	•	•	-	L/T
2 B 1, Ammonia Production		CO_2	•	•	•	•	•	•	-	-	L/-
2 B 2, Nitric Acid Production		N_2O	-	-	-	-	-	-	•	•	-/T
2 B 3, Adipic Acid Production		N_2O	•	•	•	•	-	-	•	•	L/T
2 B 9 a, By-product Emissions		HFC23	•	•	•	•	-	-	•	•	L/T
2 C 1, Iron and Steel Production		CO_2	•	•	•	•	•	•	•	•	L/T
2 F, Product Uses as Substitutes for ODS		HFC125	-	-	-	-	•	•	•	•	L/T

			Level						Trend		
2 F, Product Uses as Substitutes for ODS		HFC134a	-	-	-	-	•	•	•	•	L/T
2 F, Product Uses as Substitutes for ODS		HFC143a	-	-	-	-	-	-	•	•	-/T
2 G, Other Product Manufacture and Use		SF_6	•	•	•	•	-	-	•	•	L/T
3 A, Enteric Fermentation	dairy cows	CH_4	•	•	•	•	•	•	•	•	L/T
3 A, Enteric Fermentation	non-dairy cattle	CH_4	•	•	•	•	•	•	•	•	L/T
3 A, Enteric Fermentation	other animals	CH_4	-	-	-	-	•	•	-	-	L/-
3 B, Manure Management	dairy cows	CH_4	-	-	-	-	•	•	•	•	L/T
3 B, Manure Management	swine	CH_4	•	•	•	•	•	•	-	-	L/-
3 D, Agricultural Soils		N_2O	•	•	•	•	•	•	•	•	L/T
3 G, Liming		CO_2	-	-	-	-	•	•	•	-	L/T
3 J, Other Agriculture		CH_4	-	-	-	-	-	-	•	•	-/T
4 A, Forest Land		CO_2	-	•	-	•	-	•	-	•	L/T
4 B, Cropland		CO_2	-	•	-	•	-	•	-	•	L/T
4 C, Grassland		CO_2	-	•	-	•	-	•	-	•	L/T
4 C, Grassland		CH_4	-	-	-	-	-	•	-	•	L/T
4 D, Wetlands		CO_2	-	•	-	•	-	•	-	•	L/T
4 D, Wetlands		CH_4	-	•	-	•	-	•	-	•	L/T
4 E, Settlements		CO2	-	•	-	•	-	•	-	•	L/T
4 G, Harvested Wood Products		CO_2	-	-	-	-	-	-	-	•	-/T
5 A, Solid Waste Disposal		CH_4	•	•	•	•	•	•	•	•	L/T
5 B, Biological Treatment of Solid Waste		CH_4	-	-	-	-	-	-	•	•	-/T
5 D 1, Domestic Wastewater		CH_4	•	•	•	•	-	-	•	•	L/T
5 D 1, Domestic Wastewater		N_2O	-	-	-	-	-	-	•	•	-/T

Table 9: Key categories for Germany identified by the Approach 2 method

IPCC Source Categories	Activity	Emissions of
1 A 1 a, Public Electricity and Heat Production		N_2O
1 A 4 b, Residential		CH_4
1 A 4 b, Residential		N_2O
1 B 1, Solid Fuels		CO_2
1 B 2 c, Venting and Flaring (oil, gas, combined oil and gas)		CO_2
2 C 6, Zinc Production		CO_2
2 D 2, Paraffin Wax Use		CO_2
2 G, Other Product Manufacture and Use		N_2O
3 B, Manure Management	other animals	N_2O
3 B, Manure Management	dairy cows	N_2O
3 B, Manure Management	non dairy cattle	N_2O
3 B, Manure Management	deposition and leaching	N_2O
4 A, Forest Land		N_2O
4 B, Cropland		N_2O
4 E Settlements		N_2O
5 B, Biological Treatment of Solid Waste		N_2O

1.5 Information on the quality assurance and quality control plan, the inventory plan (including verification) and handling confidential information

1.5.1 Quality assurance and quality control procedures

1.5.1.1 QC/QA plan

Pursuant to the *2006 IPCC Guidelines*, the necessary QC/QA and verification measures for emissions reporting are to be summarised in a QC/QA plan. The primary function of a QC/QA plan is to organise and plan these measures and ensure their implementation.

The fundamental aim of the QC plan and the National System is to subject the entire inventory every year to a complete QC process in accordance with the Guidelines – to a QC process that covers all categories, regardless of whether they are key categories. The QC plan therefore consists of the QC/QA checklists (cf. Chapter 1.5.1.2) and the inventory plan (cf. Chapter 1.5.1.3). A nearly identical approach is used for the QA section of the plan. This means that quality checks are carried out each year as required by the Guidelines. At the same time, the required *peer reviews* are carried out periodically (see also below).

The QA plan thus consists of the QC/QA checklists (cf. Chapter 1.5.1.2) and the schedule for emissions reporting (cf. Chapter 1.2.4.1) with the associated tasks. These checklists and the approval processes specified by the QSE ensure that the inventories undergo a large number of internal, but above all external, quality assurance checks each year. This also includes *basic expert peer reviews* to be carried out annually by the ministries involved, the results of which, including any corrections, are incorporated into the inventories as part of the established

routines before the reports are finalised. These quality assurance activities are complemented and reinforced by periodic peer reviews (cf. Chapter 1.5.1.4).

Regular adaptation and revision of the aforementioned instruments, also taking country-specific requirements into account, ensure that the requirements of the *2006 Guidelines* are met, including with regard to appropriate consideration of national circumstances.

A general description of the structural and procedural organisation, quality assurance and quality control can be found in Chapter 1.2.2.3.1. This section also describes the principles by which QC/QA measures are managed and documented.

The requirements for quality assurance and quality control measures in emissions reporting are described in detail in the "Handbook for quality control and quality assurance in preparation of emissions inventories and reporting under the UN Framework Convention on Climate and EU Decision 525/2013/EC" ("Handbuch zur Qualitätskontrolle und Qualitätssicherung bei der Erstellung von Emissionsinventaren und der Berichterstattung unter der Klimarahmenkonvention der Vereinten Nationen sowie der EU Entscheidung 525/2013/EG". Quality checks, which are mainly carried out before the inventory is completed, form the core of the guidelines set out in the handbook.

1.5.1.2 QC/QA checklists

The quality checks are carried out using checklists (for the relevant content, cf. Chapters 1.2.2.3.1.5 and Annex 5.1.2.1.11). These lists currently comprise some 88 role-specific individual objectives and some 40 optional objectives.

Currently, some 55 German Environment Agency and external staff, in various functional roles, and in four layered, cumulative QC/QA review levels, are involved in emissions reporting. The review levels are represented in each case by the relevant expert (Fachverantwortlicher – FV); their superior, the QC/QA section representative (QKV); a specialised contact person, within the Single National Entity, for the relevant category (Fachlicher Ansprechpartner – FAP); and, finally, the coordinators responsible for achieving a consistent overall result comprising the NID, the inventory, the QSE and uncertainties estimates.

When the inventory is prepared, role-specific QC/QA checks are linked to general quality objectives (cf. Chapter Annex 5.1.2.1.10.3) and individual process steps (cf. Chapter 1.2.2.4), so that final evaluation can also take account of these objectives and steps whenever necessary. On the whole, the checks cover the entire inventory preparation process.

The subsequent evaluation of the checklists reveals, for specific categories, aspects that need to be reviewed – and, possibly, revised – with regard to fulfilment of specific inventory requirements. For this purpose, they are supplemented with further information. The great majority of all identified review requirements are added to the binding inventory plan. The inventory plan undergoes internal and interministerial approval processes and is then published in aggregated form.

1.5.1.3 Inventory plan

For the annual preparation of the inventory plan, the results of the QC/QA checklists for all categories are evaluated, and objectives that have not been achieved are assigned improvement measures as necessary, as well as deadlines for their implementation (*follow-up procedure*). These measures are then complemented by the improvement activities mentioned in the NID (cf. Chapter 10.4.1), by the results of the various review procedures of the UNFCCC and the European Commission, by audit results (cf. 1.5.1.4) and by any listings of further required improvements. The inventory plan comprises a range of individual measures that are to be

implemented by the various roles within the QSE (cf. the role concept within QSE, Chapter 1.2.2.3.1.3) and by the Federal German ministries involved in emissions reporting along with their agencies. The measures included are to be completed within the time periods defined in the inventory plan, although the relevant responsible NaSE participants have to provide the necessary personnel and financial resources for the measures.

When each IP is created, the QSE coordinator reviews whether the required actions defined in previous years have been completed. The IP is then updated with this information. Required actions that could not be completed by the defined deadlines are flagged with an "overdue" status and given higher priority (*follow-follow-up procedure*).

Because the individual measures included in the inventory plan are so numerous – there are too many to be listed here – they have been combined into overarching measures as shown in Table 10. The inventory plan is updated at least once a year in an ongoing process.

As measures in the inventory plan are implemented, large numbers of the individual measures included are processed and thereby resolved on a regular basis.

Table 10: Inventory plan – outstanding action items

Main Category	Category (CRT-Code)	Data quality objective	Source	Source-Reference-Year of Reporting
Energy	1.A.3.d+e	Check whether requirements of IPCC-Guidelines pertaining to selection of calculation method and to procedures for applicable methods changes are fulfilled or if it´s necessary to adjust already existing calculation methods/modells.	CHKL, NIR	2017, 2025
LULUCF	4		NID	2023-26
Energy	1.A.3.d.(a), 1.A.4., 1.A.4.a.i-b.i-c.i. & 1.A.5.a.	Check whether there are any gaps in time series.	CHKL	2020, 2023+25
LULUCF	4., 4.C.		CHKL, NID	2025+26
Energy	1.A.1+2, 1.A.4.a.i-b.i-c.i. & 1.A.5.a.	Check whether the source category is completely covered by the relevant data source and whether the defined data sets for EF and AR are consistently delimited.	CHKL	2026
Industrial Processes	2.C.2, 2.C.3.a		Audit	2016
Energy	1.A.1+2, 1.A.3.e.i., 1.A.4.a.i-b.i-c.i. & 1.A.5.a., 1.A.4.c.iii, 1.A.5.b.(iii)	Check whether uncertainties have been determined, are complete and up to date.	CHKL	2024+26
Industrial Processes	2.C.3.a., 2.D.3.(b)+(j)		Audit, CHKL	2012, 2016, 2026
Waste	5.A.1, 5.D.1, 5.E.1.(a)		CHKL, other	2020+24+25+26
General	0.	Check whether obligations pertaining to keeping of records and documentation are fulfilled and whether the relevant documents are complete, meaningful and up to date.	CHKL	2015, 2018
Energy	1.A., 1.A.1., 1.A.2., 1.A.2.a+g.vii+iii.,1.A.3., 1.A.4., 1.A.5.a+b.		CHKL	2018+20, 2024-26
Industrial Processes	2.A.1-3+4a, 2.B.3+8, 2.C.2+3.a., 2.D, 2.D.1.(a+b), 2.D.2, 2.D.3.(a,d,e,f,g,h,i)+j, 2.G.3.a+4.(c)		CHKL	2016, 2020, 2023, 2025+26
Agriculture	3.A+B+D+G+H+J		CHKL	2026
LULUCF	4.(V), 4.G		CHKL	2026
Waste	5.A.1, 5.B.1+2, 5.D.1, 5.E.1.(a)		Audit, CHKL	2016, 2019, 2022, 2024+26
Energy	1.A.3.b+d (a), 1.A.4.c.iii, 1.A.5, 1.A.5.b(iii)	Check whether data suppliers and contracted supporting entities are carrying out suitable routine quality controls, and whether the emissions-reporting requirements defined by the Single National Entity have been provided to such suppliers and entities and are being fulfilled.	Audit, CHKL	2012, 2016, 2021, 2023 +26
Industrial Processes	2.B.8.a, 2.B.10.(i), 2.C.2, 2.D.1.(b)		Audit, CHKL	2012, 2016+17, 2026
Waste	5.B.1+2		Audit	2016

Main Category	Category (CRT-Code)	Data quality objective	Source	Source-Reference-Year of Reporting
General	0.	Check whether requirements for cross-checking and verification of data and their underlying assumptions have been fulfilled.	ARR, CHKL, Sonstige	2015, 2018, 2025+26
Energy	1.A, 1.A.1., 1.A.2.+a+g.viii., 1.A.3.d.(a)+e.+e.i, 1.A.4.a.i.+b.i.+c., 1.A.5.a+b.		CHKL	2023-26
Industrial Processes	2.B.7, 2.C.1+2+3a+5+6, 2.D.1.(b), 2.D.3.(a,d,e,f,g,h,i), 2.G.3.(a)		Audit, CHKL	2016, 2023-26
LULUCF	4.G.		CHKL	2025
Waste	5.A.1, 5.B.1+2, 5.D.1+2, 5.E.1.(a)		CHKL, other	2018, 2020, 2024-26
General	0.	Check whether it was possible to take pointers from inventory reviews and inventory plan into account.	ARR	2010
Energy	1.A.1, 1.A.3.d(b), 1.A.3.e		CHKL	2022, 2026
Energy	1.A., 1.A.1.+2., , 1.A.2.g.vii., 1.A.3.a+e., 1.A.4.a.i+ii.+b.i+ii+c.i+ii, 1.A.5.b(i)+(ii)	Check whether data-consistency requirements are fulfilled and whether the relevant documents are complete and meaningful.	CHKL	2018+19, 2021+22, 2025+26
Industrial Processes	2.D.3.(a,d,e,f,g,h,i)		CHKL	2026
Waste	5.A.1		CHKL	2024
Industrial Processes	2.H.2.	Check whether the EF are plausible and complete (have no gaps and are completely documented) and up to date.	NIR	2021
LULUCF	4., 4.D.1		ESR, NID	2025, 2026
Energy	1.A.2.g.vii.	Check whether the AR are plausible and complete (have no gaps and are completely documented) and up to date.	CHKL	2026
LULUCF	4., 4.A.		ESR, NID	2025+26
Industrial Processes	2.D.1.(b)	Check whether data has been entered into the CSE correctly, including whether all numbers, units and conversion factors have been correctly entered and properly integrated.	CHKL	2026
General	0.	Check whether the NIR source category has been completely and logically described in terms of the required six sub-chapters for the NIR ("Source category description", "Methodological issues", etc.).	ARR	2022
Energy	1.A.1, 1.A.2.+ g.vii+iii, 1.A.3.e.+e.i, 1.A.4.a.i.+b.i+c.i, 1.A.5.a, 1.AD, 1.D.1+.2		ARR, CHKL	2022, 2024+25
Industrial Processes	2.C.2+5+6, 2.D.1.(b), 2.D.3.(a,d,e,f,g,h,i)+(j)		CHKL	2019, 2026
LULUCF	4., 4.D.1		ESR	2025
Waste	5.A.1, 5.D.1, 5.E.1.(a)		CHKL	2026
General	0.	Various types of required action.	other	2014, 2016
Energy	1.A.1, 1.A.2., 1.A.2.g.vii, 1.A.3.c+d(a+b)+e, 1.A.4.a.i+ii+b.i+ii+c., 1.A.5.a+b.		CHKL, NID, other	2015, 2017-19, 2022-26
Industrial Processes	2.D.3.(a,d,e,f,g,h,i)		CHKL	2025
Waste	5.A.1, 5.D.2		ARR, other	2015+16, 2018
Energy	1.A.3.b+e+e.i	Initiated research projects for inventory improvement.	Audit, CHKL	2016, 2024
Industrial Processes	2.A.4.b, 2.D.1.(a), 2.D.2, 2.D.3.(a,b,d,e,f,g,h,i), 2.D.3.(b), 2.G.3.a.+b(ii), 2.G.4.(c)		CHKL, NIR	2012, 2024+25

The first inventory plan was published together with the 2007 submission. Since then, several thousand required actions and improvements have been addressed in the quality system.

As of the end of the current report year, the inventory plan comprises some 380 active required actions and improvements. These items are distributed among around 77 categories.

The main areas for improvement that are currently being addressed or are in progress relate to documentation, verification and various improvements.

The overview in Table 11 presents more detailed information on the improvements that have been successfully carried out. Both tables (Table 10 & Table 11) contain review results from 2010 onwards, statements made in the NIR regarding planned improvements from 2012 onwards, other areas for improvement from 2014 onwards, and CHKL results from 2012 onwards.

Detailed information on individual improvements regarding category, priority, scheduling, responsibility, gas, fuel, required action, etc. cannot be provided here due to the scope of the information. Further excerpts from the inventory plan can be found for the completed review results in Table 467, and for the statements made in the NIR/NID on planned improvements in Table 468.

Table 11: Inventory plan – required actions/improvements that have been successfully addressed

Main Category	Category (CRF-Code)	Data quality objective	Source	Source-Reference-Year of Reporting
LULUCF	4, 4.A.1, 4.E.2	Check whether requirements of IPCC-Guidelines pertaining to selection of calculation method and to procedures for applicable methods changes are fulfilled or if it´s necessary to adjust already existing calculation methods/modells.	ESR, NIR	2023+25
Energy	1.B.2.b.iv-vi	Check whether there are any gaps in time series.	CHKL	2025
Industrial Processes	2.B.7., 2.B.10.(i)	Check whether uncertainties have been determined, are complete and up to date.	CHKL	2023+24
General	0.	Check whether obligations pertaining to keeping of records and documentation are fulfilled and whether the relevant documents are complete, meaningful and up to date.	CHKL	2015
Energy	1.A.5.b.(i), 1.B.1, 1.B.2.b.iv-vi		CHKL	2025
Industrial Processes	2.B.7, 2.B.9, 2.B.10.(i), 2.C.3.a+b, 2.C.4, 2.E.1+3+4, 2.F.1-5, 2.G.1+2+2.(c+d)		CHKL	2024+25
LULUCF	4 (V)		CHKL	2024
Waste	5.D.2, 5.E.1.(a)		CHKL	2025
General	0.	Check whether data suppliers and contracted supporting entities are carrying out suitable routine quality controls, and whether the emissions-reporting requirements defined by the Single National Entity have been provided to such suppliers and entities and are being fulfilled.	other	2016
Energy	1.A.3., 1.A.4.c.iii., 1.A.5.b.		CHKL	2015, 2024+25
Industrial Processes	2.D.1.(b)		CHKL	2025
General	0	Check whether requirements for cross-checking and verification of data and their underlying assumptions have been fulfilled.	CHKL	2024+25
Energy	1.A.4.a.ii+b.ii.+c.ii, 1.A.5.b.(iii), 1.B.1, 1.B.2.b.iv-vi		CHKL	2022, 2025
Industrial Processes	2.B.1+2, 2.G.2.(c), 2.G.4.(d)		CHKL	2023-25
LULUCF	4.G		CHKL	2025
Waste	5.D.1+2		CHKL	2025
Energy	1.B.1, 1.B.2.b.iv-vi	Check whether data-consistency requirements are fulfilled and whether the relevant documents are complete and meaningful.	CHKL	2025
Industrial Processes	2.B.10.(i)		NID	2024
Agriculture	3.D.2	Check whether the EF are plausible and complete (have no gaps and are completely documented) and up to date.	ESR	2025
LULUCF	4.E.2, 4.G	Check whether the AR are plausible and complete (have no gaps and are completely documented) and up to date.	ESR, NID	2025
General	0.	Check whether the NIR source category has been completely and logically described in terms of the required six sub-chapters for the NIR	ARR	2022
Energy	1, 1.A.1.a, 1.B.1+2.a, 1.B.2.b.i-iii, 1.B.2.b.iv-vi, 1.B.2.c. - Flaring		ARR, CHKL	2015+16, 2022, 2025

Main Category	Category (CRF-Code)	Data quality objective	Source	Source-Reference-Year of Reporting
LULUCF	4	("Source category description", "Methodological issues", etc.).	ESR	2025
LULUCF	4	Check whether any recalculations are required. If they are they must be documented in a logical manner.	NID	2025
General	0.		Other	2016
Energy	1.A.3.b, 1.A.3.d.(b), 1.B.2.b.iv-vi	Various types of required action.	CHKL	2020, 2025
Industrial Processes	2.B.10	Initiated research projects for inventory improvement.	NID	2025

1.5.1.4 Audit

In April 2016, the German Environment Agency's Quality System for Emission Inventories (QSE) was externally audited. The aims were to:

- Check whether the QSE complies with the quality requirements of the *2006 IPCC Guidelines*,
- Identify any potential for improvement,
- Identify any possible risks for the continuing maintenance of data quality.

An audit programme was developed that offers significantly more than just a representative cross-section of all emission categories, as the audited employees are in most cases responsible for other categories and their procedures there differ little from the cases used.

Using the audit plan that had been drawn up, a preliminary audit was conducted in February 2016 for two categories and the coordinators for the quality system (QSE), the Central Emissions System (ZSE; database) and the National System (NaSE) for the purpose of testing the applicability and time required and determining the need for adjustments to the audit plan. In parallel with the revision of the audit plan, a schedule was drawn up for conducting the audits, involving a total of five auditors. During the audit, the following procedure was normally carried out on three successive days: the responsible experts (Fachverantwortlicher; FV) and their specialised contact persons (Fachlicher Ansprechpartner; FAP) were audited in pairs. This work covered a total of 44 of 148 categories. The reviewed procedures and workflows in the audited categories represent more than 80% of the total emissions covered by the German greenhouse gas inventory. In addition, all coordinators who had not yet been included in the preliminary audit were included in the audit program in individual audits.

The audit plan covered the following topic areas:

1. Roles and responsibilities
2. The use of general quality control procedures
3. Implementation of requirements set forth in the QSE manual (inventory description, inventory plan, NIR)
4. Category-specific quality controls for
    - Emission factors
    - Measurements
    - Activity data
    - Calculation procedures and determination of uncertainties

The key findings of the audit include:

1. The minimum requirements for quality control/quality assurance (QC/QA), as specified by the 2006 IPCC Guidelines, are being met without exception. All target requirements are being met with the design and the implementation of the QSE.
2. The QSE's prescribed QC/QA procedures are effective in assuring data quality, in accordance with the requirements of the IPCC Guidelines, and in ensuring a process of continuous improvement. This requires consistent implementation of the QSE guidelines by the employees and departments involved.
3. The QSE goes far beyond its own requirement to meet minimum standards and can even offer best practice examples for many aspects based on the IPCC 2006 Guidelines. The design and scope of the inventory description are particularly noteworthy, as it represents a comprehensive and transparent tool for documenting data, processing status and the procedures used in almost all of the categories analysed. Only in the area of category-specific quality control – in a small number of aspects – is there some room for improvement, and the relevant improvements could well be carried out in the longer term (such as preparation of standardised spreadsheet templates).
4. The risk that data quality could decrease is seen as very low, in light of the QSE's structure and design, as well as of the extensive, detailed information contained in the inventory descriptions. Risks are more likely to arise in relation to temporary gaps in the continuous application of collection and calculation procedures, as extrapolation calculations would have to be used in some cases as a substitute in reporting if experienced staff were to be unavailable. By no means does such unavailability lead to a loss of information, however – it would always be possible to subsequently restore the database with the usual data quality.
5. In some categories, data quality could be improved even further by checking the currency of the data used more frequently. It thus could be useful to review, at mandatory intervals, whether emission factors are still current or whether in the meantime data that would support use of higher Tier approach (such as national factors instead of the IPCC defaults) have become available or could be obtained. If updates are required, the necessary studies could be included in the research budget.
6. Individual potential for improvement in the categories studied and in general areas was also identified. This was included in the existing instruments for improvement (the inventory plan).

1.5.1.5 Workshops on the National System (Peer Review)

In November 2004, the German Environment Agency held a first workshop on the National System of Emissions Inventories. This created a forum that significantly encouraged the involvement of associations and other independent organisations, as well as supporting implementation of Paragraph 15 (b) of the *Guidelines for National Systems*, which requires inventories to be reviewed by third parties (*peer review*).

As a result, several workshops were held with the purpose of facilitating review of the inventories by independent third parties pursuant to Paragraph 15 (b) of the *Guidelines for National Systems*. In 2009, a second workshop focussed on selected specific categories of the inventory, such as "N_2O from product use", "emissions from non-energy-related use of fossil fuels" and "SF6 emissions from the photovoltaics industry". The extensive and intensive discussions during the workshop contributed significantly to overall improvement of the data – and thus to the quality of the reporting.

In 2011, an international experts' workshop on the German LULUCF reporting system was carried out that reviewed the methodological changes made as a result of the *In-Country Review*

of September 2010. All of the recommendations made by experts in the workshop were fully implemented.

Technical discussions on natural gas statistics were conducted with the Federal Statistical Office in 2012 and in summer 2015. The participants in the technical discussion in 2012 included representatives of the Federal Statistical Office, the German Environment Agency (UBA) and the German Association of Energy and Water Industries (BDEW), as well as representatives of various gas companies and the German Institute for Economic Research (DIW; Working Group on Energy Balances (AGEB)). When preparing to revise the national Energy Balance, the discussion focussed on the available natural gas statistics. In the process, measures were approved that will directly improve the Energy Balance and thus will improve the emissions inventory. In addition, further research was agreed upon to verify the statistical data. The technical discussion in 2015 aimed to coordinate data exchange between the Federal Statistical Office and the German Environment Agency, also with regard to the new reporting requirements set forth in the *2006 IPCC Guidelines* (IPCC, 2006a) and the European Greenhouse gas Monitoring Mechanism Regulation (MMR)(EU, 2013a).

In March 2014, a workshop was held with European inventory experts on the implementation of the *2006 IPCC Guidelines* in German greenhouse gas reporting. The workshop, which had about 60 participants, focussed particularly on the sectors of energy (CRF 1) and industrial processes and product use (CRF 2). The opportunity to exchange experiences has significantly improved the implementation of the new methods in German greenhouse gas inventories.

1.5.1.6 *Cross-Country Review* on fluorinated gases

In February 2011, a group of experts met in Vienna for a cross-country review on reporting F gases. The participating countries were the UK, Austria and Germany. After a basic introduction to data collection in the three countries, the various individual areas of application were considered in detail and compared in terms of data sources, accuracy, emission factors and other criteria. It became clear that Germany has the most expertise in this field and is therefore probably best placed to assess the completeness and plausibility of the available data.

One key finding of the cross-country review is that all three countries have to put a lot of effort into reporting on F gases. Reducing the amount of work involved will result in reporting that is no longer IPCC-compliant.

As a result of the meeting, a report was created that was included in German reporting on F gases.

1.5.2 Activities for verification

1.5.2.1 Verification in selected categories

In the 2015/2016 report year, a verification project was carried out in accordance with the *2006 IPCC Guidelines (Vol. 1, Chapter 6)*. All of the inventory's categories were reviewed to determine whether they required verification. The following categories were identified:

- *1.A.2.a Iron & Steel*
- *1.A.3.e Other Transportation*
- *1.B.1.a.ii Surface Mining*
- *1.B.2.b.v.i Natural Gas: Other*
- *2.A Mineral Industry*

- *2.B.1 Ammonia Production*
- *2.B.2 Nitric Acid Production*
- *2.B.3 Adipic Acid Production*
- *3 Agriculture*
- *4 Land Use Matrix*
- 4 Consistency between the descriptions in the NID and the CRT tables
- *4.A Forest Land*
- *5.A.1 Managed Waste Disposal*

The project owner carried out verification for the categories listed above. Once completed, the results can be found in the verification chapter for the respective category.

1.5.2.2 Verification of the national inventory using independent data

The chronological sequence for the three most important greenhouse gases (CO_2, N_2O and CH_4) for the German emissions inventory was verified using the data sets recommended by the *2019 IPCC Refinements* (IPCC, 2019). These include, in particular, the JRC's *Emissions Database for Global Atmospheric Research* (EDGAR) (Crippa et al., 2025a) and data of the ECMWF's *Copernicus Atmospheric Monitoring Service* (CAMS) (ECMWF, 2025). In addition, data of the *Pollution Release and Transfer Register* (PRTR) (Umweltbundesamt, 2025) and the *European Environment Agency's European Emissions Trading System* (ETS) (EEA, 2025) were used for verification purposes. These four data sets are independent of the *national totals* used in the German inventory. For this reason, they can serve as an independent basis of data for verification, as described in chapters 6.10.1-6.10.2 of the IPCC Guidelines (IPCC, 2019). The EDGAR database is used here to compare trends in the three greenhouse gases mentioned above for the period 1990-2024, which can be done directly as EDGAR provides both spatially distributed and aggregated data for comparison with total national emissions (Crippa et al., 2025b). For comparisons with total national emissions quantities, the CAMS data have to be aggregated both spatially and temporally. However, during the period mentioned, a comparison is only possible with CAMS CO_2 data (Chevallier, 2020) and methane data (Seegers, Houweling and Tokaya, 2020), as nitrous oxide data is only available from 1996 onwards. The PRTR data are available for verification only for the period as of 2007 (Umweltbundesamt, 2025) and the ETS data for the period as of 2005 (EEA, 2025). Further information about the data sets, and a detailed verification analysis of the German inventory's temporal trend (with LULUCF and AFOLU) is presented in Annex 5.1.4). The time span for the comparison was determined by the largest overlapping time span between the analysed data sets and covers the period 1990-2022/2023 (depending on the time scope of the comparison data set). In this case, the EDGAR data set closely replicates the data of the German national inventory as can be seen in Annex 5.1.4. The data of the CAMS service also replicate the temporal trends of the German inventory data with the exception of the trend for the nitrous oxide data 15.1.4 (Thompson, 2021). This clearly shows how valuable inverse modelling data can be for verification work on the national emissions inventory, as shown in the *IPCC 2019 Refinements* (IPCC, 2019). However, more scientific development work needs to be carried out with a view to improving these results still further. At the European level, initiatives such as Verify and COCO2, and many future projects, are drawing on this work to deliver even better results and data products in future. As soon as the relevant data sets are provided to the inventory community, they will be incorporated into

verification activities. The PRTR data and the ETS data show similar temporal trends when they are compared with the national inventory data (with correlation values of 0.8 for both data sets). Additional analyses can be found in Annex 5.1.4.

1.5.2.3 Procedure for using monitoring data from European emissions trading

To fulfil mandatory quality criteria, improvements to GHG emission inventories are needed, particularly within the EU, based on findings from the European Emissions Trading Scheme (ETS).

Since the start of ETS monitoring, a reliable basis of data on emissions trading has been available for annual emissions. These data can be used, in aggregated form, to draw category-specific conclusions on the completeness and consistency of parts of emissions inventories. In addition, they provide a basis for reviewing the emission factors used and for verifying activity data. Since emissions calculations in the emissions inventory are all based on the same activity data for all components, this verification is of significance for all reported gases.

Emissions trading data required for improvement of inventory data subject to reporting are available in electronic form, in the installations database of the German Emissions Trading Authority (DEHSt). In 2005, a general procedure for individual data queries about inventory preparation was agreed. This essentially involves direct communication between the Single National Entity and the German Emissions Trading Authority's section V 3.3, which is responsible for reports (cf. 1.2.2.3.1.8). To be able to tap into this potential on a regular basis, this formalised procedure with set deadlines has been agreed for the annual data exchange.

Monitoring data from European emissions trading will be used to improve the quality of annual national emissions inventories for categories that include installations subject to reporting obligations under the CO_2 Emissions Trading Scheme (ETS). Relevant information is provided in the category chapters on verification, although detailed comparisons are only provided in individual cases. For reasons of confidentiality, especially regarding certain inventory details, the results of the comparisons are usually described in text form. Tables containing the data used can only be made available during inventory reviews. The comparison of fuel-related CO_2 emission factors in Annex 6.6 is an example of a successful verification.

The provision of the database from DEHSt to those responsible for the inventories has already required project-based support on several occasions. Allocation rules were developed that make it possible to compare, on a yearly basis, data from verified emissions reports with the structure of the inventory database (Öko-Institut, 2006). In the process, it became clear that the data quantities the ETS provides for inventory calculations present challenges in terms of available resources and time. When discrepancies occur in existing aggregates that fulfil requirements for confidentiality of business and operational secrets, the underlying data sets for individual operational steps have to be checked. This obstacle was confirmed for the German situation, by experts of other countries, in the framework of an international workshop within the project (Handke et al., 2013). In another project, the situation regarding the adjustment of the ETS requirements for the third trading period was assessed (Herold et al., 2016).

Currently, standardised comparative data are regularly available. It is compiled on the basis of reporting obligations in the context of the EU regulations on greenhouse gases. The following data sets are provided in the CSE inventory database:

- Data broken down in accordance with the German Greenhouse Gas Emissions Trading Act (TEHG): These data consist of emissions data aggregated from operator notifications to the Union Registry that are made available by the German Emissions Trading Authority (DEHSt).

Because the data show totals of fuel-related and process emissions, they are not directly suited for CRF comparisons.

- Data broken in accordance with CRF: Data from operators' reviewed emissions reports are provided by the DEHSt in consultation with the Single National Entity for the purpose of fulfilment of EU reporting obligations. Pursuant to a specification of the implementing regulation for the European Regulation on the Governance of the Energy Union and Climate Action[15], these data enable a quantitative comparison of EU-ETS emissions data with GHG inventory data

The methods for preparation of the aggregates mentioned above are continuously being improved and regularly discussed in expert consultations.

1.5.3 Handling of confidential information

Following the entry into force of the amended version of the Act on Energy Statistics of 26 July 2002 to the 3rd SME Relief Act (MEG – Mittelstandsentlastungsgesetz), the German Environment Agency (UBA) was granted access to data of the Federal Statistical Office that are subject to statistical confidentiality for the purposes of inventory preparation. This access was also assured in the amendment of the Act on Energy Statistics of 6 March 2017 (Federal Law Gazette (BGBl) I p. 392) in Section 13.

In addition, the Single National Entity receives activity data, emission factors and emissions data that reflect operational and business secrets and that are otherwise confidential from associations and companies.

The Single National Entity must take special precautions and follow special procedures to store and protect the confidentiality of data.

In particular, a strict separation (in terms of space and personnel) between statistics/analysis and enforcement must be ensured.

The Single National Entity and the affected sections of the German Environment Agency have taken various measures for the purpose of fulfilling these requirements. The principle always applies that persons with enforcement duties cannot assume any specialist responsibilities for emissions reporting in this area.

In 2008, the Single National Entity commissioned a legal opinion with the aim of accurately assessing the requirements and possibilities for handling and using the data for emissions reporting. The results were incorporated into revision and refinement of the Single National Entity's concept for handling confidential data and were formally implemented via in-house directive No. 04/2019 – Assurance of conformance with confidentiality requirements pursuant to the Federal Statistics Act (BStatG), the Energy Statistics Act (EnStatG), the Environmental Statistics Act (UStatG) and the Manufacturing Industry Statistics Act (ProdGewStatG) – and through contractual arrangements in Division V.

Previously, access to the Central System on Emissions (CSE) database was already limited to a specified group of authorised persons. This measure represents the key precaution for dealing with confidential data. This enables the necessary separation of personnel between statistics and enforcement to be implemented in practice. In addition, a special access-restricted area was set up in 2009 on a central server of the German Environment Agency for confidential electronic data that are not centrally stored in the CSE (for example, energy data subject to statistical

[15] REGULATION (EU) 2018/1999 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018 on the Governance of the Energy Union and Climate Action

confidentiality, emissions control declarations, data on large combustion plants, information about production processes, etc.).

Furthermore, data of the Federal Statistical Office are provided on a password-/access-protected server (i.e. available only for specifically authorised persons) of the Federal Statistical Office. In the German Environment Agency, these data are processed in a database protected by personalised access control (i.e. a database available only for specifically authorised persons).

1.6 General estimation of uncertainties, including data on the total uncertainty of the total national emissions

The *2006 IPCC Guidelines* ((IPCC, 2006a): Vol. 1, Chapter 3) characterise determination of uncertainties as a key element of any complete inventory. As a result of the need to continually improve the inventories, uncertainties in the inventories play an important role. Uncertainties information is used primarily as an aid for improving the accuracy of inventories, as well as for selecting methods and carrying out recalculations for inventories. The stated aim is to minimise uncertainties to the greatest possible degree in order to maximise the inventories' accuracy. In a first step, the uncertainties for all categories and sinks have to be quantified, to enhance assessment of inventory quality – which assessment, in turn, is the key to effective inventory planning.

In general, two methods for determining uncertainties are differentiated. The Approach 1 method combines the uncertainties in activity data and emission factors for each category and greenhouse gas and then aggregates these uncertainties for all categories and greenhouse gas components to obtain the total uncertainty for the inventory. The Approach 2 method for uncertainties is the same in principle, but it also considers the distribution function for uncertainties and carries out aggregation using a Monte Carlo simulation. In the Approach 2 method, this process also necessarily includes determining a probability density function for all activity data and emission factors. Ideally, these functions can be determined through statistical evaluation of individual data items (such as measurements for a large number of installations). In many cases, few relevant values are available, however, and thus the uncertainty is determined on the basis of experts' assessments.

Research project 202 42 266 (Handke et al., 2004) determined uncertainties for the first time in accordance with the Approach 1 and Approach 2 methods pursuant to Chapter 6 of the *2000 Good Practice Guidance* (IPCC, 2000). For the current report, the resulting data have been further improved, and additional uncertainties data for the greenhouse gas inventory have been added. In addition, the provisions of the *2006 Guidelines* (IPCC, 2006a) were adopted. In Germany, uncertainties are determined, on an annual basis pursuant to both the Approach 1 and Approach 2 methods. The uncertainties for the activity data, emission factors and emissions data used were taken from the CSE database. They are based on information provided in the literature and on estimates of experts in relevant departments of the German Environment Agency and at external institutions.

1.6.1.1 Procedures for uncertainties determination

In accordance with Chapter 3 of the 2006 IPCC Guidelines (IPCC, 2006a), uncertainties are determined on the basis of the uncertainties for activity data, emission factors (EFs) and emissions (EM), as determined on the lowest subcategory level and as listed in the CSE. In the Approach 1 method, where asymmetric uncertainties data result and a normal distribution is assumed, the larger of the two bound values is used as both the upper bound and the lower bound. The Approach 2 method, on the other hand, uses the complete data set in each case. In

each sector, the uncertainties for the individual time series are aggregated to form a total uncertainty for the sector. The uncertainty of the inventory as a whole is obtained from aggregating the sector uncertainties.

Due to a lack of data from the year of German reunification (1990) and the related technical limitations, the year 1995 is generally used, in a departure from the Guidelines, as the base year for calculation of base year and trend uncertainties.

In general, when calculating uncertainties, values for activity data can be assumed to be smaller than those for emission factors. In particular, activity data derived from fuel use data and based on the National Energy Balance exhibit low uncertainties. On the other hand, uncertainties for activity data derived from disaggregated fuel use normally increase as the relevant disaggregation increases.

The following list presents a number of sector-specific details that underlie calculation of uncertainties:

- Pursuant to the results of (Rentz et al., 2002), the uncertainties in emission factors for indirect greenhouse gases in stationary combustion (CRF 1.A.1) are relatively small as a result of regular monitoring of these emissions. Higher uncertainties are listed for N_2O emission factors, since N_2O emissions are not normally monitored. The same applies to the emission factors for CH_4.
- In the category for the iron and steel industry (CRF 1.A.2.a), uncertainties for 2017 increased because, in the absence of fuel input data (BGS curve) from the association, calculations had to be based on production data from emissions trading. The association's failure to supply data is due to antitrust reasons.
- In general, the uncertainties for the category Transport (mainly CRF 1.A.3) can be assumed to be small. Fuel consumption and vehicle fleets are very precisely known due to their tax liability, and emission factors are modelled with a high level of differentiation and usually determined by measurement. Some uncertainties may arise from systematic measuring errors or incorrect disaggregation.
- With regard to the category Fugitive emissions (CRF 1.B), the uncertainties for the activity data for liquid and gaseous fuels (CRF 1.B.2) are assumed to be very small due to the applicable tax liabilities. The only exception is flaring of gases. The activity data for Coal mining (CRF 1.B.1) are also well documented by the production volumes.
- Greater uncertainties must be expected for the emission factors, however, due to the large number and heterogeneity of technical factors relevant to diffuse emissions in the transport, storage and processing of natural gas and crude oil.
- Considerable uncertainties can be seen in many areas in the category of industrial processes (CRF 2). Activity rates based on production figures that must be reported to the Federal Statistical Office may be subject to uncertainty, primarily due to industry definitions that differ from reporting structures. Activity data determined from association information are subject to uncertainties that correlate in each case with the degree to which the relevant industrial sector is represented in this association. With regard to emission factors, the high degree of technological dependence on the one hand and the high degree of technical diversification on the other hand in particular indicate greater uncertainties depending on the greenhouse gas. It is also worth noting that, particularly in sectors with few market players (e.g. manufacture of chemical products, CRF 2.B), technology-specific emission

factors often involve trade secrets, which in turn leads to operators being generally reluctant to publish this type of data or to providing only generalised information. Furthermore, the sometimes highly complex processes involved in generating emissions from non-combustion activities, insufficient knowledge about certain emission-causing processes, and limited knowledge about the contributions of individual activities increase the level of uncertainty.

- The uncertainties for emissions parameters for the categories Managed waste disposal in landfills (CRF 5.A.1, 5.B and 5.E) and Wastewater treatment (CRF 5.D) are assumed to be high. This applies especially to the areas of composting, MBT and waste landfilling, as the diversity of different types of waste has a negative impact on the data reliability of emission parameters. Higher uncertainties for activity data can be attributed, among other things, to the fact that the underlying statistical data uses inconsistent waste and recycling terms. The general assumptions about uncertainties of activity data also apply to thermal treatment of waste.

Further information about the uncertainties for individual source categories is provided in the relevant sector-specific chapters of this report.

1.6.1.2 Results of uncertainties assessment

The total uncertainty of the inventory for the year 2024 pursuant to Approach 1 is 3.1%; pursuant to Approach 2, it is -2.15/+2.2%. The following table provides a concise overview of the uncertainties of the inventory as a whole:

Table 12: Overview of the uncertainties for the inventory as a whole

	Base year	2024	Trend	Method	Base year uncertainty		2024 uncertainty		Trend uncertainty	
	kt	kt	%		%		%		%	
National total incl. LULUCF	1,293,321	707,608	-45.29	EP	3.00		3.10		3.07	
				MC	-2.63	+2.67	-2.58	+2.53	-6.68	+6.76
National total w/o LULUCF	1,256,826	649,769	-48.30	EP	3.05		2.68		2.09	
				MC	-2.15	+2.20	-1.70	+1.76	-4.62	+4.79

The overview shows the uncertainties for the German inventory as a whole, both with and without CRF 4 (LULUCF). For both cases, the uncertainties are listed for the base year, for 2024 and for the trend. In each case, the uncertainties were determined both pursuant to Approach 1 and using the Monte Carlo simulation (Approach 2). The latter method yields considerably better insights. For example, only Approach 2 uncertainties properly highlight the difference between the two lines (with and without LULUCF).

Detailed information about the sector-specific uncertainties involved is provided in Annex 2 (cf. Annex 2). The following section describes in greater detail several sectors that have significant influence on the uncertainty of the inventory as a whole:

- The CO_2 emissions of the sector Combustion of fuels (1.A) contribute significantly to the total uncertainty. The largest share is accounted for by solid fuels in the sector Public electricity and heat production (1.A.1.a) and mobile sources (1.A.3), especially road transport (1.A.3.b) and combustion in the residential and commercial/institutional sectors (1.A.4.a/b/c).

- Nitrous oxide emissions overall also contribute significantly to the total uncertainty, which is largely determined by nitrous oxide emissions from manure management (3.B) and from agricultural soils (3.D).
- The CO_2 sinks and sources in Sector 4 LULUCF also account for an important share of the total uncertainty.

Methane emissions from animal husbandry (Enteric fermentation, 3.A) and energy inputs in industrial sectors in areas 1.A.2.a and 1.A.2.g also make considerable contributions to the total uncertainty.

1.7 General check of completeness

1.7.1 Information about completeness, including data gaps and non-reported categories

The following information about the completeness of individual categories supplements in text form the information provided in CRT Table 9.

The German emissions inventory differentiates between the following:

1. *Category-specific* emissions and sinks that do not occur (NO – *not occurring*), and
2. Category-specific emissions and sinks that have *not been calculated* and reported due to lack of relevance or because the input data cannot be obtained (with reasonable effort) (NE: *not estimated*).

The following section discusses a few category-specific approaches for improving the completeness of the inventory:

Combustion-related activities (1.A) in the energy sector are considered to be fully accounted for. In cases of sub-areas in which the Energy Balance of the Federal Republic of Germany does not provide complete coverage, the sub-areas are selectively supplemented (this applies, for example, to non-commercial wood use, secondary fuels and solid fuels used in railway transport). In some categories, the breakdown into a) combustion-related emissions and b) non-combustion-related process emissions requires further verification. In general, prevention of duplicate counting is an important part of quality assurance, however.

In the area of industrial processes, production data from association statistics and manufacturers are sometimes used. If emissions reporting is based on these sources, emphasis will continue to be placed on checking the category definitions and data collection methodology to ensure the completeness and reliability of the inventory.

1.7.2 Description of unimportant categories

Pursuant to 18/CMA.1, emissions that are reported as “not estimated” (NE) are of minor importance with regard to the overall level and the development of national emissions, as their probable level is less than 0.05 per cent of total national greenhouse gas emissions and does not exceed 500 kt CO_2 equivalent.

Some of the emissions data available to the German Environment Agency are confidential due to data protection requirements and are therefore reported in full, but only in aggregate form.

The following table presents the emission sources that are not yet directly reported – i.e. sources for which the necessary bases for calculation are either not available or could be obtained only with great effort. At the same time, the emissions need to conform to the negligibility criteria

provided in the definition of the notation keys "NE". The necessary estimates for conformance are also listed.

Table 13: Completeness: Overview of sources and sinks whose emissions are not estimated in time series (not estimated, NE), emissions data in [kt CO_2-eq]

	GHG emissions, 2024	
	National total (without LULUCF)	649,770
	thereof 0.1%	650
	thereof 0.05%	325

CRF code	CRF name	Expected or estimated emissions	Reference: cf. NID chapter:
1.B.1.b	Transformation processes	< 0	3.3.1.3
1.B.1.b	Biochar	< 0.054	3.3.1.3
1.B.2.a.6/1.B.2.b.6	Abandoned wells	< 0	emissions considered insignificant; no method provided in the 2006 GL; planned to provide a NID chapter in a future submission
1.B.2.d	Geothermal Energy	< 1	3.3.2.4
2.A.4.c	Non-metallurgical magnesium production	< 100	4.2.4.3.2
2.B.4.a	Caprolactam	< 15.9	4.3.4.2
2.B.6	Titanium dioxide production	< 270	4.3.6
2.D.3	Asphalt – asphalt roofing	< 0.2	4.5.4.2
2.D.3	Asphalt – road paving	< 2.5	4.5.5.2
5.A	Flaring	< 0.8	7.2.1.2.9
5.E.	Accidental fires (buildings, cars ...)	< 100	7.6
Total		**490**	

In the interest of consistency, and due to space limitations, we have not provided a summary of CRT Table 9 with the emissions reported elsewhere in the inventory as "IE."

1.7.3 Total quantity of emissions considered to be not significant

In light of the above-listed, conservatively estimated emissions, the total quantity of GHG emissions not yet being reported in the German inventory amounts to a maximum of 490 kilotonnes of CO_2 equivalents. This quantity is equivalent to less than 0.1% of the national total reported for the year 2024.

1.8 Metrics

In accordance with Decision 7, CP.27 and 18/CMA.1, Germany uses the global warming potentials (GWP) with 100-year time horizons provided in the Fifth IPCC Assessment Report, Table 8.A.1.

1.9 Summary of applied flexibilities

Germany cannot use flexibilities.

2 Trends in greenhouse gas emissions and sinks

The first table below shows the total emissions, as determined for this inventory, of direct and indirect greenhouse gases and the acid precursor SO_2. The second table shows the progress achieved relative to the base year 1990 and to the previous year. Considerable emissions reductions were achieved for all substances with the exception of a few F gases. In total, greenhouse gas emissions, calculated as CO_2 equivalents decreased by 48.1% relative to 1990[16].

All detailed tables related to the discussion of trends are presented in Annex 5.2.

Trend development taking into account changes from the previous year of the reporting period

Relative to the previous year 2023, total emissions decreased by 3.0%. The reasons are the increased share of renewable energy, a decrease in fossil energy generation and reduced demand for energy from industry and commerce (including a decline in industrial output) and consumers (reduced heating needs).

[16] All figures do not include emissions from the category of Land Use, Land-Use Change & Forestry (LULUCF).

Table 14: Emissions of direct and indirect greenhouse gases and SO_2 in Germany since 1990, in kilotonnes [kt]

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024
CO_2 emissions (without LULUCF)	1,054,796	939,933	898,974	866,910	829,787	798,771	646,683	679,946	670,017	591,373	573,925
Net CO_2 emissions/removals	1,081,618	926,712	897,408	869,065	831,511	796,508	686,158	715,588	719,867	654,005	622,132
CH_4 (without LULUCF)	4,775	4,178	3,469	2,628	2,178	2,024	1,706	1,667	1,628	1,605	1,576
CH_4 (with LULUCF)	5,076	4,468	3,759	2,913	2,481	2,299	1,960	1,963	1,866	1,950	1,881
N_2O (without LULUCF)	197	190	129	131	109	108	96	97	91	91	86
N_2O (with LULUCF)	202	195	133	136	113	112	100	101	95	95	90
F gases sum (CO_2 equivalent, 1995 base year)	**12,325**	**16,023**	**12,707**	**13,608**	**13,683**	**14,617**	**11,165**	**10,499**	**9,571**	**9,035**	**8,867**
Total Emissions (without LULUCF) (CO_2 eq)	**1,253,128**	**1,123,404**	**1,042,998**	**988,947**	**933,250**	**898,606**	**730,972**	**762,773**	**749,266**	**669,578**	**649,770**
Total Emissions/Removals with LULUCF (CO_2 eq)	**1,289,623**	**1,119,487**	**1,050,728**	**1,000,238**	**944,562**	**905,194**	**778,619**	**807,721**	**806,865**	**742,849**	**707,608**
NO_X	2,850	2,173	1,871	1,634	1,468	1,381	983	969	928	841	809
SO_2	5,461	1,743	643	468	397	341	239	249	247	210	199
NMVOC	3,942	2,361	1,813	1,497	1,367	1,140	1,032	1,052	1,044	968	953
CO	13,319	7,187	5,096	3,825	3,461	3,033	2,428	2,551	2,507	2,340	2,322

Table 15: Changes in emissions of direct and indirect GHGs and SO_2 in Germany since the relevant reference year (1990/1995)

Emissions trends changes compared to base year/prev. year (%)	Base year	Base year to 2023	Base Year 2024	Compared to prev. Year (2023-2024)
CO2 emissions (without LULUCF)	1990	-43.9	-45.6	-3.0
Net CO2 emissions/removals	1990	-39.5	-42.5	-4.9
CH4 (without LULUCF)	1990	-66.4	-67.0	-1.8
N2O (without LULUCF)	1990	-53.7	-56.3	-5.7
F gases sum	1995	-43.6	-44.7	-1.9
Total Emissions (without LULUCF)	1990	-46.6	-48.1	-3.0
NO_X	1990	-70.5	-71.6	-3.8
SO_2	1990	-96.1	-96.4	-5.3
NMVOC	1990	-75.4	-75.8	-1.6
CO	1990	-82.4	-82.6	-0.8

2.1 Description and interpretation of trends in aggregated greenhouse gas emissions

From 1990 to 2024, greenhouse gas emissions were reduced considerably by 48.1%[17]. The individual greenhouse gases contributed to this development to varying degrees (cf. Table 4). In terms of direct greenhouse gases, emissions of the most abundant gases were significantly reduced, with methane seeing the sharpest decline. The main reasons for these developments are found in the following areas:

- Transition from the use of solid fuels to the use of liquid and gaseous fuels, which have lower emissions, in the period since 1990;
- Increasing importance of renewable energy use and the associated substitution of fossil fuels;
- Increased plant (installation) efficiencies, but also a decline in industrial output in recent years;
- Changes in animal housing methods and reductions in livestock populations;
- Fulfilment of legal regulations in the waste management sector;

The reasons are explained in more detail below in the discussion of trends for individual greenhouse gases.

The release of carbon dioxide – mainly caused by stationary and mobile combustion processes – dominates the overall picture of aggregate greenhouse gas emissions. Due to a disproportionately large decrease in emissions of the other greenhouse gases, the proportion of total greenhouse gases attributable to CO_2 emissions has increased since 1990 (cf. Table 5). All other greenhouse gases together account for only slightly more than one-tenth of greenhouse gas emissions. Germany's range of GHG emissions is typical for a highly industrialised country.

[17] All figures do not include emissions from the category of Land Use, Land-Use Change & Forestry (LULUCF).

2.2 Description and interpretation of emission trends, by categories and greenhouse gases

Figure 14: Relative development of carbon dioxide, methane and nitrous oxide since 1990

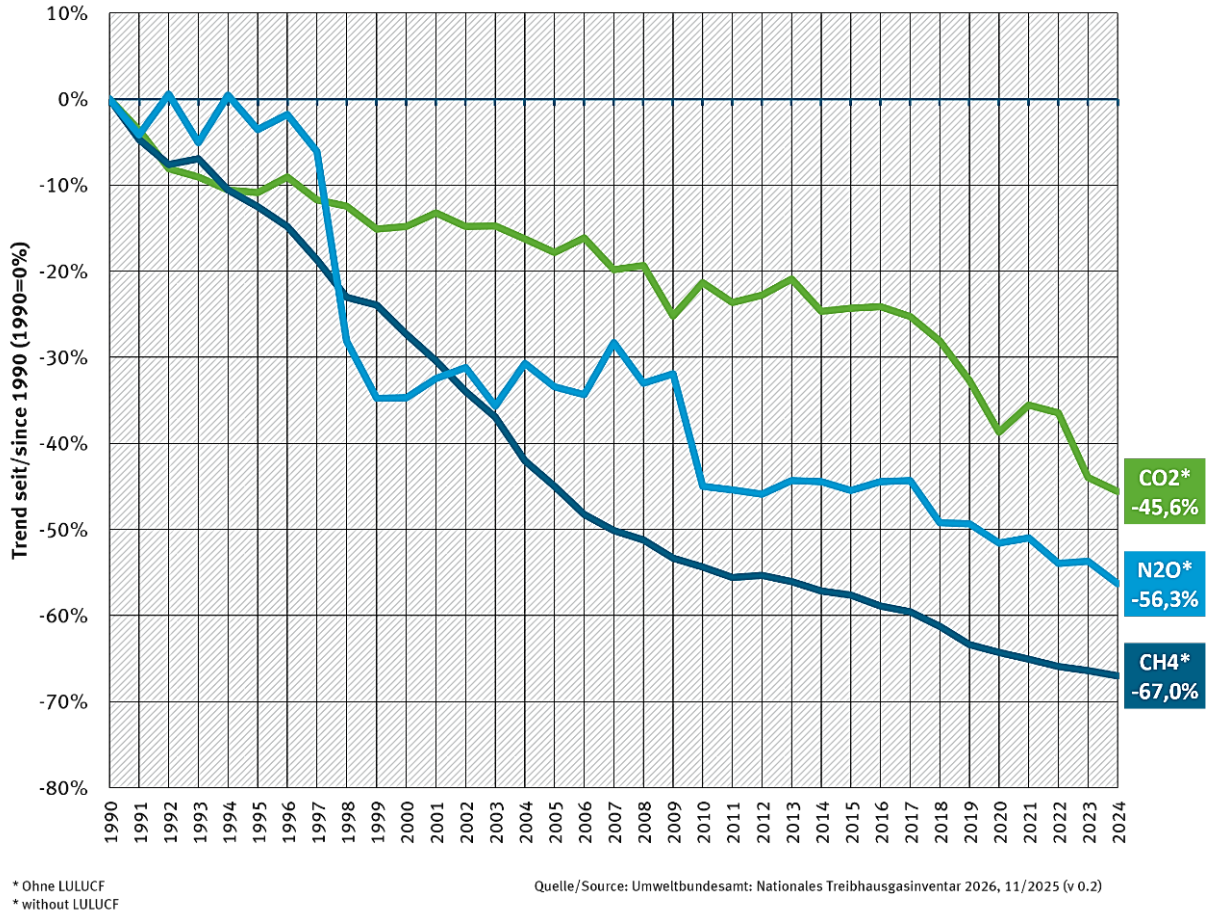


Figure 14 shows the relative development of emissions of the various greenhouse gases since 1990. The trend development of each of these greenhouse gases is largely influenced by specific developments in individual categories. The following subchapters therefore address emissions trends by category.

2.2.1 Description and interpretation of emission trends by category

Energy

The emissions reduction in the energy sector results primarily from a sharp decrease in combustion-related CO_2 emissions (cf. also the results of the key category analysis). On the other hand, emissions of other greenhouse gases are negligible in this sector. The situation is different solely for emissions that are not combustion-related (category 1.B.). In this area, CO_2 emissions are very low, while emissions trends are significantly influenced by CH_4 emissions caused by the distribution of liquid and gaseous fuels.

On the whole, energy-related emissions of all greenhouse gases have decreased by 48% since 1990. The transport emissions contained in this figure fell by around 11.9% during the period, mainly due to special effects. In the case of emissions from stationary combustion, the reductions result from changes in the mix of fuels used, increased energy efficiency and technical efficiency. In addition, increasing the use of renewable energy sources is having an effect,

because they are replacing fossil fuel-based electricity generation, although carbon dioxide from use of biomass is not reflected in the emissions trends. For distribution emissions, it is the result of the increased use of mine gas, the modernisation of gas distribution networks and the introduction of vapour recovery systems in fuel distribution.

Table 486 in the Annex shows the relevant emissions changes, compared to the previous year in each case, for the period since 1990. For CO_2 from the energy sector, for example, it is clear that largely temperature-related fluctuations over time – especially variations in winter temperatures – influence heating patterns. These fluctuations thus affect energy consumption for space heating, thereby having a major impact on annual trends in energy-related emissions. Any trend analysis should thus always cover periods of several years.

Industrial processes (including product use)

In the area of emissions from industrial processes, carbon dioxide and nitrous oxide are the main greenhouse gases. Relatively noticeable changes in emissions of F gases, on the other hand, have no major impacts on overall trends, because these emissions account for only a small share of total emissions.

Emissions from industrial processes are closely tied to production levels. CO_2 emissions trends in particular reflect economic trends in the mineral, chemical and metal-producing industries.

The trend for N_2O emissions has been decoupled from production ever since adipic acid producers' emissions-reducing measures began taking effect. In 1997 and 2010 in particular, those measures yielded considerable reductions in this sector's N_2O emissions. Overall, the sector's N_2O emissions have decreased to about one-twentieth of their 1990 levels.

For all industrial processes and product uses combined, this results in a 48.6% reduction in GHG equivalents since 1990, but a slight increase in emissions compared to the previous year 2023.

Agriculture

The 28% decrease in agricultural emissions since 1990 is mainly due to a decline in livestock numbers, but also to reductions in emissions from agricultural soils and fertiliser use. The trend of recent years has thus continued.

Land use, land-use change and forestry

The LULUCF sector's net emissions are influenced mainly by forest biomass and by related storage in harvested wood products. The impact of natural disruptions (e.g. calamities such as drought, storm damage, insect infestation) on the carbon stocks of forest biomass cannot sufficiently compensate for the consistently high total emissions from organic soils and water bodies over many years. This means that the entire LULUCF sector has been a source of greenhouse gas emissions over many years of the reporting period. From 2018 onwards, emissions from the LULUCF sector will be on a par with emissions from the industrial and agricultural sectors. Compared with the base year, net emissions from the LULUCF sector were 58.5% higher in 2024.

The following section discusses the trends in the various land-use categories:

Forest Land: The reduction in greenhouse gas removals through land-use change and forestry is due primarily to a change of the sink function in the category "Forest Land remaining Forest Land". On the one hand, this is the result of individual storm events causing very high levels of damage to timber. In 1990, a series of hurricanes struck Germany, resulting in approximately 70 million cubic metres of damaged timber. In 2007, hurricane Kyril struck, leaving behind about 37 million m^3 of damaged timber. On the other hand, the combination of drought, storm damage

and insect infestation between 2018 and 2022 has caused the death of forest stands, mainly spruce, covering an area of over 500,000 hectares (BMEL, 2024a).

Cropland: The total emissions in 2024 fell by 35% in comparison to the base year. The trend in emissions essentially reflects the trend in emissions from mineral soils, which show significant annual variations, mainly due to weather conditions. Despite the sharp annual fluctuations in the emissions curve, the trend for GHG emissions from mineral soils under cropland shows a significant average decrease between the base year 1990 and 2024 (approx. 62%), attributable to changes in weather conditions (increasing dryness), the decrease in arable land area (> 10,000 km^2-Eq ≙ -8%), and the significant decrease in grassland conversion (area: approx. -26%). Emissions from organic soils show little difference in absolute terms between 1990 and 2024. However, increasing drought, particularly in extreme years (e.g. 2018), accompanied by correspondingly low groundwater levels, led to absolutely extreme emission events. The amplitude curve of the emission curve for organic soils is therefore the opposite of that for mineral soils. Overall, net emissions from the soil account for 94.5% of total greenhouse gas emissions from the cropland sector (CRF 4.B.; 4.B.1; 4.B.2, including all subcategories).

Grassland: The total emissions in 2024 decreased by 4% in comparison to the base year. These emissions consist of the sum of the emissions from the subcategories grassland (in the strict sense), woody grassland, and hedges. GHG emissions in each of these subcategories differ considerably from those in the other subcategories, both quantitatively and qualitatively. In the time series for total emissions, emissions in the subcategory grassland (in the strict sense) – in particular, emissions from organic soils – predominate in terms of absolute emissions quantity. The course of the time series is also affected by emissions and removals from biomass and mineral soils. While carbon removals from biomass and CO_2 emissions fluctuate between years, mineral soils act as a sink at a constant level.

Wetlands: The emissions from the Wetlands category remained virtually unchanged throughout the reporting period. The emissions in this category result mainly from CO_2 emissions from organic soils, as well as from methane emissions from flowing and standing man-made water bodies. The CO_2 emissions are caused by two, nearly equal, contributing factors: peat extraction and drainage of terrestrial organic soils. The small changes in emissions are mainly caused by changes in the water level in organic soils.

Settlements: The trend in the land-use category Settlements is also inconsistent and is mainly determined by emissions from biomass and mineral soils as a result of land use changes from forest land, cropland and grassland to settlements

Compared to the base year, emissions from the entire settlement category will show a significant increase in 2024 (+1,312.8 kt CO2-eq ≙ +39.4%). The increase in settlement area during this period was 28.3%, which was a major cause of the increase in emissions.

Waste and wastewater

The most significant emissions reduction of around 87% relative to the base year occurred in the area of waste & wastewater. Here, the ban on landfilling biodegradable waste (mainly achieved through mechanical biological waste treatment), which has been in place since June 2005, and the introduction of increased recycling of reusable materials (yellow bags, packaging regulations, etc.) have led to a reduction in the amount of waste disposed of in landfills each year. The result is a reduction in landfill emissions of around 95% compared to the base year. Emissions from wastewater treatment, which also belong to the category waste & wastewater, are significantly lower in volume than landfill emissions, but have also fallen very sharply.

The relevant detailed data are presented in Table 486 in Annex 5.2.

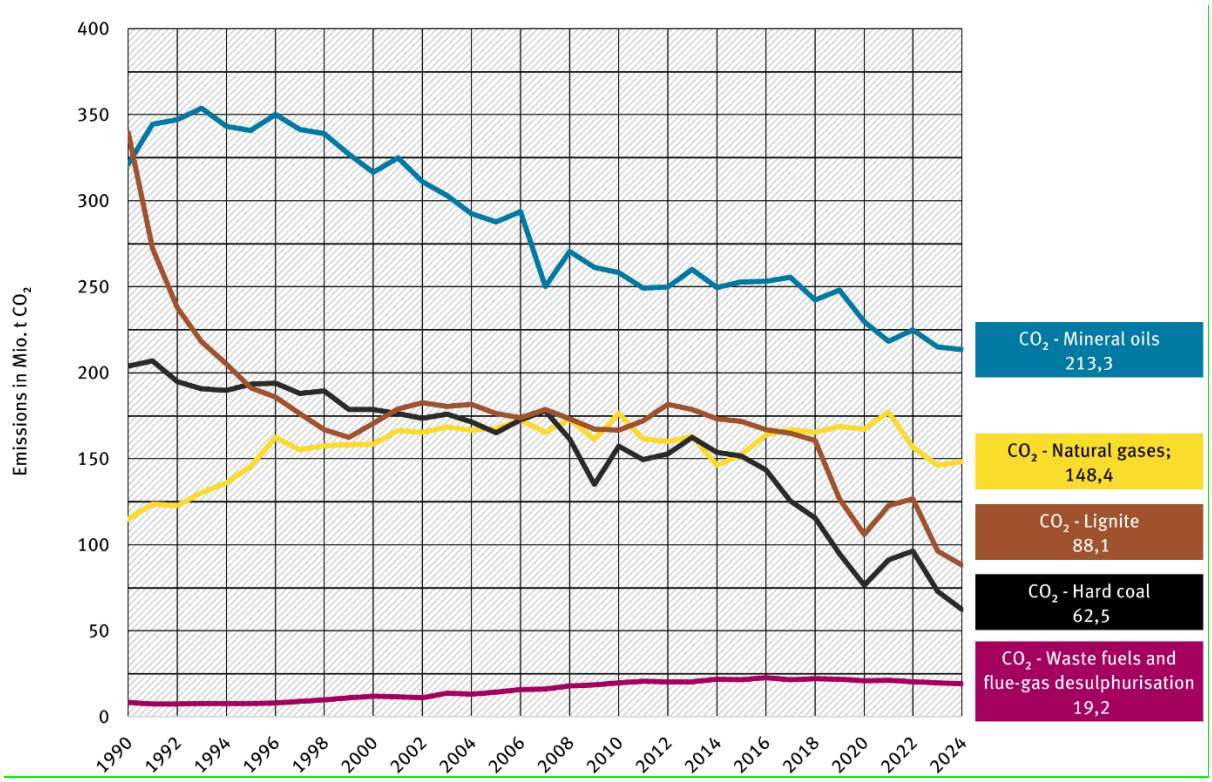
Table 16: Percentage changes in German GHG emissions, by category

Development with respect to 1990	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024
1. Energy	0.00%	-11.64%	-16.43%	-19.97%	-23.48%	-26.39%	-41.33%	-38.36%	-38.92%	-46.19%	-47.97%
2. Industrial processes	0.00%	1.64%	-17.83%	-21.95%	-33.65%	-35.76%	-41.07%	-39.04%	-44.81%	-49.56%	-48.63%
3. Agriculture	0.00%	-12.42%	-13.40%	-18.19%	-18.80%	-16.83%	-22.78%	-23.92%	-26.67%	-25.48%	-28.04%
5. Waste	0.00%	-1.17%	-28.83%	-52.27%	-70.66%	-79.68%	-85.28%	-85.78%	-86.40%	-86.89%	-87.30%
Emissions trend with respect to the corresponding previous year	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2021**	**2022**	**2023**	**2024**
1. Energy	/	-0.45%	-0.42%	-1.96%	4.67%	0.72%	-9.05%	5.05%	-0.91%	-11.91%	-3.31%
2. Industrial processes	/	-1.63%	4.33%	-4.16%	-3.49%	-1.35%	-6.99%	3.45%	-9.47%	-8.60%	1.84%
3. Agriculture	/	-0.55%	-0.23%	-0.34%	-0.28%	-1.12%	-2.44%	-1.47%	-3.62%	1.62%	-3.43%
5. Waste	/	-2.99%	-5.96%	-7.72%	-9.32%	-6.83%	-7.39%	-3.42%	-4.39%	-3.55%	-3.16%

2.2.2 Carbon dioxide (CO_2)

The reduction in CO_2 emissions is closely linked to trends in the energy sector. The sharp emissions reduction in this area seen in the early 1990s was primarily the result of restructuring in the new German federal states – in particular, of related conversions to cleaner fuels and decommissioning of obsolete facilities. The changes in the mix of energy sources/fuels continued, at a somewhat more moderate pace, until the current report year, with disruptions only in the crisis years since 2020:

Figure 15: CO_2 emissions in CRF 1.A, by fuel and without emissions from biomass and international transport



Source: own illustration, German Environment Agency

The situation is somewhat different only in the transport sector, which is dominated by road transport: CO_2 emissions in this area increased until 1999 to nearly 184 million t and then

decreased slightly as a result of reductions in consumption, the shift of refuelling to other countries[18], the substitution of diesel fuel for gasoline[19] and use of admixtures with biodiesel. In about 2007, the trend began stagnating, in part as a result of ongoing increases in average engine power. From 2013, that stagnation ended as a result of further increases in transport densities and mileages and as a result of decreased use of biofuels. After reaching an interim high in 2017 (167 million t), emissions decreased again, initially only slightly, and from 2020 have remained considerably below the long-term trend, as a result of various special effects.

Trend development taking into account changes from the previous year of the reporting period

Compared with the previous year, CO_2 emissions from the energy sector, which dominates in terms of volume, fell (-7.6% or just under 15 million tonnes). Emissions in the manufacturing sector (1.A.2) decreased only slightly (-0.8% or -0.8 million t), as did emissions from the transport sector (-0.4% or -0.6 million t) Emissions from industrial processes (-2.9% or -1.1 million t) and households (-1.8% or -1.4 million t) decreased more significantly.

2.2.3 Nitrous oxide (N_2O)

Since 1990, N_2O emissions have decreased by about 56.3%. The main causes are the use of nitrogen fertilisers in agriculture, fuel use and animal husbandry. Similarly low emissions arise from wastewater treatment, the chemical industry and product use of N_2O (for example, as an anaesthetic). Industry has had the greatest influence on emissions reductions, especially in the area of adipic acid production – through the installation of waste gas treatment systems in 1997 and 2009. Through technological reduction measures, the chemical industry's emissions have been reduced by 99.2% relative to 1990. Since 1999, trends in the remaining emissions have been strongly influenced by economic trends in the chemical industry.

Trend development taking into account changes from the previous year of the reporting period

Driven by a continued decline in emissions from agriculture, which also dominates in terms of volume (-4.5%), total emissions fell slightly (-1.8%) compared with the previous year.

2.2.4 Methane (CH_4)

Methane emissions are caused mainly by animal husbandry in agriculture, waste landfilling and distribution of liquid and gaseous fuels; energy-related and process-related emissions and emissions from wastewater treatment play an almost negligible role. Methane emissions have been reduced by 67.0% since 1990. This trend has been primarily the result of environmental policy measures (waste separation with intensified recycling and increased energy recovery from waste) that have decreased landfilling of organic waste. A second significant cause is the increased use of mine gas for energy purposes, accompanied by a simultaneous decline in production (closure of hard coal mines). As a result, emissions in category 1.B, fugitive emissions from fuels, have decreased by 95% since 1990. Repairs and modernisations of outdated gas distribution networks in Germany, along with improvements in fuel distribution have brought about further reductions of total emissions. Yet another reason for the emissions reductions is

[18] The emissions are calculated on the basis of domestic fuel sales. Fuel quantities not purchased in Germany are thus not reflected in the German emissions inventory.

[19] Diesel fuel's share of total fuel consumption in road transport has increased sharply throughout the entire time period. In 1990, nearly two-thirds of road transport emissions were the result of gasoline consumption. Now, this ratio has nearly been reversed.

that livestock populations in the new German federal states have declined, mainly in the first half of the 1990s.

Trend development taking into account changes from the previous year of the reporting period

In comparison to the previous year, emissions decreased by 1.8%. The largest emissions decreases in quantitative terms occurred in the areas of agriculture, landfills and fugitive emissions from fuels.

2.2.5 F gases

In 2024, released F gases accounted for about 1.4% of total national emissions. Of those F gas emissions, 78% were HFCs, 20% were SF_6 and 2% were PFCs. Overall, these emissions have decreased by 44.7% since 1995 (the base year for F gases). At the same time, the trends for the different individual substances and substance groups involved differ considerably:

HFC emissions increased from 1995 to 2015 primarily as a result of intensified use of HFCs as refrigerants in refrigeration and air-conditioning systems and of the parallel increase in disposal of these systems. This more than offset emissions reductions resulting from their reduced use in insulating materials and foams. A considerable downward trend has emerged since 2016, however. It is due primarily to the prohibitions and quantity limits applying under European F gas legislations.

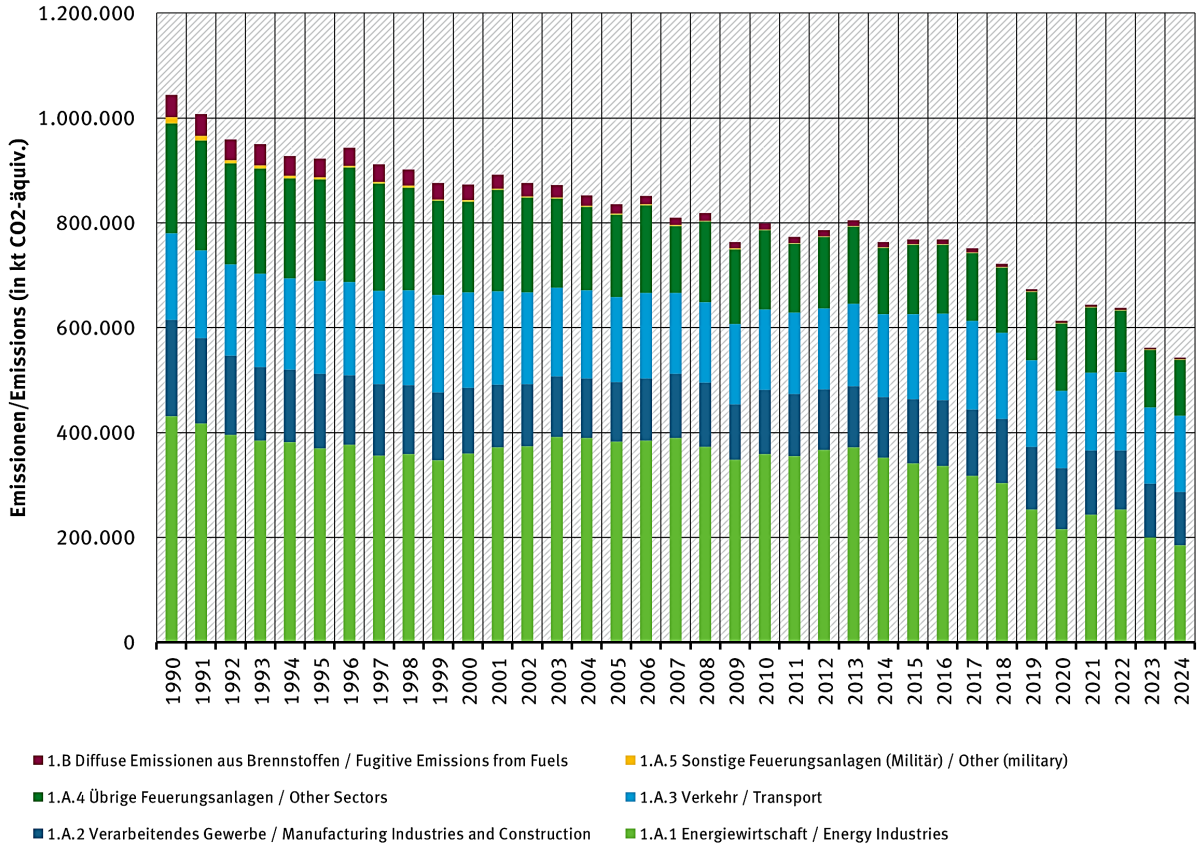
The emissions reductions for *PFCs* were achieved primarily through efforts of primary aluminium producers and semiconductor manufacturers.

The decline in SF_6 emissions until around 2003 is primarily due to the phase-out of various applications since the mid-1990s. Their use in soundproof windows has also been banned since 2007/2008. The majority of current and future emissions of SF_6 (will) result from the improper disposal of old windows. Emissions from electricity transmission facilities have also decreased considerably and levelled off in recent years. Important remaining emissions sources include the use in particle accelerators and emissions from the semiconductor industry.

Since 2015, NF_3 has been used in Germany in semiconductor production with a rise in emissions.

3 Energy - Sector 1)

Figure 16: Overview of greenhouse gas emissions in CRF Sector 1



Source: own illustration, German Environment Agency

3.1 Overview (CRF Sector 1)

To determine the activity data from combustion, different models are used for mobile and stationary sources. Stationary sources are modelled in the “Balance of Emissions Sources” (“Bilanz der Emissionsursachen” – BEU) and the ENERDAT database, while the model used for mobile sources is the “Transport Emission Estimation Model” (TREMOD). In both work processes, combustion-related activities are determined and then entered into the “Central System of Emissions” (CSE) emissions database.

Within the CSE, relevant emissions are then calculated by multiplying these combustion-related activities by the emission factors (cf. Annex 6.6). In the process, complete oxidation of the carbon contained in the fuels is assumed.

3.2 Combustion of fuels (1.A)

The BEU model, which was developed by the German Environment Agency and, since 2023, the more recent calculations of activity data in the ENERDAT database, use as their primary database the Energy Balance of the Federal Republic of Germany, which is prepared primarily on the basis of official statistics. The Energy Balance is described in detail in Annex 6.1 to Annex 6.4.

The following Energy Balance lines are used for the determination of emissions-relevant fuel inputs from stationary sources:

A: Transformation inputs (comprises Energy Balance lines 9 through 19); of these

1. **Public thermal power stations** (line 11) are plants operated by entities within the public utility sector. This category also includes industrial plants that operate their power stations together with electricity utility companies as joint ventures. The fuel input for electricity generation is reported here. This line of the Energy Balance also includes the fuel input in public thermal power stations attributable to electricity production.
2. **Industrial thermal power stations (only for electricity generation)** (line 12) comprise the following operator groups:

   - Power stations in the hard coal mining sector,
   - Power stations in the lignite mining sector,
   - Power stations in the petroleum processing sector (refinery power stations),
   - Power stations that generate single-phase power for Deutsche Bahn AG (German Railways) (until 1999, the relevant input amounts for Deutsche Bahn power stations were reported under 1.A.2.g.vii (EB line 12); as of 2000, they have been reported together with public power stations under 1.A.1.a (EB line 11)),
   - Industrial power stations (quarrying, other mining, manufacturing industry).

3. Hydroelectric, wind-power, photovoltaic systems and other systems (line 14): "other systems" comprises all systems/plants that generate electricity from biogas, landfill gas, sewage gas or solid or liquid biomass and feed the electricity into the public grid. In addition, this section of the Energy Balance also reports on fuel inputs in mini-CHP systems fired with natural gas or light heating oil. Since no cut-off limit applies in statistical collection of data on such systems, this category includes very small systems in the residential and commercial/institutional sectors.
4. Thermal (CHP) power stations for the public supply (line 15): only the fuel input that can be allocated to district heat generation is provided. Adding lines 11 and 15 together produces the total fuel input in public thermal power stations. The district heat generated is fed into the public heating grid. These stations also supply industrial customers with process heat.
5. District heating stations (line 16): here, the fuel input for the public district heat supply, from heating stations, is given.

B: Energy consumption in the transformation sector (Energy Balance lines 33 through 40)

6. Lines 33 to 39 and the total line 40 include the fuel input for heat generation that is needed to operate the transformation stations. No distinction is made here with regard to the type of heat generation involved. This means that fuel inputs for heat generation in combined heating and power stations, steam and hot water boilers and process firing installations are combined.
   The balance sheet for lignite pits and briquette plants is one of the special aspects of the transformation sector to consider. The own consumption of lignite pits and briquette plants is listed together with production-related transformation inputs of briquette plants in line 10. As a result, the emissions-causing inputs of own consumption cannot be read from the Energy Balance; they must be calculated from the transformation input.

The total fuel inputs consist of the fuel inputs for CHP-based heat generation and the fuel inputs for electricity generation by power stations in the hard coal mining, lignite mining and refinery sectors. Deduction from the total listed in line 40, of fuel inputs for heat generation in power stations leaves the quantity of fuel used in process firing installations, steam and hot water boilers.

C: **Final energy consumption** (Energy Balance lines 46 through 67)

7. In **final energy consumption by industry** (mining, non-metallic minerals, manufacturing and line 60 of the Energy Balance), the fuel inputs refer to the fuel used for heat generation for production and for space heating. No distinction is made with regard to the type of heat generation concerned. The total fuel input in industry facilities consists of part of the final energy consumption in these categories and industrial power stations' fuel input for electricity generation.
8. The data on the **Final energy consumption in the residential sector** (Energy Balance line 66) comprise fuel inputs for heat generation and include the application areas of heating, water heating and cooking.
9. The data on final energy consumption in the commercial/institutional sector (Energy Balance line 67) comprise fuel inputs for hot water production, space heating and process heat generation in this sector.

The information contained in the Energy Balance is no longer able to accommodate all of the diverse requirements of national and international energy and emissions reporting. For example, the Energy Balance combines fuel inputs

- in facilities with different requirements under immission protection legislation (e.g. large furnaces, medium-sized furnaces, small furnaces, waste incineration plants);
- in plants that operate according to different technical principles (e.g. steam turbine power stations, gas turbine power stations, combustion engine stations);
- that exhibit regional peculiarities (e.g. different individual mining regions have different qualities of crude lignite);
- with different category allocations in national and international emissions reporting;
- that are listed in different Energy Balance lines, in keeping with their intended purpose (for electricity or heat generation), but are used in a single facility group (e.g. steam turbine power stations).

These characteristics have impacts on emissions behaviour. To take these various requirements into account, the Energy Balance data in the Balance of Emissions Causes (BEU) model and in the ENERDAT database were disaggregated and supplemented to the extent necessary for an adequate emissions description using various additional statistics and calculations and on the basis of various assumptions. Table 17 below provides an overview of the relevant structure:

Table 17: Characteristics of the German Environment Agency's structure of the Balance of Emission Causes for disaggregating the Energy Balance

Balance of emission causes (BEU)*	
Category	• Public thermal power stations • Hard coal mining • Lignite mining • Deutsche Bahn AG (until 1999) • Production of refined petroleum products • District heating stations • Other energy transformation • Quarrying of non-metallic minerals, other mining and manufacturing industry (further sub-classification of process combustion) (The residential, commercial/institutional and other consumers sectors are analysed in the energy data database (ENERDAT))
Types of facilities involved:	• Steam turbine power stations • Gas turbine power stations • Gas and steam turbine power stations • Motor power stations • Boiler furnaces (excluding power station boilers) • Process furnaces (sub-classified into 12 processes)
On the basis of immission protection legislation provisions:	• Installations under the 44th Ordinance on the Implementation of the Federal Immission Control Act • Installations under the 13th Ordinance on the Implementation of the Federal Immission Control Act • Installations under the 17th Ordinance on the Implementation of the Federal Immission Control Act • Installations under the 1st Ordinance on the Implementation of the Federal Immission Control Act • Installations under the Technical Instructions on Air Quality Control (TA-Luft) • Installations not subject to licensing
By energy source:	• About 40 different fuels

Abbreviations:

BImSchV Ordinance on the Implementation of the Federal Immission Control Act (Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes),

TA-Luft First General Administrative Provision on the Federal Immission Control Act (Clean Air Directive)

The BEU model provides a data structure that can be used for a range of different reporting obligations. In particular, this disaggregation into consistent time series is needed to determine emissions of "classical" air pollutants and for calculation of nitrous oxide and methane emissions. Since 2023, calculation methods from the BEU that need to be updated are being re-established in the ENERDAT database, where they are documented and quality-assured in the same way as the input data for these calculations. In the medium to long term, this transfer is intended to replace the BEU as a data storage system. The hybrid data storage and calculation arising from this approach has no material effect on the structural description presented above, but is being done solely for IT-related reasons. For this reason, the model will continue to be described holistically as the BEU.

For the breakdown described, the fuels pursuant to the Energy Balance are also listed individually in the database. In some cases, it is necessary to further subdivide the fuels using energy statistics, coal industry statistics and a few association statistics. In accordance with reporting requirements, the various grades of fuel with different carbon content levels are assigned to the five categories gases, liquid fuels, solid fuels, biomass and other fuels. Because of the many different fuels involved, and because the fuels' shares of the various categories vary, the implied emission factors listed in the CRF tables often change.

To determine activity data for waste in waste incineration plants and for co-combustion in combustion systems in the sectors Public electricity and heat generation (1.A.1) and Manufacturing (1.A.2), the German Environment Agency, as part of a research project of its own, has carried out a thorough evaluation of fuel inputs in energy statistics (Energiestatistik) 060 and 066 (Statistisches Bundesamt, FS 3, R 3.1.7) and waste statistics (Statistisches Bundesamt, 2023) of the Federal Statistical Office. The waste quantities reported in both statistics are compared by sector and industry and assigned to the fuel groups used in the energy statistics: solid biomass, sewage sludge, household and settlement waste and industrial waste. Since the introduction of the Energy Statistics Act in 2003, the fuel quantities recorded in energy statistics have continually increased as a result of the improved data situation.

Since the quantities reported in the energy statistics continue to be lower than those reported in the waste statistics, the activity rates for household and industrial waste are calculated on the basis of the energy balance and adjusted by the difference. Waste wood is reported as solid biomass in the Energy Balance and is therefore deducted in waste statistics from use in waste incineration and combustion plants to prevent double counting.

With regard to waste composition, the fossil and biogenic fractions of household/municipal waste are listed separately in a ratio of 1:1. This split factor was verified in a research project, "Use of biogenic waste fractions for energy generation" ("Nutzung der Potenziale des biogenen Anteils im Abfall zur Energieerzeugung") (Hoffmann et al., 2011); Förderkennzeichen (funding reference number) 3707 33 303). The biogenic fractions of industrial waste depends largely on the industrial sector and installation type. Accordingly, for the sector Manufacturing (1.A.2) and for the sectoral classifications iron and steel, paper, cement and lime, detailed substitute fuel data continue to be used that are provided by the associations German Iron and Steel Institute (VDEh), German Pulp and Paper Association (VDP), the German Lime Association (BV Kalk) and the German Cement Works Association (VDZ). The data on the biogenic fraction of the industrial waste in these sectors are based on the research project "Inputs of secondary fuels" ("Einsatz von Sekundärbrennstoffen") (Lechtenböhmer, Nanning, et al., 2006b), funding reference number 20442203/02).

In the research project "Base year and updates" (Zander & Merten, 2006), the originally reported activity data for stationary combustion systems of the new German federal states for the year 1990 (and subsequent years) were revised due to problems with the official statistics of the GDR in the year of reunification in 1990 and the creation of uniform official statistics for the whole of Germany (cf. the 2010 NIR (UBA et al., 2010)).

To convert fuel inputs that were only available in natural units, the calorific value table published by the Working Group on Energy Balances (AGEB) was previously used.

It was published with a delay of one reporting year, so that the calorific values from the table for year x-1 were carried forward for the most recent previous year. This method was changed starting with the calculations for the 2026 inventory. The calorific values of the energy balance line for primary energy consumption (energy balance line 8) are applied to the energy per fuel

section. This improves the accuracy of these calorific values, also with regard to their allocation to fuel use.

The calorific values are provided together with the energy balance data.

The change was made for data sets in the time series from 2003 onwards.

3.2.1 Verification of the sectoral approach for CRF 1.A

3.2.1.1 Comparison with the CO_2 Reference Approach

Reporting on combustion-related CO_2 emissions is very important in the context of international climate action, because these emissions account for a predominant share of total emissions. To this end, industrialised countries apply a sectoral approach that addresses the level of individual energy consumption sectors and therefore permits greater differentiation in analysis of emissions structures.

In addition to being determined via this "Sectoral Approach" (1.AA), the CO_2 emissions are also determined with the Reference Approach (1.AB) pursuant to the 2006 IPCC Guidelines (IPCC (IPCC, 2006a): Reference Approach), which makes use of primary data on production, imports and exports of fuels, as well as of data on changes in stocks that are taken directly from the Eurostat energy balances.

As with the Sectoral Approach, complete oxidation is assumed. In conformance with the 2006 IPCC Guidelines, the carbon emission factors used are equivalent to those of the Sectoral Approach and thus comprise nationally referenced values. The CO_2 emissions data calculated this way are used for verification of the Sectoral Approach.

The Reference Approach is carried out for all years as of 1990. In each case, the basis for relevant calculations consists of the National Energy Balances on primary energy consumption. Each time the inventory is prepared, only a provisional balance is available for the year immediately preceding the current year.

The results of the Reference Approach (1.AB) are presented in the following figures and tables, as well as in Annex 3 of this report. In Figure 17 and Figure 18, they are compared with other available data sets.

3.2.1.2 Comparison with other data sets available for Germany

In accordance with the provisions of the IPCC Guidelines, the results of detailed sectoral energy-related CO_2 emissions calculations are to be compared with other data sets available for the reporting country.

As part of this verification, a comparison with the data set *CO_2 emissions from fuel combustion: World CO_2 Emissions from Fuel Combustion (detailed estimates)* of the International Energy Agency (IEA) is presented here.

Table 18 and Figure 17 compare the results of the approaches for calculating CO_2 emissions over the different years. The key development trends are shown in all calculation approaches, including the Reference Approach, albeit at differing levels. To illustrate these differences in levels, the relative deviations between the various data sets are shown in Figure 18.

Table 18: Comparison of CO_2 inventories with IEA data; absolute values in millions of t

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024
UBA (1.AA)	988.1	879.0	835.9	810.8	778.8	749.8	599.9	630.6	625.0	550.1	531.5
IEA	955.5	873.6	829.8	804.1	776.0	742.5	605.1	630.7	622.6	560.5	524.2
Difference	32.6	5.41	6.08	6.69	2.76	7.27	-5.25	-0.10	2.47	-10.4	7.33
	3.42%	0.62%	0.73%	0.83%	0.36%	0.98%	-0.87%	-0.02%	0.40%	-1.85%	1.40%
UBA (1.AB)	982.8	870.8	829.5	808.5	776.0	749.2	599.3	629.2	622.7	543.2	518.3
Difference	5.28	8.20	6.34	2.29	2.81	0.60	0.57	1.37	2.30	6.92	13.2
	0.54%	0.94%	0.76%	0.28%	0.36%	0.08%	0.09%	0.22%	0.37%	1.27%	2.55%

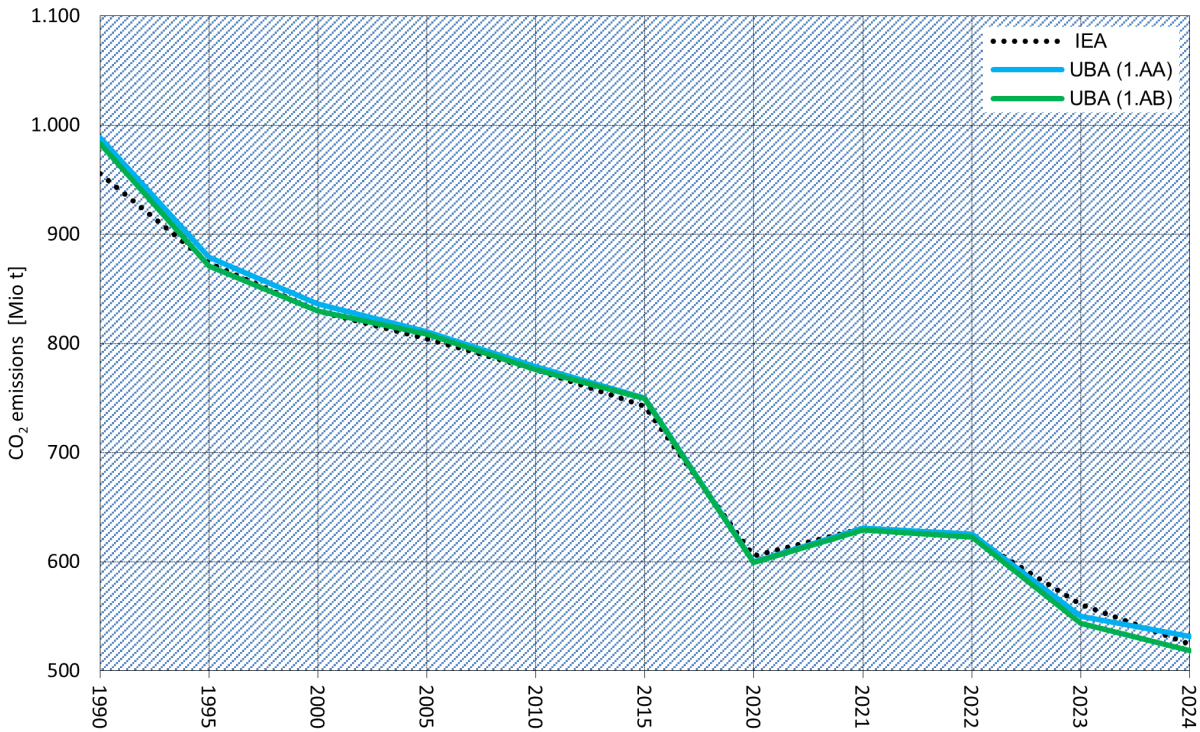
Source: UBA(1.AA) & UBA (1.AB own calculations; IEA: CO_2 emissions from fuel combustion: World CO_2 Emissions from Fuel Combustion (detailed estimates), IEA, Paris, 2025[20]

The data used for the comparison are compiled and published by the IEA. Since various institutions in Germany collect, process and provide data for the IEA questionnaires, and since the IEA carries out its own calculations for the preparation of IEA Energy Balances, these results are not 100% consistent with the data in the national Energy Balances.

In spite of these methodological restrictions, the comparison with the IEA data shows an average discrepancy of only 0.88% and therefore confirms the CO_2 emissions determined for Germany.

The national comparative emissions for the years up to 1995, 1999 to 2017 and 2022 are higher than the results published by the IEA (min: +0.33% (2017); max: +3.42% (1990)), and lower for all other years (min: -0.16% (2018); max: -1.85% (2023)).

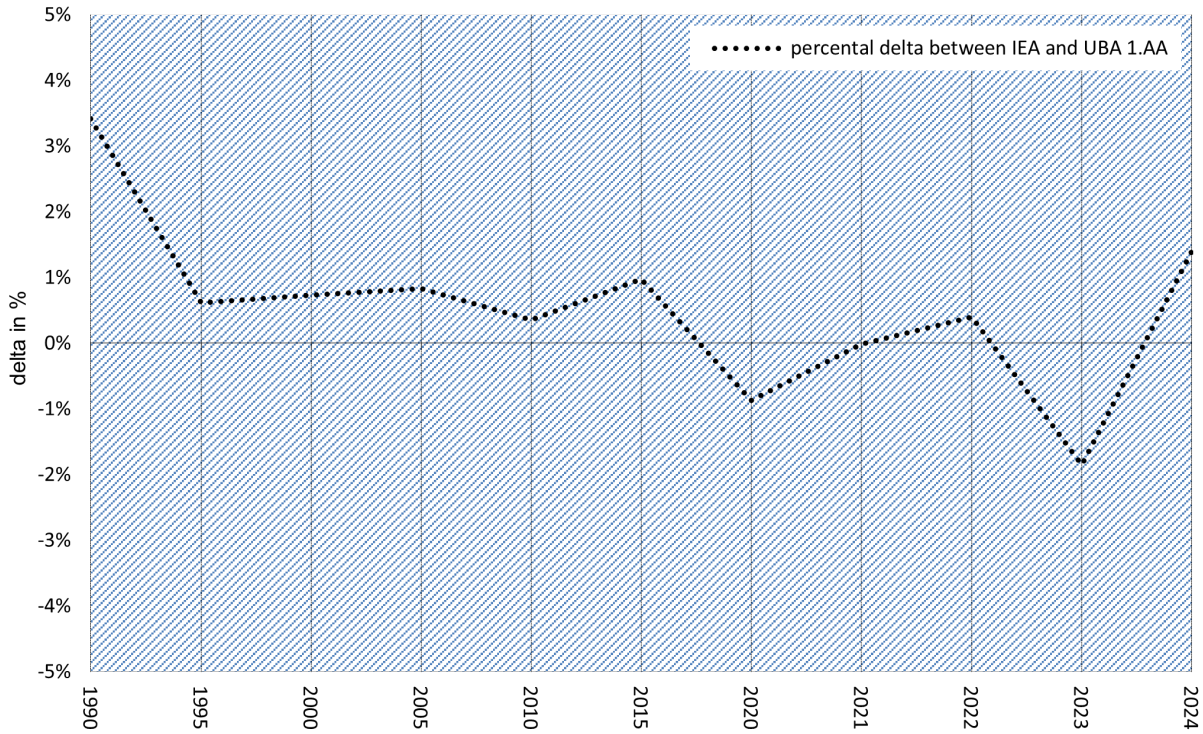
Figure 17: CO_2 emissions in Germany – comparison of the results of national and international calculations



Source: own illustration, German Environment Agency

[20] https://www.iea.org/data-and-statistics/data-product/greenhouse-gas-emissions-from-energy#co2-emissions-from-fuel-combustion-detailed-estimates

Figure 18: CO_2 emissions in Germany – relative discrepancies with respect to the IEA data



Source: own illustration, German Environment Agency

3.2.2 International bunker fuels

3.2.2.1 Emissions from international transport (1.D.1.a/1.D.1.b)

The area of international transport is divided into international civil aviation (1.D.1.a) and international shipping (1.D.1.b).

3.2.2.2 Emissions from international civil aviation (1.D.1.a)

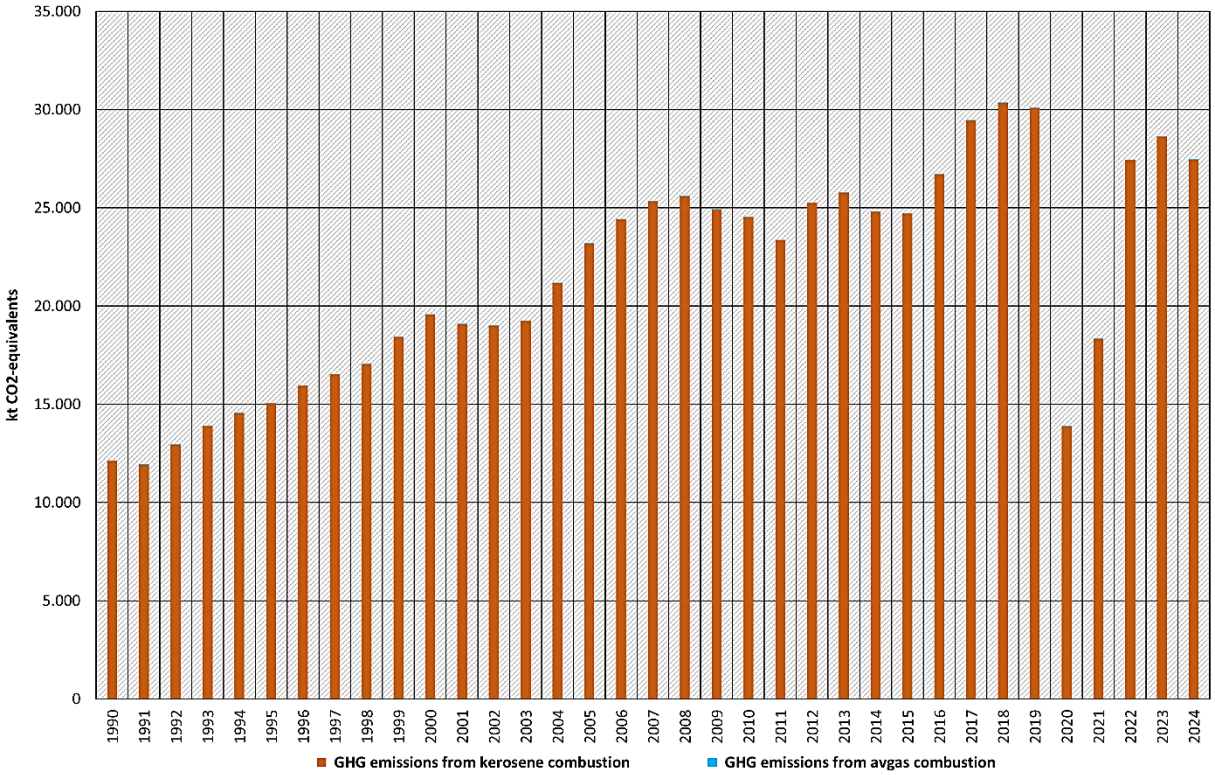
3.2.2.2.1 Category description (1.D.1.a)

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS (Tier 3)	NS/IS/M	CS/D [a]
CH_4	CS (Tier 3)	NS/IS/M	CS (M)
N_2O	CS (Tier 3)	NS/IS/M	CS (M)
NO_x, CO, NMVOC	CS (Tier 3)	NS/IS/M	CS (M)
SO_2	Tier 1	NS/IS/M	CS

[a] Co-combusted lubricants

The emissions from the consumption of fuels for international civil aviation are included in the inventory calculations, but are not reported as part of the national overall inventories, and are not therefore included in the key category analysis.

Figure 19: Greenhouse gas emissions of international air transport departing from Germany since 1990



Source: own illustration, German Environment Agency

3.2.2.2.2 Methodological issues (1.D.1.a)

Neither the AGEB (AGEB, 2025c) nor the Official Mineral Oil Statistics for the Federal Republic of Germany (Amtliche Mineralöldaten) published by the Federal Office for Economic Affairs and Export Control (BAFA, 2025a) allow for a breakdown of annual fuel volumes between international and domestic air transport. This is done retrospectively on the basis of the annual share of national air transport in total fuel consumption, which is calculated within TREMOD AV (Knörr, Allekotte, et al., 2025).

The shares of international air transport in the reported fuel quantities in the aforementioned German energy statistics, determined implicitly in this way, are as follows:

Table 19: International flights' annual shares of domestic fuel deliveries, in [%]

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024
Kerosene	84.7	87.2	89.0	91.2	91.6	92.4	93.8	96.3	96.4	93.6	96.2
Aviation gasoline	14.0	14.1	13.9	13.8	13.7	13.8	2.54	7.22	7.20	20.8	19.5

Source: TREMOD AV (Knörr, Allekotte, et al., 2025)

Additional information on the activity data and emission factors used is provided in Chapter 3.2.8.1 on national civil aviation.

In addition, the quantities of co-combusted lubricants, along with the resulting CO_2 emissions, are recorded and reported. Pursuant to Wallfarth (2014), it is assumed that the quantities of co-combusted lubricants are equivalent to 0.01% of the fuel quantities used (cf. Annex 7.1.4).

3.2.2.2.3 Uncertainties and time series consistency (1.D.1.a)

Cf. Domestic aviation, Chapter 3.2.8.1.3.

3.2.2.2.4 Category-specific QA/QC and verification (1.D.1.a)

Cf. Domestic aviation, Chapter 3.2.8.1.4.

3.2.2.2.5 Category-specific recalculations (1.D.1.a)

Compared with the 2024 submission, the recalculations result from the revision of the energy balances for 2003 to 2023 on the one hand and from updating the TREMOD Aviation model on the other.

Table 20: Revised domestic deliveries of fuel, in terajoules [TJ]

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Jet fuel/kerosene										
2026 submission	193,329	233,437	297,258	343,828	361,751	361,651	199,931	257,520	384,975	401,833
2025 submission	193,329	233,437	297,258	343,828	361,751	361,651	199,931	257,520	384,975	402,121
Absolute change	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-289
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.07%
Aviation gasoline										
2026 submission	2,438	1,142	1,120	697	567	569	214	159	175	133
2025 submission	2,438	1,142	1,120	698	568	570	214	159	175	130
Absolute change	0.00	0.00	0.00	-0.43	-0.35	-0.35	-0.13	-0.10	-0.11	3.05
Relative change	0.00%	0.00%	0.00%	-0.06%	-0.06%	-0.06%	-0.06%	-0.06%	-0.06%	2.34%

Table 21: Revised shares of domestic deliveries of kerosene in 2023, in %

	2023
2026 submission	96.3
2025 submission	96.4
Absolute change	-0.003
Relative change	-0.003%

Source: Own calculations, based on TREMOD AV

The resulting change in fuel consumption is as follows:

Table 22: Revised fuel quantities for international flights 1990-2023, in terajoules

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Jet fuel/kerosene										
2026 submission	163,828	203,448	264,512	313,568	331,542	334,046	187,577	247,979	371,062	387,156
2025 submission	163,828	203,448	264,512	313,568	331,542	334,046	187,577	247,979	371,062	387,445

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Absolute change	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-289
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.07%
Aviation gasoline										
2026 submission	340	161	156	96.2	77.9	78.6	5.43	11.5	12.6	27.6
2025 submission	340	161	156	96.3	78.0	78.6	5.43	11.5	12.6	27.0
Absolute change	0.00	0.00	0.00	-0.06	-0.05	-0.05	0.00	-0.01	-0.01	0.63
Relative change	0.00%	0.00%	0.00%	-0.06%	-0.06%	-0.06%	-0.06%	-0.06%	-0.06%	2.34%
TOTAL FUEL INPUTS										
2026 submission	164,168	203,609	264,668	313,664	331,620	334,125	187,582	247,991	371,074	387,184
2025 submission	164,168	203,609	264,668	313,664	331,620	334,125	187,582	247,991	371,074	387,472
Absolute change	0.00	0.00	0.00	-0.06	-0.05	-0.05	0.00	-0.01	-0.01	-288
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.07%

Source: Own calculations, based on TREMOD AV

This means that emissions will also be recalculated for all years from 2003 onwards, although these will be so low for the years up to 2022 that they cannot be shown here:

Table 23: Revised GHG emissions 1990-2023, in kt and kt CO_2-equivalents

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Carbon dioxide - CO_2										
2026 submission	12,026	14,915	19,388	22,978	24,293	24,476	13,742	18,167	27,183	28,363
2025 submission	12,026	14,915	19,388	22,978	24,293	24,476	13,742	18,167	27,183	28,385
Absolute change	0.000	0.000	0.000	-0.004	-0.003	-0.003	0.000	-0.001	-0.001	-21.10
Relative change	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	-0.074%
Methane- CH_4										
2026 submission	0.192	0.158	0.133	0.133	0.138	0.149	0.070	0.072	0.108	0.113
2025 submission	0.192	0.158	0.133	0.133	0.138	0.149	0.070	0.072	0.108	0.113
Absolute change	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Nitrous oxide- N_2O										
2026 submission	0.382	0.470	0.611	0.728	0.769	0.774	0.435	0.576	0.862	0.8987
2025 submission	0.382	0.470	0.611	0.728	0.769	0.774	0.435	0.576	0.862	0.8994
Absolute change	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.0007
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.07%

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Total greenhouse gases										
2026 submission	12,144	15,059	19,574	23,198	24,526	24,711	13,873	18,340	27,443	28,634
2025 submission	12,144	15,059	19,574	23,198	24,526	24,711	13,873	18,340	27,443	28,655
Absolute change	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-21.3
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.07%

Source: Own calculations; [a] not including CO_2 from lubricant co-combustion

3.2.2.2.6 Category-specific planned improvements (1.D.1.a)

Cf. Domestic aviation, Chapter 3.2.8.1.6.

3.2.2.3 Emissions from international shipping (1.D.1.b)

3.2.2.3.1 Category description (1.D.1.b)

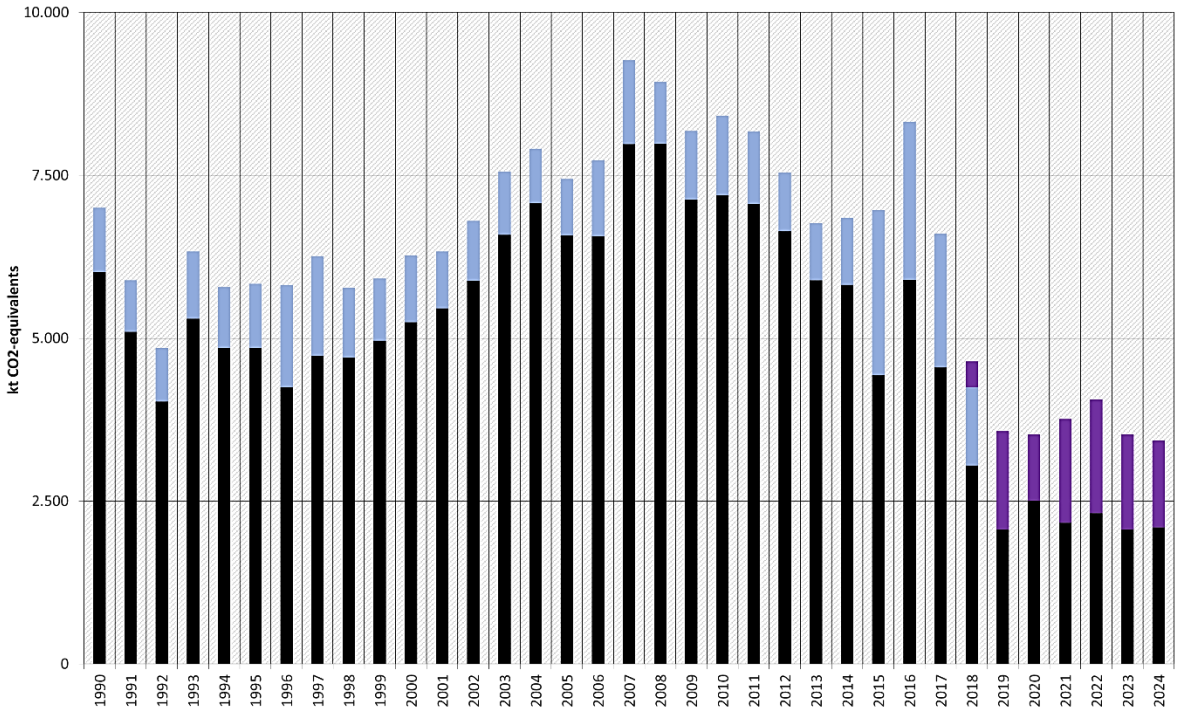
Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS (Tier 2)	NS/IS/M	D[a]/S
CH_4	CS (Tier 2)	NS/IS/M	CS (M)
N_2O	CS (Tier 2)	NS/IS/M	CS (M)
NO_X, CO, NMVOC, SO_2	CS (Tier 2)	NS/IS/M	CS (M)

[a] Co-combusted lubricants

The emissions caused by international shipping from German ports are not reported as part of the national overall inventories and are thus not included in the key category analysis.

The sold fuel quantities and the emissions resulting from their combustion are subject to significant annual fluctuations. This can be explained as the result of fuel price differences between seaports (for example): since seagoing vessels do not have to stock up on fuel every time they are in port, they can avoid high fuel costs. In addition, sales are influenced by storage in ports.

Figure 20: Development of GHG emissions from international shipping since 1990



Source: own illustration, German Environment Agency

3.2.2.3.2 Methodological issues (1.D.1.b)

Germany reports in accordance with Tier 1. This means that emissions are calculated as the product of fuel sales in Germany, country-specific emission factors for CO_2 and default emission factors for CH_4 and N_2O.

In general, the activity data for seagoing ships are taken from the Energy Balances of the Federal Republic of Germany (AGEB, 2025c). In Energy Balance line 6 (EBZ 6), those Balances list international bunkering for IMO-registered ships separately because this bunkering is subject to different taxation.

For years for which an NEB is not available in time, a special evaluation of the Official Mineral Oil Statistics for the Federal Republic of Germany (Amtliche Mineralöldaten) published by the Federal Office for Economic Affairs and Export Control (BAFA) (BAFA, 2025a) is used, which is incorporated into the National Energy Balances.

The bunkered quantities of ocean ships travelling domestic routes (freight and passengers (1.A.3.d), fisheries (1.A.4.c iii) and military (1.A.5.b iii)) included in these statistically recorded quantities is always calculated separately in accordance with Deichnik (2025) and deducted from the total quantities recorded in EB line 6. The resulting remainder is allocated to international shipping departing from Germany.

The sharp increase seen between 2014 and 2015 in the quantities of diesel used, from about 15% to over 30% of the total fuel quantity involved, results from a de-facto ban on heavy fuel oil in "SECAs" (*Sulphur Emission Control Areas*), which include the North Sea and the Baltic Sea, as a result of the entry into force of significantly stricter limits for the sulphur content of ship fuels.[21]

[21] Since 1 January 2015: 0.10%, instead of the previous maximum permitted level of 1.00% (https://www.imo.org/en/OurWork/Environment/Pages/Air-Pollution.aspx)

With the 2024 report, a new time series for "light heating oil" was introduced in the CSE. While light heating oil has been listed as a fuel type in the NEB since 2018, it was subsumed under "diesel" until the 2023 submission.

In addition, the quantities of co-combusted lubricants, along with the resulting CO_2 emissions, are reported. They are calculated on the basis of the quantities of fuel sold. Pursuant to Wallfarth (2014), it is assumed that the quantities of co-combusted lubricants are equivalent to 0.15% of the fuel quantities used (cf. the Chapter 4.5.1).

With regard to the emission factors for carbon dioxide, we refer to Annex 6.6.

The methane and nitrous oxide emissions are calculated with the emission factors from Deichnik (2025) that are used for domestic water-borne navigation.

On the other hand, also with regard to co-combustion of lubricants, it is assumed that the N_2O and CH_4 emissions are already included in the emission factors for the fuels used and thus have to be reported here as IE (*included elsewhere*).

3.2.2.3.3 Uncertainties and time series consistency (1.D.1.b)

Cf. Chapter 3.2.8.4.3.

3.2.2.3.4 Category-specific QA/QC and verification (1.D.1.b)

Cf. Chapter 3.2.8.4.4.

3.2.2.3.5 Category-specific recalculations (1.D.1.b)

Compared with the 2024 submission, the recalculations result from the revision of the energy balances for 2003 to 2023 (cf. 3.2.8.4.5).

Table 24: Revised fuel volumes, in terajoules

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Diesel fuel										
2026 submission	13,162	13,096	13,709	11,546	16,273	33,836				
2025 submission	13,162	13,096	13,709	11,546	16,273	33,836				
Absolute change	0.00	0.00	0.00	0.00	0.00	0.00				
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%				
Light heating oil										
2026 submission							13,606	21,258	23,257	19,519
2025 submission							13,606	21,260	23,267	18,657
Absolute change							-0.53	-2.12	-10.4	862
Relative change							0.00%	-0.01%	-0.04%	4.62%
Heavy fuel oil										
2026 submission	76,942	62,066	67,080	84,127	91,992	57,278	32,053	27,713	29,416	26,591
2025 submission	76,942	62,066	67,080	84,127	91,992	57,278	32,053	27,713	29,414	26,633
Absolute change	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	2.46	-42.2
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	-0.16%
TOTAL ENERGY INPUTS										
2026 submission	90,104	75,162	80,789	95,672	108,266	91,114	45,659	48,971	52,673	46,110

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
2025 submission	90,104	75,162	80,789	95,672	108,266	91,114	45,660	48,973	52,681	45,290
Absolute change	0.00	0.00	0.00	0.00	0.00	0.00	-0.54	-2.12	-7.92	820
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.02%	1.81%

Source: Deichnik (2025)

At the same time, the CO_2 emission factors from heavy fuel oil were adjusted for 2022 and 2023 pursuant to (Deichnik, 2025):

Table 25: Revised CO_2 emission factors for heavy fuel oil, in kg/TJ

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
2026 submission	77,241	77,241	77,241	77,241	77,241	76,445	77,188	77,188	77,753	76,554
2025 submission	77,241	77,241	77,241	77,241	77,241	76,445	77,188	77,188	77,188	77,188
Absolute change	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	565	-634
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.73%	-0.82%

These adjustments result in a recalculation of the emission volumes from 1990.

Table 26: Revised GHG emissions in 2022, in kt and kt CO_2-equivalents

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Carbon dioxide [a]										
2026 submission	6,927	5,772	6,205	7,363	8,322	6,893	3,486	3,718	4,015	3,486
2025 submission	6,927	5,772	6,205	7,363	8,322	6,893	3,486	3,718	3,999	3,442
Absolute change	0.00	0.00	0.00	0.00	0.00	0.00	-0.04	-0.16	16.03	43.79
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.40%	1.27%
Methane										
2026 submission	0.168	0.139	0.149	0.179	0.201	0.174	0.129	0.121	0.134	0.118
2025 submission	0.168	0.139	0.149	0.179	0.201	0.174	0.129	0.121	0.134	0.117
Absolute change	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.01%	1.02%
Nitrous oxide										
2026 submission	0.309	0.257	0.277	0.328	0.371	0.315	0.159	0.169	0.183	0.159
2025 submission	0.309	0.257	0.277	0.328	0.371	0.315	0.159	0.169	0.183	0.156
Absolute change	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.01%	1.74%
TOTAL GREENHOUSE GASES [a]										
2026 submission	7,014	5,844	6,283	7,455	8,426	6,982	3,532	3,766	4,067	3,531
2025 submission	7,014	5,844	6,283	7,455	8,426	6,982	3,532	3,767	4,051	3,487
Absolute change	0.00	0.00	0.00	0.00	0.00	0.00	-0.04	-0.16	16.0	44.5
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.40%	1.28%

3.2.2.3.6 Category-specific planned improvements (1.D.1.b)

No improvements are currently planned, apart from ongoing routine revisions of the calculation model used.

3.2.3 CO_2 emissions from non-energy-related use of fuels

The great majority of the coal, oil and gas that Germany uses is used for energy-related purposes. Part of these fuels are also used for non-energy-related purposes as feedstock for production processes. In the German Energy Balance (EB), this non-energy-related consumption is listed separately in line 43 (EB line 43).

The predominant consumer in this area is the chemical industry: it uses fossil fuels in steam crackers, in reforming processes, in synthetic gas production and in the production of graphite electrodes. The most important derived products obtained through cracking and reforming include ethylene, propylene, 1,3-butadiene, benzene, toluene and xylene; the most important from production of synthesis gas include ammonia and methanol.

Bitumen, lubricants and paraffin waxes are produced in refineries: applications for bitumen include road surfacing and production of roof sheeting, while lubricants are used, among other things, in road vehicles and various types of machines.

Without suitable adjustments, it is not possible to compare the consumption data listed in EB line 43 with the data on CO_2 and NMVOC emissions from non-energy-related applications that are reported in the inventory under *CRF 2 – Industrial processes*. One reason is that "industrial processes" only accounts for emissions from product manufacture and use, while EB line 43 comprises all feedstock emissions, including both process-specific emissions and the carbon quantities stored in the relevant products. The latter account for by far the largest share of feedstock emissions.

Another important difference is that calculation of emissions from product use takes account of imported and exported quantities. In the interest of complete accounting, Table 27 (see below) takes account of the carbon stored in the relevant fossil fuel products. The allocation of emissions from material applications and products to individual energy sources is based on Table 1.3 from Volume 3 of the 2006 IPCC-GL and on information provided by associations, producers and experts. In some cases, it was necessary to make our own estimates of how use is distributed across the individual energy sources.

The produced quantities of the products listed in the table was obtained from data reported by the Federal Statistical Office and by the Federal Office for Economic Affairs and Export Control (BAFA) and were converted to CO_2 equivalents. For petrochemical products, the conversion is made on the basis of a) the specific carbon content pursuant to Table 3.10 in Volume 3 of the 2006 IPCC Guidelines (IPCC, 2006a) and the molar mass of CO_2. The CO_2 equivalent emissions are then split among the three feedstocks used in Germany (naphtha, LP gas and other petroleum products) according to (internal) data provided by associations.

For simplification purposes, carbon black is assumed to consist of pure carbon that is also converted to CO_2 equivalents.

The production quantities for bitumen, lubricants and paraffin waxes were obtained from the Official Mineral Oil Statistics and are based on gross refinery production. The production quantities were converted to CO_2 equivalents using the following IPCC standard values (Table 1.2 and Table 1.4 from Vol. 2 of the 2006 IPCC Guidelines(IPCC, 2006a)).

Table 27: IPCC standard values for EFs & lower calorific value

	EF in t CO_2/TJ	Calorific value in TJ/kt
Bitumen	80.6	40.2
Paraffin wax	73.3	40.2

For the year 2021, the sum total of the emitted carbon and the carbon stored in products is equivalent to 107% of the carbon from non-energy-related consumption pursuant to EB line 43. Consequently, the relevant material-related use can clearly be shown to include the quantities listed in the Energy Balance. No gaps in determination of non-energy-related CO_2 emissions are apparent in the inventory.

Table 28: Verification of the completeness of reported CO_2 from non-energy-related use of fossil fuels, for 2021

			COAL				PETROLEUM					GAS	
			Hard coal + hard coal coke	Lignite	Other lignite products	Total solid fuels	Naphtha	Petroleum coke	Liquefied petroleum gas	Other mineral oil products	Total liquid fuels	Natural gas	Total gas
A: Listed NEW quantity (Energy Balance line 43)		TJ	3,112.5	256.0	13,239.1	16,607.6	355,278.8	6,319.1	92,092.0	383,023.9	836,713.8	129,621.4	129,621.4
B: Carbon content		kg C/GJ	26.8	30.2	26.9		20.0	27.8	18.1	19.0		15.2	
C: Total input as feedstock/non-energy use		kt C	83.4	7.7	356.6	447.8	7,102.3	175.4	1,666.0	7,276.9	16,220.7	1,973.1	1,973.1
D: Total input as feedstock/non-energy use		kt CO_2	305.9	28.4	1,307.5	1,641.8	26,041.9	643.3	6,108.8	26,682.1	59,476.1	7,234.8	7,234.8
E: Implied oxidised carbon fraction		%	147%				112%	109%	123%	105%	110%	98%	98%
	AD in [kt]	**EM in [kt CO_2]**	**Activity data + emissions (C in Gg CO_2)**										
F: Total reported fossil IPPU CO_2		7,003	449				29,270	702	7,527	28,037	65,536	7,115	7,115
2 Industrial processes		7,003	449				29,270	702	7,527	6,724	44,223	7,115	7,115
2.B: Chemical industry		5,859					29,270	6	7,527	6,724	43,527	7,115	7,115
2.B.1: Ammonia production	2,892	5,246										5,246	5,246
2.B.5: Carbide production	C	6						6			**6**		
2.B.6: Titanium dioxide production		NE											
2.B.8: Petrochemical industry (1)													
Methanol	1,359											1,869	1,869
Ethylene	5,196						11,416		2,935	1,957	16,308		
Propylene	3,553						7,809		2,008	1,339	11,155		
Butene and 1,3-Butadiene	2,186						4,982		1,281	854	7,117		
Benzene	1,578						3,736		961	641	5,338		
Toluene	567						1,328		341	228	1,897		
Xylene													
Carbon black	309	607								1,706	1,706		
	AD in [kt]	**EM in [kt CO_2]**	**Activity data + emissions (C in Gg CO_2)**										
2.C: Metal industry		1,145						696			696		

			COAL				PETROLEUM					GAS	
2.C.1: Iron and steel production (2)		IE	469										
2.C.2: Production of ferroalloys	54	6											
2.C.3: Primary aluminium production	509	696	6					696			696		
2.C.5: Lead production (2)	C	IE											
2.C.6: Zinc production (2)	C	IE											
2.D: Non-energy-related products from fuels and solvents (1)													
Lubricants	2,522									21,313	21,313		
Waxes, paraffins, vaseline, etc.	338									7,434	7,434		
Bitumen	3,972									998	998		
Solvents and other product use (3)	IE	IE								12,881	12,881		

(1) To ensure that a complete carbon balance is obtained, a departure is made here from the report format used for the source categories in the inventory. For this reason, the production quantities listed here cannot be compared with the inventory figures in 2.B.8 and 2.D. The emissions provided in the table refer to complete transformation of products into CO_2 – instead of, as in the inventory categories – to emissions from production or use.

(2) For reasons of confidentiality, these data are reported in aggregated form.

(3) Since over 90% of solvents from basic chemicals are produced in steam crackers, it is assumed that carbon emitted from NMVOCs comes from products of such crackers.

3.2.4 Public electricity and heat production (1.A.1.a)

3.2.4.1 Category description (1.A.1.a)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
L/T	1 A 1 a, Public Electricity and Heat Production	fossil fuels	CO_2	338451.16	26.17	151375.41	21.40	-55.27
L/T	1 A 1 a, Public Electricity and Heat Production		CH_4	192.83	0.02	2637.87	0.38	1267.99
-/-/2	1 A 1 a, Public Electricity and Heat Production		N_2O	2140.86	0.17	1241.79	0.18	-42.00

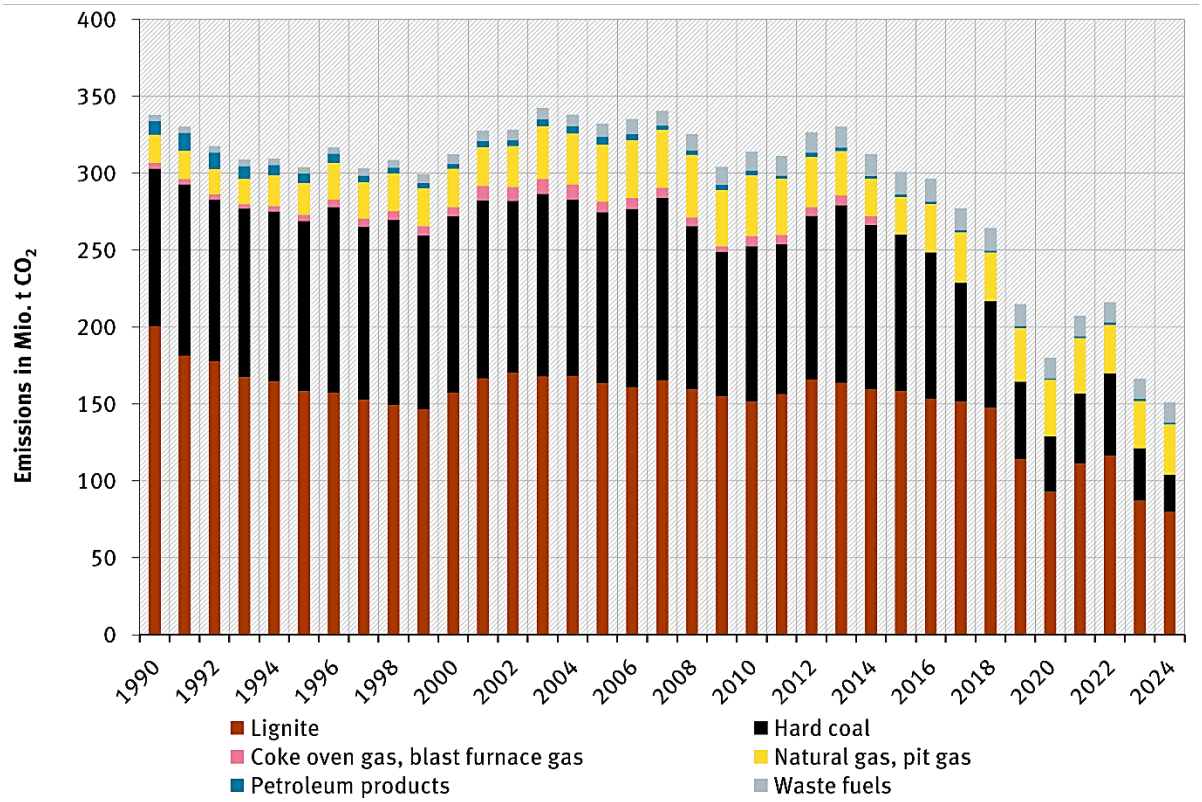
Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	NS	CS
CH_4	Tier 2	NS	CS
N_2O	Tier 2	NS	CS
NO_X, CO, NMVOC, SO_2	CS	NS	CS

The category “Public electricity and heat production” is a key source of CO_2 and CH_4 emissions in terms of emissions level and trend, and for N_2O in terms of Approach 2.

Category 1.A.1.a, “Public electricity and heat production,” includes district heating stations and electricity and heat production of public power stations. Plants that feed electricity produced from biomass into the public grid are also assigned to category 1.A.1.a.

The following figure presents an overview of development of CO_2 emissions in category 1.A.1.a:

Figure 21: Development of CO_2 emissions of category 1.A.1.a



Source: own illustration, German Environment Agency

The emission trend is largely influenced by the development and structure of electricity generation plants, as these account for the majority of emissions. In general, the trend is driven mainly by economic trends (such as the collapse of industry in the new German federal states in the 1990s, the economic and financial crisis of 2009 in particular and the coronavirus pandemic in 2020); by (relative) fuel prices; by carbon allowance prices in emissions trading; by regulatory decisions (such as the 2020 Act on termination of coal-fired power generation (Kohleverstromungsbeendigungsgesetz 2020) and the 2011 amendment of the Atomic Energy Act); by the foreign trade balance for electricity (for example the increase in exports that occurred as of 2012 and the change in an import balance from 2023); by weather conditions (such as the cold winters of 2010, 2012, 2013, 2021); and by statistical artefacts related to the reclassification of power plants to other sectors.

The key fuel-specific driving factors include:

Lignite

- Through 1999, many lignite-fired installations in the new German federal states were decommissioned.
- In 2012, the last three new power plant blocks went into operation.
- Thereafter, until the end of the current reporting period, additional power plants will be decommissioned and put into four-year standby mode (particularly in 2018 and 2019, with a significant impact on electricity generation in 2019 and 2020) so that they are temporarily available in the event of bottlenecks and to accommodate the increasingly frequent operation of power plants in the medium load range.

Hard coal

- Viewed over the time series, hard coal-fired power stations show greater fluctuations in fuel consumption because, unlike lignite, they are usually operated in the medium load range and therefore react more strongly to fluctuations in demand and are also dependent on import prices.
- In the mid-1990s and in 2012: re-classification of companies from “industry” to the “public supply”
- 2016, 2017, 2020: price-related shifts in the fuel mix, leading away from hard coal to natural gas
- 2023, 2024: Several hard coal-fired power stations were decommissioned

Coke oven gas, blast furnace gas and basic oxygen furnace gas, fuel gas

- In 2015, re-classification of blast furnace gas-powered power plants to the steel industry

Natural gases (natural gas, mine gas):

- Since 1990, a considerable increase in the use of natural gas for electricity generation
- As of 2005, commissioning of an entire group of large gas and steam power plants and medium-sized gas turbine power plants
- Gas-fired power plants are increasingly being used to stabilise grids as a result of fluctuating generation from renewable energies
- Increased natural gas consumption in 2024 due to lower wholesale prices for natural gas compared to the previous year

Petroleum

- Petroleum plays only a minor role in Germany’s electricity supply. It is used primarily for auxiliary and supplementary firing in coal-fired and waste-to-energy CHP power stations, as well as for peak-load generation.

Cross-fuel

- Since 2005 rising deployment of renewable energy (mainly wind and PV), displacing fossil fuels and changing the operating mode of the remaining power plants.
- The nuclear power phase-out, which took place successively up to the end of 2023, initially resulted in higher emissions, mitigated by increased availability of RES electricity.
- Following the nuclear phase-out, there was a fall in electricity generation; since 2023, more electricity has been imported than exported.
- The energy crisis that resulted from Russia’s war on Ukraine impacted fuel consumption in electricity and heat generation: the use of natural gas declined while the use of heating oil and coal increased. Some coal-fired power plants on security standby were temporarily brought back into service, and the nuclear phase-out was postponed until the end of 2023

The trend for the greenhouse gas N_2O is determined primarily by coal use. Since energy generation plants are not known to have any measures in place for reducing N_2O emissions, it can be assumed that the downward trend since 1990 is due to the reduced use of coal.

CH_4 emissions, by contrast, have been increasing since 1990. The considerable increases in biogas use since 2003 have played an especially noticeable role in this trend. Biogas is used primarily in combustion engines that have high specific methane emissions.

A more detailed discussion of the trends in the years 1990 through 2020 is provided in the descriptive chapter of the category (1.A.1.a) in the 2022 NIR (UBA et al., 2022).

3.2.4.2 Methodological issues (1.A.1.a)

Activity data

In the "Balance of Emissions Sources" model, the energy inputs listed in the Energy Balance are divided among several time series using statistical data. The aim of the calculations is to produce a data basis that is adapted to the special technical characteristics of electricity and heat production. As a result, fuel-and technology-specific emission factors can be applied to the relevant activity data.

In 2014, the German Environment Agency (UBA) developed a procedure for taking account of known efficiencies (using the UBA's power station database) in calculations. This made it possible to calculate use of natural gas and light heating oil for electricity and heat generation, in gas turbines, gas-and-steam (combined cycle) systems, steam turbines and gas engines. As a result, fuel inputs can now be calculated from the electricity generation data for the aforementioned installation types as shown in energy statistics. The data are updated at regular intervals for the current reporting.

As of 2012, the Energy Balance lists mini-CHP systems as producers for the public grid (i.e. they feed energy into the grid). Consequently, emissions from combustion of natural gas and light heating oil in these installations are reported in source category 1.A.1.a. The fuel inputs for heat generation are reported in source category 1.A.4.

For the 2006 report, the activity data for the new German federal states for the year 1990 were revised and substantiated within the framework of a research-project sub-project A, "Überarbeitung und Dokumentation der Brennstoffeinsätze für stationäre Feuerungsanlagen in den neuen Bundesländern für das Jahr 1990" (Revision and Documentation of Fuel Inputs for Stationary Combustion Systems in the new German federal states for the year 1990) (Zander & Merten, 2006).

For electricity and heat generation in waste incineration plants of public power stations and of heat generation in waste incineration plants of public district heating stations, the activity data for household and municipal waste and industrial waste are taken from both the Energy Balance and from waste statistics (Statistisches Bundesamt, 2023).

Prior to the year 2003, the waste quantities listed in energy statistics and in the Energy Balance were both considerably lower than those shown in the waste statistics. Since then, the quality of energy statistics data has improved considerably so that the figures on energy use have largely converged. Thanks to more detailed fuel specifications, solid biomass (especially waste wood and wood residues), biogenic gases, sewage sludge and waste heat can now be reported separately. Industrial waste appeared as a fuel category in energy statistics for the first time in 2008. To ensure that all waste-related fuel inputs are taken into account as completely as possible, it is necessary to make use of additional data from waste statistics.

As of the NIR 2006, the fossil and biogenic fractions of household/municipal waste are listed separately in a ratio of 1:1. The fossil/biogenic composition of industrial waste varies depending on the type of facility involved. As a result, the biogenic fractions for co-combustion in lignite-fired and hard coal-fired power stations and for electricity and heat generation in public power stations fired with substitute fuels are listed separately.

The activity data for other fuels are taken directly from the Energy Balance. Where statistical data or expert assessments are available, fuel inputs are additionally divided into two size classes (combustion systems smaller and larger than 50 MW). The dividing line between these two categories is based on legal regulations governing licensing of combustion systems in the Federal Republic of Germany.

As of the NIR 2011 (UBA et al., 2011), CO_2 emissions from blast furnace gas combustion in public power stations are reported in category 1.A.1.a. In 2015, all power stations fired with blast furnace gas that, until then, had been reported in the public supply sector were reclassified to report in the industry sector. For this reason, category 1.A.1.a no longer includes the use of blast furnace gas. Table 25 in the 2022 NIR (UBA et al., 2022) provides an overview of relevant emissions from the use of blast furnace gas for the entire time series since 1990.

From NID 2025 (UBA et al., 2025) on, the data basis for reporting activity rates for the most recent previous year has been improved. The disaggregation of energy balance data was changed from the previous distribution model to modelling using statistical data available at the time of calculating the activity data or determined by the Federal Statistical Office using imputation methods.

Furthermore, since 2023, energy balances from 2003 onwards have been revised every two years in the event that new, improved data bases and/or calculation methods have been identified and implemented.

Emission factors

Since CO_2 emissions depend on fuel quality, CO_2 emission factors are calculated and used across sectors. A detailed description of the procedures, and a list of the factors used is provided in Annex 6.6.

The underlying data for the emission factors for all other greenhouse gases and precursor substances is provided in the report on the research project “Ermittlung und Evaluierung von Emissionsfaktoren für Feuerungsanlagen in Deutschland für die Jahre 1995, 2000 und 2010” (“Determination and evaluation of emission factors for combustion plants in Germany for the years 1995, 2000 and 2010” (Rentz et al., 2002)). The values for the intermediate years 1996 - 1999 and 2001 - 2009 were determined by linear interpolation. This project, along with the linear interpolation for the intermediate years, also provided the basis for the emission factors provided in Chapters 3.2.5, 3.2.6 and 3.2.7, in instances where the factors include power stations, gas turbines and boilers for generation of steam and hot/warm water. The aim of the research project was to determine and evaluate representative emission factors for the main air pollutants produced by combustion systems in Germany that are subject to licensing requirements, valid for the years 1995, 2000 and 2010. This primarily involves analysing and characterising the emitter structure and the associated emission factors for 1995 and updating this data to reflect the situation in 2000 and 2010. This allows emission factors to be systematically determined for the substances SO_2, NO_X, CO, NMVOC, particulates and N_2O. Furthermore, a distinction is made between 12 coal fuels, 4 liquid fuels, 7 gaseous fuels and firewood. In addition, the available data on the emission factors of other substances are also compiled; these other substances include PAH, PCDD/F, As and Cd for combustion systems

subject to licensing requirements, and CH_4 for gas turbines and combustion systems subject to licensing requirements that fall under the TA Luft and the 44th Ordinance on the Implementation of the Federal Immission Control Act Annex 3 of the 2022 NIR describes the procedure used in the research project.

In 2011, the emission factors (except that for CO_2) were updated as part of a larger research project (Fichtner et al. (2011)). In Germany, N_2O is monitored only in exceptional cases; for this reason, no relevant data from regular measurements are available. On the other hand, relevant emissions behaviour in combustion of hard coal and lignite, especially in fluidised bed combustion, was specifically studied, primarily in the 1990s. In 2008, VGB carried out additional relevant measurements. The project Fichtner et al. (2011) reviewed and updated the values used to date. Table 29 shows the results for large installations of public power stations (with thermal outputs from combustion of 50 megawatts or more), while Table 30 shows the results for smaller installations of the energy sector and industry. These factors have been used as a basis for calculating the category-specific emission factors for the CSE.

Table 29: Technological emission factors for nitrous oxide from large combustion systems, in [kg/TJ]

Fuel/combustion technology	EF
Public power stations:	
Hard coal/dry firing	1.0
Hard coal/slag tap firing	1.9
Lignite/dry firing	3.5
Liquid fuel/boiler firing	1.0
Natural gas/boiler firing	0.5
Industrial power stations, industrial boilers and district heating stations:	
Hard coal/dry firing	1.0
Hard coal/slag tap firing	2.0
Hard coal/fluidised bed combustion	20
Hard coal/grate firing	4.0
Lignite/dry firing	3.4
Lignite/fluidised bed combustion	8.0
Lignite/grate firing	3.5
Liquid fuel/boiler firing	1.0
Natural gas/boiler firing	0.5
Gas turbines and gas and steam turbine plants:	
Natural gas	1.7
Light heating oil	2.0
Waste incineration plants	1.2

Table 30: Technological emission factors for nitrous oxide from systems < 50 MW furnace thermal output, in [kg/TJ]

Fuel/combustion technology	EF
Boiler firing with:	
Hard coal	10.0
Lignite	10.7
Biomass	3.0
Light heating oil	1.1
Heavy fuel oil	3.0
Natural gas	0.6
Gas turbines and gas and steam turbine plants:	
Natural gas	1.7
Light heating oil	2.0

Table 31: Methane emission factors for combustion systems with at least 50 MW furnace thermal output and for gas turbines, in [kg/TJ]

Facility type	Fuel	EF
Combustion systems ≥ 50 MW furnace thermal output	Hard coal	1.0
	Lignite	0.63
	Fuel oil, heavy	4.1
	Fuel oil, light	3.3
	Natural gas	2.0
Gas turbines (including gas and steam systems)	Fuel oil, light	8.0
	Natural gas	10.925
Combustion engines	Natural gas	309.0
	Biogases	312.3
Waste incineration		1.8

In a research project carried out by the Institute for Future Studies and Technology Assessment (IZT), "Processing of data in emissions declarations pursuant to the 11th Ordinance on the Implementation of the Federal Immission Control Act" ("Aufbereitung von Daten der Emissionserklärungen gemäß 11. BImSchV" (Jörß & Gronewäller, 2010)), special CH_4 emission factors for gas engines were determined. The average value for natural gas as a fuel, 309 kg/TJ, is markedly higher than the previously used value, 0.3 kg/TJ, which is approximately the same as the value for steam turbine power stations. The significant methane leakage caused by the leakage of unburned natural gas was confirmed by data from emissions monitoring. The measurements can vary considerably, depending on the type of engine and engine maintenance standards. For biogas, sewage gas and landfill gas, an average CH_4 emission factor of 312.3 kg/TJ is used. This value was determined in the project "Emissions analysis and quantification of material flows through biogas plants, with regard to ecological assessment of agricultural biogas production and to inventorisation in the German agricultural sector" ("Emissionsanalyse und

Quantifizierung von Stoffflüssen durch Biogasanlagen im Hinblick auf die ökologische Bewertung der landwirtschaftlichen Biogasgewinnung und Inventarisierung der deutschen Landwirtschaft"), carried out by the Deutsches Biomasseforschungszentrum (German biomass research centre (Liebetrau et al., 2011)).

Most of the emission factors used for waste incineration originate from a research project carried out by the waste-management and recycling firm ATZ, "Review of emission factors for waste incineration" ("Überprüfung der Emissionsfaktoren für die Abfallverbrennung" (Daschner et al., 2010). The N_2O emission factors were taken from a Danish study, "Emissions from decentralized CHP plants 2007" (Nielsen et al., 2010). Since the emission factors for other pollutants are consistent with those for German waste incineration plants, also the relevant N_2O factors can be adopted for the German inventory. For co-incinerated waste, weighted emission factors are used that vary depending on the shares of the various coal types that are used as the main fuel.

Information on process-related CO_2 emissions from flue-gas scrubbing (flue gas desulphurisation) in large combustion systems

As part of the research project "limestone balance" ("Kalksteinbilanz"; (Lechtenböhmer, Nanning, et al., 2006b), FKZ 20541217/02), data for CO_2 emissions from flue gas desulphurisation were determined for the category Electricity and heat production in public power stations (cf. 3.2.4.2). Flue gas desulphurisation plants (FGD) are designed to convert the sulphur dioxide contained in combustion gases into less harmful substances through chemical and physical processes. Limestone is commonly used as a reagent in flue gas desulphurisation. Desulphurisation systems are essentially based on immission control requirements and the economic usability of the resulting residual substances (gypsum). The main process used in electricity generation plants is limestone scrubbing. Around 87% of power stations in Germany use this process, measured in terms of installed capacity (Rentz et al., 2002).

Desulphurisation with $CaCO_3$ consists of several sub-reactions. For stoichiometric calculation of limestone inputs in the limestone scrubbing process, the relevant chemical gross reaction equation for the process is used (Strauß, 1998):

Equation 1:

$$CaCO_3 + SO_2 + \frac{1}{2}O_2 + 2H_2O \rightarrow CaSO_4 \cdot 2H_2O + CO_2$$

This equation can be used to derive the limestone/gypsum molar mass ratio. It follows that 581.39 kilograms of limestone are used per produced tonne of gypsum. The gypsum production data can be used to derive the theoretical maximum limestone consumption for FGD in hard coal and lignite-fired power stations. The gypsum production figures do not indicate whether limestone or lime was used, however. This problem was resolved using statistics of the German Lime Association (BV Kalk) on sales of burnt and unburnt lime for the air quality control sector. Using the above reaction equation, the process-related CO_2 emissions can be determined from the mass relationship between $CaCO_3$ and CO_2. The results of the calculation are shown in the following table. They take account of the data on gypsum production in all years since 1990. From 2009 onwards, data on gypsum production from the VGBE are used. For the current reporting year, an estimate of gypsum production was made based on the previous year's data for gypsum production in hard coal and lignite-fired power stations and the amount of electricity generated by these power stations, assuming proportionality between annual electricity generation and gypsum production. This procedure was selected as electricity generation varied considerably over recent years and simple extrapolation would not have been

appropriate. As soon as the data are available from the VGBE, the provisional figures for gypsum production are replaced. This regularly results in recalculations for the most recent previous year.

Table 32: CO_2 emissions from flue gas desulphurisation in public power stations, in [kt]

1990	618	**1997**	878	**2004**	1,162	**2011**	1,028	**2018**	936
1991	652	**1998**	1,005	**2005**	1,142	**2012**	1,053	**2019**	769
1992	629	**1999**	966	**2006**	1,076	**2013**	1,030	**2020**	577
1993	662	**2000**	1,135	**2007**	1,017	**2014**	974	**2021**	709
1994	616	**2001**	1,069	**2008**	985	**2015**	989	**2022**	742
1995	683	**2002**	1,094	**2009**	952	**2016**	921	**2023**	547
1996	867	**2003**	1,156	**2010**	919	**2017**	979	**2024**	435

Source: Calculation on the basis of the "limestone balance" project ((Lechtenböhmer, Nanning, et al., 2006b), FKZ 20541217/02); updated in 2008 (cf. (UBA, 2009))

These CO_2 emissions were allocated to emissions from the use of solid fuels in the inventory because this is where the cause of the FGD and CO_2 emissions lies. Pursuant to expert estimates by the group carrying out the research, the uncertainty for limestone use and thus the uncertainty for related CO_2 emissions, is ±10%.

3.2.4.3 Uncertainties and time series consistency (1.A.1.a)

Uncertainties for activity data were first determined for the 2004 reporting year and continue to apply (Juhrich & Wachsmann, 2007b). The method for determining the uncertainties is described in Annex 2, Chapter 13.6 of the NIR 2007.

Other aspects related to time series consistency of activity data are explained in Annex 6.4.

The figures for the uncertainty of the CO_2 emission factor and for the statistical distribution function for that uncertainty were estimated by the German Environment Agency. The figures are based on the range covered by the carbon content of the various individual fuels.

The uncertainty of the determined emission factors was evaluated as part of the project (mentioned in Chapter 3.2.4.2) of Rentz et al. (2002) and Fichtner et al. (2011).

3.2.4.3.1 Methods for determining uncertainties of emission factors

The uncertainties in emissions data result from several different factors. This is the accuracy, affected by random and systematic errors in the context of an emission measurement, as well as the completeness of the data basis with regard to missing measurements. Another factor consists of the variability of the emissions. A distinction must be made here between the variability of emissions from a plant within the period under review (intra-plant variability) and the different emission behaviour of the various sources under consideration (inter-plant variability).

Other sources of possible uncertainties can affect calculation of emissions using emission factors. In the framework of the IPCC-GPG (Penman et al. (2000): Chapter 6), methods – adapted, in each case, to data availability – are proposed:

In the case of continuous measurements, uncertainties should be characterised by directly determining statistical parameters such as standard deviation and 95% confidence interval.

When determining plant-specific emission factors, any available local measurements should be used. In addition, any special operational states (startup and shutdown processes) and load changes must be taken into account, and the representativeness of available measurement data must be checked with regard to the emission behaviour of the plant.

When using emission factors from the literature, all information provided there regarding data quality should be used. Furthermore, transferability must be assessed to determine the extent to which the emission factor is representative of the situation in the respective area. If the factor is not representative, an expert assessment should be carried out.

Use of expert estimates is generally recommended in cases where available empirical data are not adequate for quantification. A sample explanation is provided in Annex 3, Chapter 14.1.2.2, of the NIR 2007 (UBA, 2007).

3.2.4.3.2 Result for NO_2

The individual evaluations of the uncertainties for the N_2O emission factors are described in the final report of the research project Fichtner et al. (2011). A Monte Carlo simulation carried out by the research contractor yielded percentage uncertainties of up to ±50% for CRF category 1.A.1.a (as well as for categories 1.A.1.b, 1.A.1.c and 1.A.2.gviii/all other) (remark: values for ± ranges must be divided by 2; cf. IPCC-GPG Penman et al. (2000): Chapter 6, p. 6.14). In the process, we continue to assume uniform distribution of uncertainties.

3.2.4.3.3 Result for CH_4

Combustion systems in Germany are not subject to monitoring of CH_4 emissions; for this reason, no systematic measurement data are available in this area. The individual figures available for Germany and Switzerland were therefore used. Due to this limited data availability, the research project did not attempt to systematically assign the data to the source groups discussed there (cf. Chapter 3.2.4.2). The CH_4 emission factors that were determined, for various fuels, in the research project Fichtner et al. (2011), and that are used in this report for combustion and gas turbine systems (including gas and steam systems), were last provided in Chapter 19.1.2.2 of the 2022 NIR. As part of an expert estimate carried out by the research contractor, pursuant to Tier 1 of the IPCC-GPG (Penman et al. (2000): Chapter 6), an upper limit of ± 50% was estimated for the percentage uncertainty in source category 1.A.1.a (as well as in source categories 1.A.1.b, 1.A.1.c and 1.A.2.g/all other); in the process, we assume uniform distribution of uncertainties – as was the case for N_2O.

3.2.4.3.4 Time series consistency of the emission factors

The emission factors for 2011 N_2O were determined as part of a research project Fichtner et al. (2011), for the year 2004 (reference year). The research project found no indications of changes over time in the individual emission factor. Previous assumptions that at least the values for gas turbines could vary over time were not confirmed. For every time series, therefore, it has been assumed that the values have remained constant in the period since 1995.

Against this backdrop, the time series for N_2O must be assessed as consistent overall.

The time series of CH_4 emission factors were also reviewed and found to be consistent. To ensure time series consistency, the CH_4 emission factors determined for combustion engine systems were retroactively applied for the period back to 1990. Methane leakage is likely to have been higher in the early 1990s than it is for modern engine systems. Too few measurements are available for this period, however.

For most biogenic fuels, statistical fuel-input data are available only for the period since 2003. As a result, it is not possible to provide a consistent time series for these fuels for the period since

1990. This limitation affects only the trend for CH_4 emissions, which increases sharply as of the year 2003.

3.2.4.4 Category-specific QA/QC and verification (1.A.1.a)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

To document its quality assurance measures in preparation of Energy Balances, the Working Group on Energy Balances (AGEB) submits quality reports to the German Environment Agency (cf. Annex 6.4.1). Since 2012, the AGEB has carried out systematic comparisons of the estimated Energy Balance of year x-1 (provisional) and the Energy Balance of year x-2 (final); for the first time for the report year 2010 (cf. Annex 6.4.1).

Quality assurance for official statistics is carried out by means of an internal quality system. These quality reports are published on the website of the Federal Statistical Office (Statistisches Bundesamt, fortlaufend).

In addition to these measures, the AGEB plays a role in the annual review process as necessary, and regular exchanges take place with the AGEB, the Federal Statistical Office and the Federal Office for Economic Affairs and Export Control as part of an annual meeting or written circulation procedure organised by the German Environment Agency (UBA). At these meetings, methodological issues are addressed based on the experience gained from inventory creation and inventory review, and a general exchange takes place to promote a better understanding of data collection and data verification.

The general quality assurance measures relating to the emission factors of combustion plants within the scope of the research projects Rentz et al. (2002) and Fichtner et al. (2011), are specified in the methodology description in Annex 7.1.1.1. The results were reported in the NIR 2005 (UBA et al., 2005).

3.2.4.5 Category-specific recalculations (1.A.1.a)

Table 33: Recalculations for CRF 1.A.1.a, in [kt] and [%]

	CO_2 difference, absolute					CO_2 difference, relative
	Gaseous fuels	Liquid fuels	Solid fuels	Other fuels	Total	Total
2004	-40.74	0.00	0.00	0.01	-40.73	-0.01%
2005	-47.85	0.00	0.00	0.01	-47.84	-0.01%
2006	-54.61	0.00	0.00	0.01	-54.60	-0.02%
2007	-56.29	0.00	0.00	-285.59	-341.88	-0.10%
2008	-57.34	0.00	0.00	-0.03	-57.37	-0.02%
2009	-68.22	0.00	0.00	-24.94	-93.16	-0.03%
2010	-59.95	0.00	0.00	-26.33	-86.28	-0.03%
2011	-33.56	0.00	0.00	-29.28	-62.84	-0.02%
2012	-36.15	0.00	0.00	-23.11	-59.26	-0.02%
2013	-24.40	0.00	0.00	-13.85	-38.25	-0.01%
2014	-15.09	0.00	0.00	-34.33	-49.43	-0.02%
2015	-10.04	0.00	0.00	-35.09	-45.13	-0.02%

	CO_2 difference, absolute					CO_2 difference, relative
2016	-32.93	0.00	0.00	-37.93	-70.86	-0.02%
2017	-33.97	0.00	0.00	-0.01	-33.98	-0.01%
2018	789.93	19.03	0.00	-22.11	786.86	0.30%
2019	842.77	7.97	0.00	-15.93	834.81	0.39%
2020	984.29	19.18	0.00	-1.57	1001.89	0.56%
2021	1263.91	26.14	0.00	-0.38	1289.67	0.63%
2022	1260.01	53.71	0.00	-4.80	1308.92	0.61%
2023	1250.35	141.42	-12.69	-101.01	1278.08	0.77%

As usual, recalculations are carried out for all energy sources in the current border year, after the preliminary data has been replaced by the final energy balance. Since 2023, AGEB has been providing revisions to the time series every two years starting from 2003. Revisions were again made for the 2026 reporting year, resulting in recalculations for previous years.

The values from waste statistics are incorporated into the calculation model for the waste sector, along with the relevant Energy Balance data. Since the statistics are available only every two years, in each case non-Energy Balance sections are carried forward to the most recent previous year and then corrected in the following year.

3.2.4.6 Category-specific planned improvements (1.A.1.a)

No improvements are planned at present.

Where previous reports have listed further improvements in this chapter, those improvements are presented, in overview form, in Table 468 in Chapter 10.4 Inventory Improvements. Improvements that have been completed are listed in Table 467 in the same chapter.

3.2.5 Petroleum refining (1.A.1.b)

3.2.5.1 Category description (1.A.1.b)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
L/T	1 A 1 b, Petroleum Refining	fossil fuels	CO_2	24212.49	1.88	21079.80	2.98	-12.94
-/-	1 A 1 b, Petroleum Refining	0	CH_4	17.99	0.01	17.28	0.01	-3.97
-/-	1 A 1 b, Petroleum Refining	0	N_2O	89.27	0.01	56.08	0.01	-37.18

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	NS	CS
CH_4	Tier 2	NS	CS
N_2O	Tier 2	NS	CS
NO_X, CO, NMVOC, SO_2	CS	NS	CS

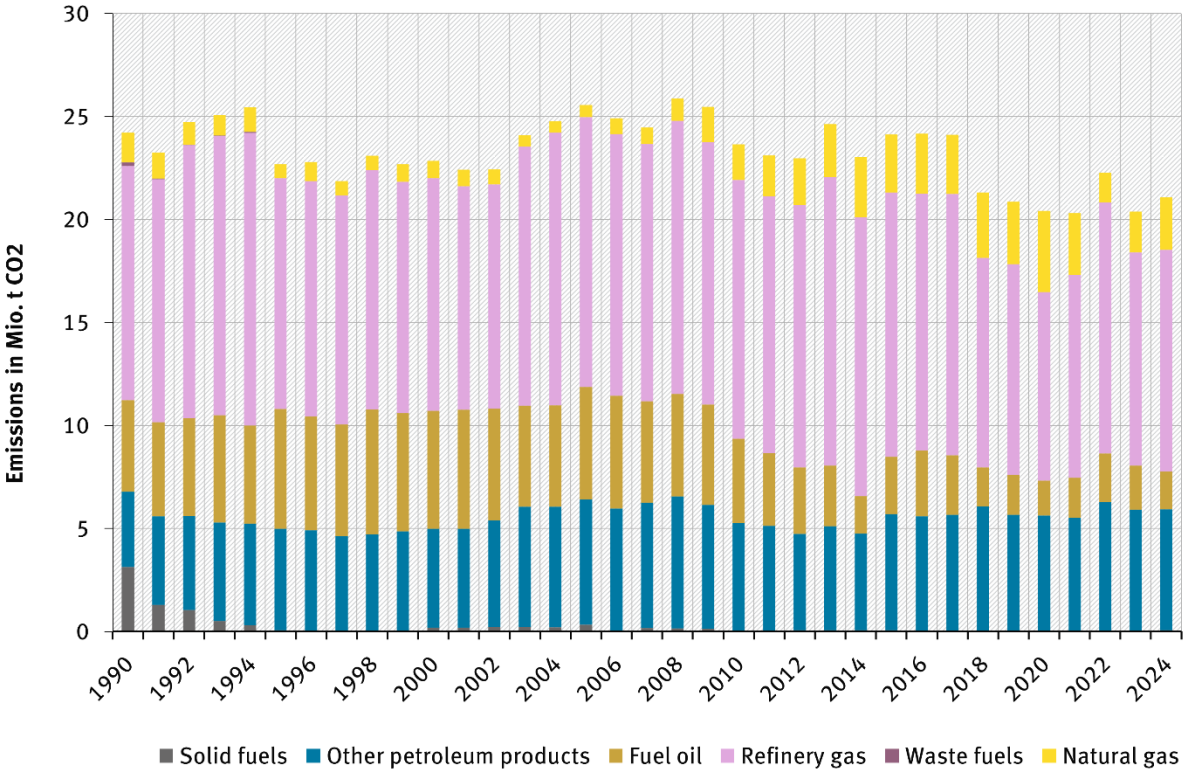
The category Petroleum refining is a key category for CO_2 emissions in terms of emissions level and trend.

The figures provided above apply for refinery power stations (part of category 1.A.1.b).

Under category 1.A.1.b, Petroleum refining, the CSE lists the subcategories “refinery bottom-heating systems” and “electricity and heat production of refinery power stations”.

The following figure provides an overview of emissions trends in category 1.A.1.b:

Figure 22: Development of CO_2 emissions of category 1.A.1.b



Source: own illustration, German Environment Agency

The emission trend largely follows the development of production. The peak output level of 123.6 million t of manufactured petroleum products was attained in 2005. Up to 2011, gross refinery output dropped considerably, and then saw little change until 2019. Production decrease was recorded in 2020 and 2021. Due to the gas crisis, demand for petroleum rose in 2022, leading to a rise in gross refinery output and thus to higher emissions. Another major force driving the emission trend is the fuel switch for in-house consumption from heavy petroleum products to natural gas. As a result, emissions decreased considerably. Efficiency measures also reduced emissions. On the other hand, increased production of lighter petroleum products and intensified ultra-hydrodesulphurisation, initially led to increases in specific fuel consumptions and thus to higher emissions. In 2023, gross refinery production reached its lowest point. The main reasons are the reduced demand for petroleum products, since the lower gas prices mean that more natural gas is being used again in all sectors. More natural gas was also used for in-house refinery needs again. The embargo on Russian oil also reduced output. Overall, emissions fell again 2023. In 2024, emissions rose again with the increasing use of natural gas and higher production.

3.2.5.2 Methodological issues (1.A.1.b)

Activity data

All Energy Balance data related to the production of petroleum products originated from the Official Mineral Oil Statistics. The Mineral Oil Statistics provide a comprehensive picture of imports, transformation inputs in refineries and refineries' own consumption. To ensure consistency, reporting in this area adheres to the structure and definitions used in Mineral Oil Statistics. In energy statistics, other companies that process coal also report under the industrial sector (Wirtschaftszweig) 19.2 Petroleum processing (Mineralölverarbeitung) along with refineries for waste oil and lubricants. These installations are reported in category 1.A.1.c. In category 1.A.1.b, therefore, only processing of crude oil is reported.

For reporting on emissions from crude oil refineries, the plants are subdivided into refinery power stations and refinery bottom-heating systems. The activity data for refinery process bottom heating are obtained by deducting fuel inputs in refinery power stations from the relevant energy statistics data and from refineries' own energy consumption (from the Official Mineral Oil Statistics). While not relevant for the calculation of greenhouse gas emissions, the distinction between the two groups of plants is important for the calculation of emissions of precursor substances and other air pollutants, since the two groups differ in their emissions behaviour.

The figures for own consumption of petroleum coke that are listed in the Official Mineral Oil Statistics represent coke burn-off in catalyst regeneration within the plants. Since the basis on which the plant operators calculate their petroleum coke inputs is not known, it is not possible to determine a suitable CO_2 emission factor. For the years 2005 through 2014, emission factors were determined from the total emissions available from emissions trading from catalyst burn-off and own consumption of petroleum coke. This allows emissions from coke burn-off in catalyst regeneration to be recorded accurately and in accordance with emissions trading for the current years. To make it possible to determine the respective factors retroactively back to 1990, a specific factor was first defined that relates to the capacity of the conversion plants involved. After various tests, this approach has proven to be the most realistic method, as the inputs and outputs of reformers and FCC plants are not captured in statistics. The result is that emissions from coke burn-off in catalyst regeneration were considerably lower in 1990 than they were in the current year. This seems plausible, since processing of heavy petroleum products has increased considerably since 1990.

As no own consumption of petroleum coke was reported for the new German federal states for the years 1990 to 1993, these values had to be calculated using the emission factor determined from the emissions trading data.

Since virtually all of oil refineries' emissions result from combustion processes, the refineries' emissions are reported in category 1.A.1.b. Only fugitive emissions from production of calcined petroleum coke and flare emissions are reported in category 1.B.2.a.iv.

Emission factors

A description of the relevant procedures and a list of the CO_2 emission factors used is provided in Annex 6.6.

The emission factors for N_2O, CH_4 and precursor substances for refinery power stations were taken from the research projects Rentz et al. (2002) and Fichtner et al. (2011). A detailed description of the procedure is provided in Chapter 3.2.4.2. The cited project does not provide any emission factors for the bottom-heating systems that supply process heat. As an alternative,

the same values for N_2O and CH_4 were therefore selected for bottom-heating systems as those used for refinery power stations.

3.2.5.3 Uncertainties and time series consistency (1.A.1.b)

Uncertainties for the activity data were determined for the first time in report year 2004 (Juhrich & Wachsmann, 2007b). The method for determining the uncertainties is described in Annex 2, in the Chapter "Uncertainties in the activity data of stationary combustion systems" (UBA, 2007)).

3.2.5.3.1 Result for NO_2

The results of Chapter 3.2.4.3.2 apply accordingly.

3.2.5.3.2 Result for CH_4

The results of Chapter 3.2.4.3.3 apply accordingly.

3.2.5.3.3 Time series consistency of the emission factors

The results of Chapter 3.2.4.3.4 apply accordingly.

3.2.5.4 Category-specific QA/QC and verification (1.A.1.b)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

For further information on quality assurance, cf. CRF 1.A.1.a (Chapter 3.2.4.4).

With regard to emission factors, the results of Chapter 3.2.4.3 apply accordingly.

3.2.5.5 Category-specific recalculations (1.A.1.b)

Table 34: Recalculations for CRF 1.A.1.b by fuel, in [kt] and [%]

	CO_2 difference, absolute				CO_2 difference, relative	
	Gaseous fuels	Liquid fuels	Solid fuels	Other fuels	Total	Total
2013	169.68	0.00	0.00	-	169.69	0.69%
2015	0.00	-2.46	0.00	-	-2.46	-0.01%
2016	0.00	-15.01	0.00	-	-15.01	-0.06%
2017	0.00	53.15	0.00	-	53.15	0.22%
2018	0.00	14.05	0.00	-	14.05	0.07%
2019	0.00	28.04	0.00	-	28.04	0.13%
2020	0.00	27.94	0.00	-	27.94	0.14%
2021	0.00	27.06	0.00	-	27.06	0.13%
2023	186.12	-33.77	-152.24	-	0.11	0.00%

Provisional values were replaced when the figures from the final Energy Balance for 2023 became available. This led to recalculations for all fuels. Since 2023, AGEB has been providing revisions to the time series every two years starting from 2003. Revisions were again made for the 2026 reporting year, resulting in recalculations for previous years.

3.2.5.6 Category-specific planned improvements (1.A.1.b)

No improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

3.2.6 Manufacture of solid fuels and other energy industries (1.A.1.c)

3.2.6.1 Category description (1.A.1.c)

KC	Category	Activity	EM of	1990 (kt CO2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] (1990-2024)
L/T	1 A 1 c, Manufacture of Solid Fuels and Other Energy Industries	fossil fuels	CO_2	65289.06	5.05	8735.95	1.24	-86.62
-/-	1 A 1 c, Manufacture of Solid Fuels and Other Energy Industries	0	CH_4	103.02	0.01	113.12	0.02	9.81
-/-	1 A 1 c, Manufacture of Solid Fuels and Other Energy Industries	0	N_2O	586.23	0.05	116.43	0.02	-80.14

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	NS	CS
CH_4	Tier 2	NS	CS
N_2O	Tier 2	NS	CS
NO_X, CO, NMVOC, SO_2	CS	NS	CS

The category Manufacture of solid fuels and other energy industries is a key category for CO_2 emissions in terms of emissions level and trend.

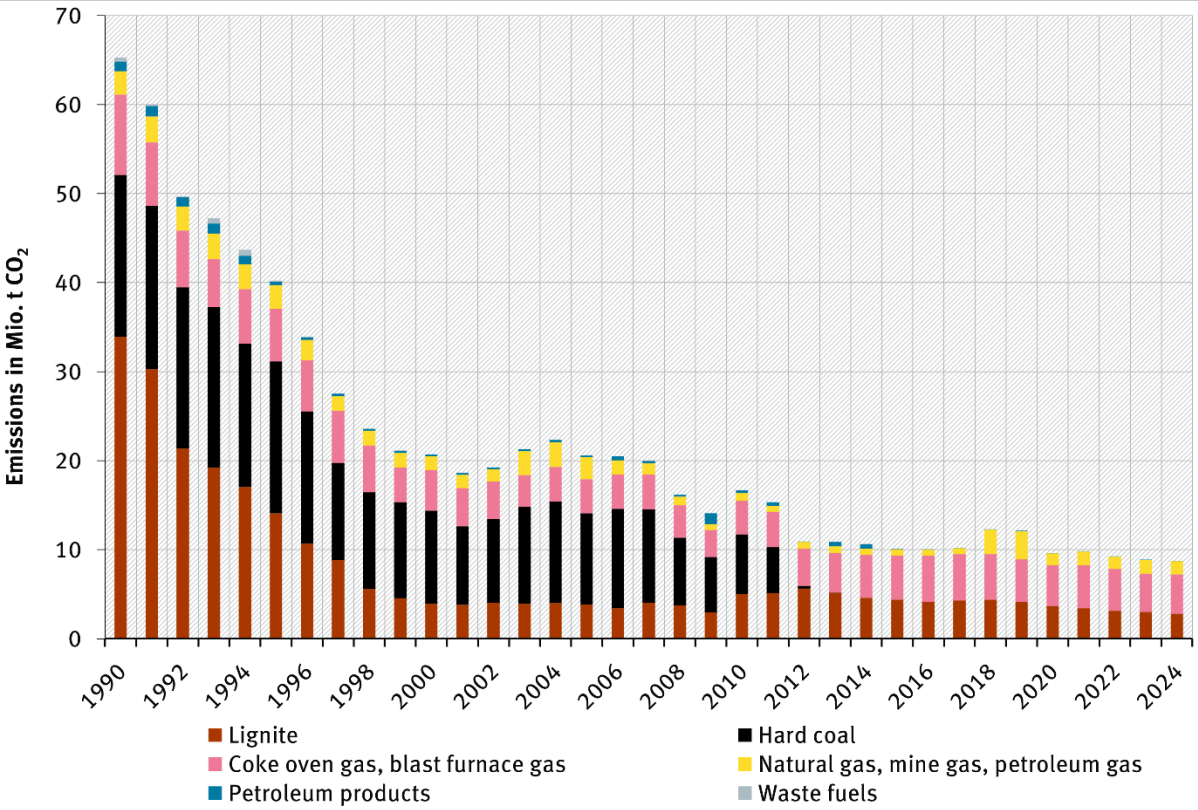
The above figures refer to power stations and to other boiler furnaces for production of steam and hot/warm water in category 1.A.1.c.

Category 1.A.1.c includes hard coal and lignite mining, coking and briquetting plants and extraction of crude oil and natural gas. The fuel inputs required for installations' own operations are reported in category 1.A.1.c.

In category 1.A.1.c Manufacture of solid fuels and other energy industries, the CSE differentiates the following: electricity and heat production in steam turbine power stations, broken down by hard coal mining and lignite mining (mine power stations); electricity and heat production in gas turbines, gas engines and diesel engines of all colliery and mine power stations; other heat production in industrial boilers within the transformation sector (not including refineries); and manufacture of hard coal coke and operation of diesel engines for propulsion purposes in colliery and mine power stations. In reporting, they are broken down into the categories "large combustion plants" and "plants falling under the Technical Instructions on Air Quality Control" (TA Luft).

The following figure provides an overview of emissions trends in category 1.A.1.c, broken down by aggregated fuels. The figure clearly shows how sharply emissions in this category have decreased since 1990:

Figure 23: Development of CO_2 emissions of category 1.A.1.c



Source: own illustration, German Environment Agency

Lignite

The sharpest decline in emissions occurred in lignite, which fell significantly in the new German federal states in the early 1990s. The GDR economy was based primarily on lignite and had to be converted to other fuels on a large scale by the end of the 1990s, with significant lignite capacities lost without being replaced. This was particularly true of the mine power stations of relevance to this sector and the lignite processing, because most of the coal-fired boilers widely used in GDR households were replaced by more modern heating systems fuelled by heating oil and natural gas by the end of the 1990s. As a result, demand for briquettes fell sharply, and most production facilities ceased production.

Over the years, there have been repeated statistical reclassifications of mine power stations, resulting in shifts in emissions between source groups 1.A.1.c and 1.A.1.a.

Hard coal

Emissions from use of hard coal in sector 1.A.1.c have decreased markedly since 1990. The main reason is that hard coal production decreased sharply and then, in 2018, was discontinued altogether. As a consequence, energy generation installations for hard coal mining were also decommissioned. The remaining mine power stations were reclassified to public supply in 2012. In the relevant year, this resulted in an increase in the CO_2 emissions in source category 1.A.1.a. This statistical effect was validated by means of a cross-sectoral trend analysis with sector 1.A.1.a with regard to actual changes in emissions.

The striking fall in emissions in 2009 was due to the general downturn in economic output during the financial crisis.

Coke oven gas; blast furnace gas and basic oxygen furnace gas (industrial gases)

The figures show a significant reduction in emissions, particularly up to the end of the 1990s, mainly due to the discontinuation of town gas production by 1996 and a significant decline in coke production (1990: 19 million t; 2009: 6.7 million t; 2018: 9.2 million t hard coal coke). In 1990, a total of 8 mine coking plants were still in operation. The remaining 6 coking plants still in operation today all belong to the steel industry. Hard coal coke production is affected by steel production, which is affected by economic trends. Overall, plant closures and efficiency increases have decreased emissions markedly in this sector.

For years now, as a result of the Federal Government's ambitious climate targets, which call for phasing out coal-fired electricity generation, companies that produce solid fuels have been having to make operational adjustments that go hand in hand with emission reductions.

3.2.6.2 Methodological issues (1.A.1.c)

A country-specific calculation method (Tier 3) has been used for key categories identified via current key category analysis.

Fuel inputs for electricity production in power stations of the hard coal and lignite mining sector are listed in Energy Balance line 12, "Industrial thermal power stations". Fuel inputs for heat production in the transformation sector are listed in Energy Balance lines 33-39 and in sum line 40 ("Total energy consumption in the transformation sector").

Fuel inputs for electricity production in power stations of the hard coal mining sector are determined using figures from the Federal Statistical Office (Statistisches Bundesamt, 2025b). The activity data for heat production in power stations of the hard coal mining sector correspond to Energy Balance line 34 "Energy input in collieries and briquette plants of the hard coal mining sector".

The listed fuel input for electricity production in mine power stations is based on association information (personal communication from DEBRIV, the federal German association of all lignite producing companies and their affiliated organisations). Inputs for heat production, especially for lignite drying for production of lignite products, are not shown in the Energy Balance. They are calculated from figures for the production of lignite products[22] and from the specific fuel inputs required for drying, and they are listed and reported as "non-Energy-Balance inputs" in the CSE. The data are obtained annually from the DEBRIV Federal German association of lignite-producing companies and updated.

The quantities of fuel used for production of hard coal coke are taken directly from Energy Balance line 33 (coking plants). This line includes the coking plants' own consumption. Fuel combustion for bottom-heating systems is the largest emission source in the coking plant sector. In the coking process, fugitive emissions also occur before the coke is quenched, however; these are reported in category 1.B.1.b.

The fuel input for heat production in the other transformation sector is obtained by combining the energy consumption figures in Energy Balance lines 33 to 39 (total energy consumption in the transformation sector). Those figures include mines' own consumption; facilities for petroleum and natural gas production and for processing of waste oil; plants that produce coal products; plants for production and processing of fissile and fertile materials; and wastewater treatment facilities' own consumption.

[22] Coal sector statistics, cf. https://kohlenstatistik.de/daten-fakten/ (Braunkohlen im Überblick)

CO_2 emissions from blast furnace gas combustion in coking plants are also reported in category 1.A.1.c. The following table provides an overview of CO_2 emissions from use of blast furnace gas in coking plants for the entire time series since 1990.

Table 35: CO_2 emissions from blast furnace gas combustion in coking plants, in [millions of t]

1990	5.340	**1997**	4.969	**2004**	3.356	**2011**	3.558	**2018**	4.809
1991	5.251	**1998**	4.362	**2005**	3.247	**2012**	3.962	**2019**	4.479
1992	4.590	**1999**	3.145	**2006**	3.281	**2013**	4.154	**2020**	4.275
1993	4.083	**2000**	3.652	**2007**	3.226	**2014**	4.554	**2021**	4.537
1994	5.066	**2001**	3.741	**2008**	3.023	**2015**	4.648	**2022**	4.436
1995	4.924	**2002**	3.684	**2009**	2.500	**2016**	4.872	**2023**	4.016
1996	4.707	**2003**	3.029	**2010**	3.245	**2017**	4.910	**2024**	4.144

Revision of the data for 1990 and for the subsequent years 1991-1994 for the new German federal states was last described in Annex 19.1.1 of the 2022 NIR.

Emission factors

A list of the CO_2 emission factors used and a description of the relevant methods are provided in Annex 6.6.

The emission factors for power stations and other boiler combustion for production of steam and hot/warm water, in category 1.A.1.c, were taken from Rentz et al. (2002) and Fichtner et al. (2011). A detailed description of the procedure is provided in Chapter 3.2.4.2. Within the sector, the research projects differentiate between power stations in the hard coal mining sector, power stations in the lignite mining sector and other boiler combustion for production of steam and hot/warm water.

Most emission factors for coking plants were taken from Hensmann et al. (2012). The emission factors determined there for captured sources were assigned to category 1.A.1.c, as these emissions mainly result from the bottom-heating of coke ovens. By contrast, the emission factors determined for fugitive sources were allocated as per the definition to category 1.B.1.b. In addition to other pollutants, CO emissions from coking plants are also calculated in both categories.

3.2.6.3 Uncertainties and time series consistency (1.A.1.c)

Uncertainties for the activity data were determined for the first time in report year 2004 (research project FKZ 204 41 132, Juhrich and Wachsmann (2007b)). The method for determining the uncertainties is described in Annex 2, Chapter 13.6 of the NIR 2007 (UBA, 2007).

The procedure for determining uncertainties for the emission factors is described in Chapter 3.2.4.3.1.

3.2.6.3.1 Result for NO_2

Relatively large numbers of fluidised-bed combustion systems are used in plants within the lignite mining sector – which are part of sector 1.A.1.c. These systems are known to have relatively higher N_2O emissions than systems using other types of coal-combustion technologies. The relevant emissions behaviour in the combustion of hard coal and lignite, particularly in fluidised bed combustion, has been specifically studied, especially in the 1990s. For this reason,

enough measurement data were available to permit systematic surveying of N_2O emission factors in the research project. The details in Chapter 3.2.4.3.2 apply accordingly.

3.2.6.3.2 Result for CH_4

The results of Chapter 3.2.4.3.3 apply accordingly.

3.2.6.3.3 Time series consistency of the emission factors

The results of Chapter 3.2.4.3.4 apply accordingly.

3.2.6.4 Category-specific QA/QC and verification (1.A.1.c)

General and category specific quality control and quality assurance have been carried out in conformance with the requirements of the QSE-manual and its associated applicable documents, by the Single National Entity.

The results of Chapter 3.2.4.2 apply accordingly.

3.2.6.5 Category-specific recalculations (1.A.1.c)

Table 36: Recalculations for CRF 1.A.1.c, in [kt] and [%]

	CO_2 difference, absolute					CO_2 difference, relative
	Gaseous fuels	Liquid fuels	Solid fuels	Other fuels	Total	Total
2003	19.40	0.15	0.00	0.00	19.56	0.09%
2004	36.45	0.30	0.00	0.00	36.75	0.16%
2005	52.41	0.89	0.00	0.00	53.30	0.26%
2006	55.64	1.24	0.00	0.00	56.88	0.28%
2007	88.12	2.05	0.00	0.00	90.17	0.45%
2008	60.64	7.60	0.00	0.00	68.24	0.42%
2009	234.90	0.02	0.00	0.00	234.92	1.70%
2010	38.11	2.75	0.00	0.00	40.86	0.25%
2011	286.77	2.12	0.00	0.00	288.89	1.92%
2012	492.60	1.72	0.00	0.00	494.32	4.73%
2013	529.77	1.43	0.00	0.00	531.20	5.12%
2014	341.60	1.16	0.00	0.00	342.76	3.33%
2015	413.80	0.78	0.00	0.00	414.58	4.30%
2016	142.94	2.99	0.00	0.00	145.93	1.48%
2017	330.80	4.55	0.00	0.00	335.34	3.40%
2018	75.67	3.74	0.00	0.00	79.41	0.65%
2019	73.08	3.17	0.00	0.00	76.25	0.63%
2020	62.56	4.80	0.00	0.00	67.37	0.71%
2021	50.06	4.67	0.00	0.00	54.73	0.56%
2022	68.03	4.37	0.00	0.00	72.40	0.79%
2023	405.01	3.56	543.88	0.00	952.44	12.05%

Provisional values were replaced when the figures from the final Energy Balance for 2023 became available. This led to recalculations. Since 2023, AGEB has been providing revisions to the time series every two years starting from 2003. Revisions were again made for the 2026 reporting year, resulting in recalculations for previous years.

3.2.6.6 Category-specific planned improvements (1.A.1.c)

No improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

3.2.7 Manufacturing industries and construction (1.A.2)

The calculation algorithms for BEU structural elements in category 1.A.2 were revised in the research project "Substantiation of the data quality of activity data" (FKZ 204 41 132, Juhrich and Wachsmann (2007b)), and are now governed by a uniform system. They are largely based on reliable data from the Federal Statistical Office.

Sectoral differentiation of activity data was carried out solely for process combustion. The calculation algorithms were documented in detail in the above research project.

For the most part, process-combustion data are reported on a sector-specific basis. Given the available data, disaggregation is not possible in a manner that is fully compliant with the UNFCCC. For example, heat and power production of industrial power stations and thermal power stations cannot be fully allocated to specific sectors; it is therefore reported collectively under 1.A.2.gviii Other.

Differentiation of energy-related process combustion for heat and power production in industrial power stations and boiler systems was carried out using Statistik 067 (Statistics 067; electricity production systems of the manufacturing sector and the mining and quarrying sectors (Stromerzeugungsanlagen des Verarbeitenden Gewerbes sowie des Bergbaus und der Gewinnung von Steinen und Erden); (Statistisches Bundesamt, 2025b).

Until 2001, Statistik 067 showed only the fuel inputs for electricity production in electricity production systems. As of 2002, it also includes the fuel inputs for both heat and electricity production. (No data are available for inputs for heat production for years prior to 2002).

The relationship between the fossil and biogenic fractions of industrial waste is obtained from waste statistics (Statistisches Bundesamt, 2023), from the relevant industrial associations' figures on substitute fuels and from the research project "Use of secondary fuels" ("Einsatz von Sekundärbrennstoffen") Lechtenböhmer, Nanning, et al. (2006b), FKZ 204 42 203/02). All of the listed amounts of standard fuels used in all subcategories have been taken from the Energy Balance and disaggregated in the Balance of Emission Causes (BEU). Beyond the energy balance, substitute fuels identified in the research project Lechtenböhmer, Nanning, et al. (2006b) are taken into account in three relevant industrial sectors and have since been updated annually using association data.

Detailed sector-specific data on the use of substitute fuels in process combustion and industrial power stations are used for the industrial sectors paper and pulp production and lime production.

Special aspects of the various subcategories are described in the relevant subchapters. The special aspects of the collective group 1.A.2.gviii "Other" should be taken into account.

The uncertainties for the new structural elements referred to in the research project "Documentation of the data quality of activity data" ("Dokumentation der Datenqualität von Aktivitätsraten") (Juhrich & Wachsmann, 2007b) were determined in accordance with the method described in the research project Lechtenböhmer, Nanning, et al. (2006b). This is described in the final report for the research project Juhrich and Wachsmann (2007b) and in Annex 13.6 of the NIR (UBA, 2007).

Carbon dioxide emissions dominate in CRF category 1.A.2. Other greenhouse gases account for only very small shares of total emissions in this category.

A sharp reduction in greenhouse gas emissions occurred in the period 1990 through 1994. It was caused by decommissioning inefficient manufacturing plants in the new German federal states following German reunification in 1990.

The emissions fluctuations that occurred in subsequent years reflect production trends in Germany's manufacturing sector, which were affected by overall economic trends.

From the 2025 GHG inventory, the data basis for the reporting of the activity data for the most recent previous year is improved. The disaggregation of energy balance data was changed from the previous distribution model to modelling using statistical data available at the time of calculating the activity data or determined by the Federal Statistical Office using imputation methods.

3.2.7.1 Manufacturing industries and construction – iron and steel (1.A.2.a)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
L/T	1 A 2 a, Iron and Steel	fossil fuels	CO_2	35269.33	2.73	33166.23	4.69	-5.96
-/-	1 A 2 a, Iron and Steel	0	CH_4	69.95	0.01	63.73	0.01	-8.89
-/-	1 A 2 a, Iron and Steel	0	N_2O	137.93	0.02	88.33	0.02	-35.96

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	NS	CS
CH_4	CS	NS	CS
N_2O	CS	NS	CS
NO_X, CO, NMVOC, SO_2	CS	NS	CS

The category "Manufacturing industries and construction – iron and steel" is a key category for CO_2 emissions in terms of emissions level and trend.

The iron and steel industry (subcategory 1.A.2.a) is the second important CO_2 emissions source, along with the cement industry, in the area of process combustion.

3.2.7.1.1 Category description (1.A.2.a)

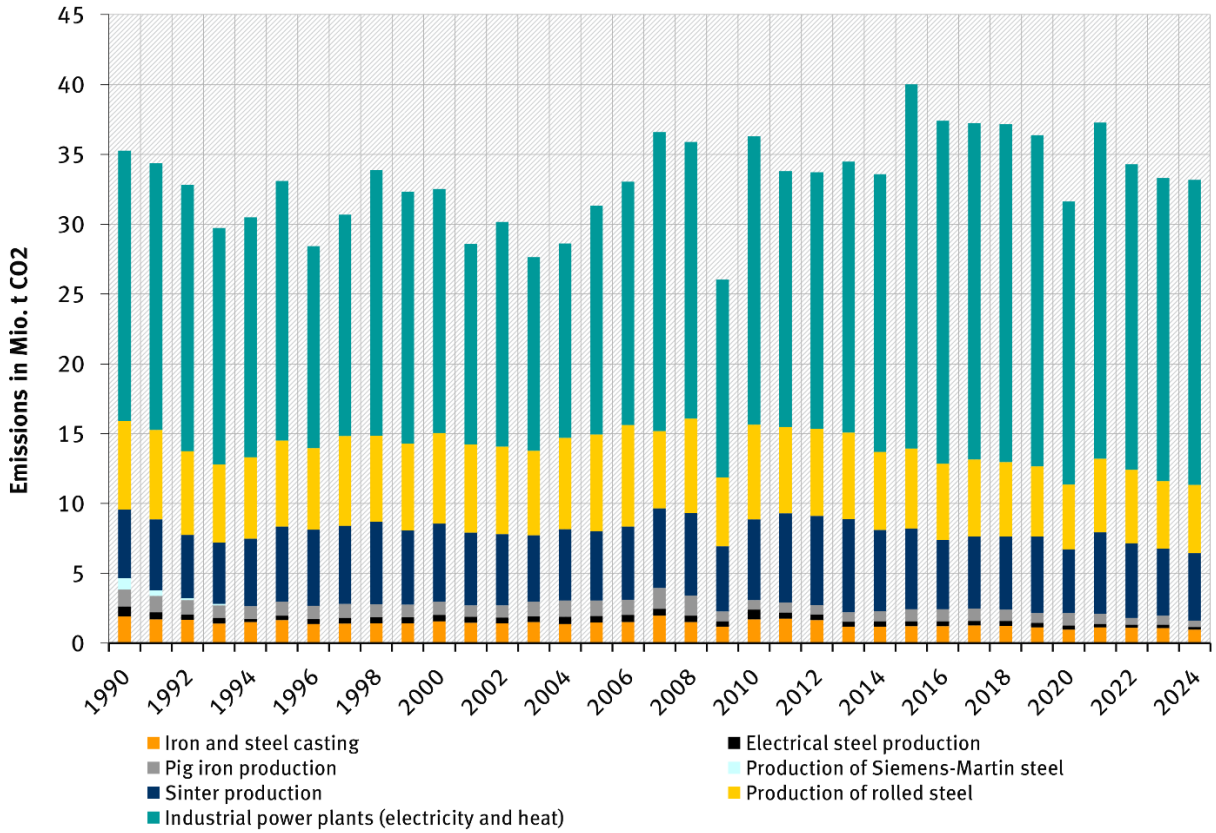
This subcategory comprises process combustion in the various production areas of the iron and steel industry. The category includes the production areas of pig iron (blast furnaces), sponge iron (direct reduction), sinter, rolled steel, iron and steel casting, Siemens-Martin steel (up to 1993), electric steel and the power stations and boilers of the entire steel industry.

Sponge iron (direct-reduced iron (DRI)) is produced in Germany only on a relatively small scale and only in one plant. The CO_2 emissions that occur in DRI production result from the use of natural gas, i.e. from use of a reducing-agent mixture, comprising H_2 and CO from natural gas. The relevant quantities of natural gas used are included throughout the entire time series in the natural gas inputs that are reported under 1.A.2.a. For reasons of confidentiality, it is not possible to list the CO_2 emissions separately.

In the production of pig iron, large amounts of the fuels used in blast furnaces are needed for the reduction processes that take place in the furnaces, while most of the fuel used in other production areas of the iron and steel industry is used for heat production.

The following figure provides an overview of CO_2 emissions in the various subcategories in 1.A.2.a. Overall, the CO_2 emissions follow the development of primary steel production.

Figure 24: Development CO_2 emissions in category 1.A.2.a, by products



Source: own illustration, German Environment Agency

The overview shows, in some cases, significant fluctuations over the years, which mainly follow production trends and thus economic developments in the steel industry. In the period 1990 to 1994, emissions reductions occurred primarily as a result of restructuring of the iron and steel sector in the new German federal states after 1990. The development in the years 2009 and 2010 was a reflection of the economic and financial crisis of the time and the economic recovery that followed.

The noticeable increase in emissions in 2015 is due to the reclassification of some blast furnace gas power plants from public supply (CRF 1.A.1.a) to industry (1.A.2.a). This shifted the relevant emissions. On the whole, CO_2 emissions increased only slightly in this year as a result of the production increase. This is clearly apparent in Figure 44 in Chapter 4.4.1.

Installations in the areas of rolled steel and sinter production account for the second-highest shares of emissions after industrial power stations (to generate electricity for their own use from blast furnace gas and basic oxygen furnace gas). In the blast furnace category, only the natural gas and coking gas inputs required for furnace operation are reported in category 1.A.2.a. Process-related emissions are listed in category 2.C.1.

The marked CO_2 emissions decrease that occurred in 2020 was the result of production decreases linked to the coronavirus pandemic.

3.2.7.1.2 Methodological issues (1.A.2.a)

As of report year 2011, reporting on the "BGS" group (the "BGS form"; including the fuel, gas and electricity industries of blast furnaces, steelworks and rolling mills; and forging plants, press works and hammer mills, including the various other plants (without their own coking plants) locally connected to these operations) was used a source of activity data for conventional fuels in this category. This has improved disaggregation of the energy data in the Balance of Emissions Sources (BEU). As of report year 2012, data are provided in the same format on the basis of an agreement with the Wirtschaftsvereinigung Stahl German steel industry association.

In addition to providing activity data for sintering plants, blast furnaces, basic oxygen furnaces (converters) and rolling mills, these data support additional disaggregation of the electric steel sector.

The BGS group data also enable data-based differentiation of the solid fuel categories "hard coal and hard coal briquettes"; "coke" and "coke breeze with particle size less than 10 mm". In the database, the fuel inputs for coke and coke breeze are listed in total as "coke", since the energy statistics list the aggregated fuel "coke". The "liquid fuels" listed for the BGS group are classified under "heating oil, heavy".

Since the BGS group reports fuel consumption in natural units, these are converted into energy units using the calorific values for solid and liquid individual fuels reported by the Working Group on Energy Balances (AGEB). From NID 2026 onwards, the calorific values will be used in the energy balance structure in accordance with the calorific values provided by the Working Group on Energy Balances. Here are the calorific values of energy balance line 8 for primary energy consumption. For gases, the BGS group data use a norm of 35.16912 MJ/ m^3 which was adopted into the methodology for calculating activity data for blast furnace gas, coke oven gas, natural gas and basic oxygen furnace gas.

The method for calculating emissions from secondary fuels is based on the results of the research project "Inputs of secondary fuels" ("Einsatz von Sekundärbrennstoffen"); Lechtenböhmer, Nanning, et al. (2006b), FKZ 204 42 203/02).

In the area of the iron and steel industry, a distinction is made for the entire time series as of 1990 between process-related emissions and energy-related emissions. The method for calculation of process-related emissions is described in Chapter 4.4.1 of category 2.C.1.

3.2.7.1.3 Uncertainties and time series consistency (1.A.2.a)

In 2004, uncertainties were determined for all fuels (except for substitute fuels) and for substitute reducing agents with regard to the entire time series. The method is described in Lechtenböhmer, Nanning, et al. (2006b). The uncertainties for the activity data were updated in the research project "Documentation of the data quality of activity data" ("Dokumentation der Datenqualität von Aktivitätsraten"; FKZ 204 41 132 (Juhrich & Wachsmann, 2007a)) and included in the relevant final report.

3.2.7.1.4 Category-specific QA/QC and verification (1.A.2.a)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

For further information on quality assurance, cf. CRF 1.A.1.a (Chapter 3.2.4.4).

The quality assurance of BGS data by the association in accordance with the QSE manual was laid down in the association agreement. The association's quality report is provided along with the data.

3.2.7.1.5 Category-specific recalculations (1.A.2.a)

Table 37: Recalculations for CRF 1.A.2.a, in [kt] and [%]

	CO_2 difference, absolute					CO_2 difference, relative
	Gaseous fuels	Liquid fuels	Solid fuels	Other fuels	Total	Total
2023	-7.72	0.78	-511.28	-	-518.22	-1.53%

Provisional figures for the year 2023 were replaced with figures from the now available final Energy Balance for that year. This has led to recalculations.

3.2.7.1.6 Category-specific planned improvements (1.A.2.a)

No improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

3.2.7.2 Manufacturing industries and construction – non-ferrous metals (1.A.2.b)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
L/-	1 A 2 b, Non-ferrous metals	fossil fuels	CO_2	1629.22	0.13	1524.28	0.22	-6.44
-/-	1 A 2 b, Non-ferrous metals	0	CH_4	1.55	0.01	1.86	0.01	19.71
-/-	1 A 2 b, Non-ferrous metals	0	N_2O	15.25	0.01	7.39	0.01	-51.54

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	NS	CS
CH_4	CS	NS	CS
N_2O	CS	NS	CS
NO_X, CO, NMVOC, SO_2	CS	NS	CS

The non-ferrous metals category is the key category for CO_2 based on emission levels.

3.2.7.2.1 Category description (1.A.2.b)

This category aggregates process combustion of various areas of non-ferrous metal production. The available data do not support a more detailed description.

3.2.7.2.2 Methodological issues (1.A.2.b)

The fuel inputs are included in the Balance of Emission Causes (BEU). The source for the fuel inputs consists of manufacturing-industry statistics (Statistik 060) – Energieverwendung des produzierenden Gewerbes ("Energy use in the manufacturing sector") (Statistisches Bundesamt, 2025a) Melde-Nr. (reporting number) 27.43 alt (old) (WZ 2003, (Statistisches Bundesamt, 2003)) → 24.43 neu (new) (WZ 2008, (Statistisches Bundesamt, 2008)) ("WZ" refers to the German Classification of Economic Activities): "Production and initial processing of lead, zinc and tin" ("Erzeugung und erste Bearbeitung von Blei, Zink und Zinn") and 27.44 old (WZ 2003, (Statistisches Bundesamt, 2003)), (Statistisches Bundesamt, 2008) 24.44 new (WZ 2008): "Production and initial processing of copper" ("Erzeugung und erste Bearbeitung von Kupfer") and for differentiation from heat and electricity production, cf. Statistik 067 (Statistisches Bundesamt, 2025b).

The calculation algorithms are described in detail in the final report for the research project "Documentation of the data quality of activity data" ("Dokumentation der Datenqualität von Aktivitätsraten") (FKZ 204 41 132, (Juhrich & Wachsmann, 2007a)).

The 1990 activity data for the new German federal states were revised and documented using new data in the project "Base year and updating" ("Basisjahr und Aktualisierung") (Zander & Merten, 2006); cf. Annex Chapter 19.1.1 of the NIR (UBA et al., 2022).

3.2.7.2.3 Uncertainties and time series consistency (1.A.2.b)

Uncertainties for all activity data were determined in 2004. The relevant method is described in Annex Chapter 13.6 of the NIR 2007 (UBA, 2007).

3.2.7.2.4 Category-specific QA/QC and verification (1.A.2.b)

Due to limited resources and minimal relevance QA/QC for EF has not been conducted for this years reporting in this category.

For further information on quality assurance, cf. CRF 1.A.1.a (Chapter 3.2.4.4).

3.2.7.2.5 Category-specific recalculations (1.A.2.b)

Table 38: Recalculations for CRF 1.A.2.b, in [kt] and [%]

	CO_2 difference, absolute					CO_2 difference, relative
	Gaseous fuels	Liquid fuels	Solid fuels	Other fuels	Total	Total
2023	-3.24	-15.78	4.88	-	-14.14	-0.94%

Provisional values for the year 2023 were replaced when the figures from the final Energy Balance for 2013 became available. This has led to recalculations.

3.2.7.2.6 Category-specific planned improvements (1.A.2.b)

No improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

3.2.7.3 Manufacturing industries and construction – Chemicals (1.A.2.c)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
-/-	1.A.2.c	All fuels	IE	IE	IE	IE	IE	IE

In the chemical industry, the main plants consist of industrial power stations and boilers. These installations are reported for all sectors in subcategory 1.A.2.g Other.

Fuel inputs in calcium carbide production are process-related and are reported under CRF 2.B.5 (cf. Chapter 4.3.5).

This approach was confirmed in the research project "Base year and updating," for 1990 in the new German federal states (Zander & Merten, 2006): the relevant coke was used as a feedstock and not as a fuel for energy. Calcium carbide production is thus not a source of energy-related CO_2 emissions.

Due to limited resources and minimal relevance QA/QC for EF has not been conducted for this years reporting in this category.

The emissions for the entire subcategory 1.A.2.c are thus included elsewhere (IE). For this reason, subcategory 1.A.2.c is not listed separately in the key category analysis.

Most emissions in the chemical industry originate from combustion processes. Since fuel input data for the chemical industry are available only as of the year 2003, no time series as of 1990 can be produced. For this reason, emissions from energy-related use of fuels in the chemical industry are reported together with emissions for other industrial sectors in category 1.A.2.gviii "Other". Nonetheless, the existing data can be cross-checked against the available data from emissions trading. Double counting with the IPPU sector must prevented in the process. In addition, it is important to ensure that emissions from combustion of other produced gases are not underestimated.

Only as of the year 2012 do energy statistics report significant quantities of gas. The first analytical step was therefore to identify the chemical industry areas in which other produced gases occur and are used for energy generation. Over half of the total gas produced is used in production of other organic basic materials and chemicals. The next largest share is used in the production of other inorganic basic materials and in production of dyes and pigments. A smaller share of these gases is used in the production of plastics in primary forms. For recalculation of the relevant gas consumption prior to 2012, the main products produced in each sector were determined. These data are available for the period back through 1990 in the annual "Chemical Industry in Figures" ("Chemiewirtschaft in Zahlen") reports of the VCI chemical industry association. Data are only missing for the new German federal states in the year 1990. Since the Energy Balance lists major quantities of "fuel gases" ("Brenngase") for the new German federal states, it may be assumed that those gases have been taken into account by the AGEB in the Energy Balance. With the help of the production data, and the gas quantity data listed in the energy statistics for the year 2013, specific factors were developed for each subsector that enabled the fuel inputs to be calculated retroactively.

3.2.7.4 Manufacturing industries and construction – Pulp, paper and print (1.A.2.d)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
-/-	1 A 2 d, Pulp, Paper and Print	fossil fuels	CO_2	3.65	0.01	8.85	0.01	142.57
-/-	1 A 2 d, Pulp, Paper and Print	0	CH_4	0.73	0.01	2.67	0.01	264.38

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
-/-	1 A 2 d, Pulp, Paper and Print	0	N_2O	2.50	0.01	9.09	0.01	264.38

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	NS	CS
CH_4	CS	NS	CS
N_2O	CS	NS	CS
NO_x, CO, NMVOC, SO_2		IE	

The category “Pulp and paper” is not a key category.

3.2.7.4.1 Category description (1.A.2.d)

The energy consumption for production of pulp and paper can be modelled only for substitute fuels. These fuels account for a large fraction of the fuels used overall.

Emissions from the use of standard fuels in process combustion and emissions from the company’s own power generators are not reported separately in this source group, but are reported collectively under 1.A.2.g *Other*.

3.2.7.4.2 Methodological issues (1.A.2.d)

Only some of the substitute fuels used by the paper industry are listed in the Energy Balance. These fuels consist of waste from the relevant sectors’ own production areas. The data on the types and amounts of substances used were provided by the German Pulp and Paper Association (VDP). The great majority of the substitute fuels used in the sector consist of wood and pulp fibres – and, thus, of biomass. The biogenic and fossil fractions of fuels were derived in the research project “Inputs of secondary fuels” (“Einsatz von Sekundärbrennstoffen”) Lechtenböhmer, Nanning, et al. (2006b). In addition, CO_2 emission factors were derived on the basis of data on carbon content, water content and calorific values.

The official statistical data on inputs of standard fuels in the paper industry were reviewed. According to the currently used system for classification of economic activities (Wirtschaftszweigsystematik – WZ 2008), (Statistisches Bundesamt, 2008) fuel inputs in this category are to be assigned to classification number (Wirtschaftszweignummer) 17, “Production of paper, paperboard and products” (“Herstellung von Papier, Pappe und Waren”).

It is not possible to clearly assign the source to a time series in accordance with the old economic sector classification (WZ 2003, (Statistisches Bundesamt, 2003)). Industrial activity (WZ) area 17 within the new system for classification of economic activities (WZ 2008) corresponds to parts of WZ areas 17, 21, 22 and 36 under the old system, WZ 2003, which is no longer used.

Currently, the individual fuel inputs cannot be listed in disaggregated form due to the need to protect confidentiality. The same applies for Statistik 067 (Statistisches Bundesamt, 2025b), which is used for differentiation from electricity and heat generation.

3.2.7.4.3 Uncertainties and time series consistency (1.A.2.d)

As part of the research project Lechtenböhmer, Nanning, et al. (2006b), the uncertainties of the CO_2 emission factors derived for substitute fuels were determined using the Monte Carlo method. In the process, figures for C content, water content and calorific value were taken into

account. These figures are based on estimates with fluctuations and only a few measurement or analysis results, leading to a large margin of uncertainty. The CO_2 emission factors for secondary fuels, along with the relevant uncertainties, apply throughout the entire relevant time series because no findings on trends are available.

3.2.7.4.4 Category-specific QA/QC and verification (1.A.2.d)

Due to limited resources and minimal relevance QA/QC for EF has not been conducted for this years reporting in this category.

The paper industry has long kept records of inputs of secondary fuels. The data are published annually in a performance report. In spite of minor structural discontinuities, the data provided in that source clearly show the paper industry's increasing use of substitute fuels in place of regular fuels.

3.2.7.4.5 Category-specific recalculations (1.A.2.d)

No recalculations were required.

3.2.7.4.6 Category-specific planned improvements (1.A.2.d)

No improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

3.2.7.5 Manufacturing industries and construction – Sugar production (1.A.2.e)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
-/T	1 A 2 e, Food Processing, Beverages and Tobacco	fossil fuels	CO_2	2015.91	0.16	280.87	0.04	-86.07
-/-	1 A 2 e, Food Processing, Beverages and Tobacco	0	CH_4	5.02	0.01	0.19	0.01	-96.14
-/-	1 A 2 e, Food Processing, Beverages and Tobacco	0	N_2O	21.92	0.01	2.23	0.01	-89.81

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	NS	CS
CH_4	CS	NS	CS
N_2O	CS	NS	CS
NOX, CO, NMVOC, SO_2	CS	NS	CS

The Sugar production category is a key category for CO_2 emissions in terms of trend (cf. Table 8). Because emissions have fallen sharply since 1990, and thus an extremely low emissions level has been achieved, the Single National Entity has decided, as part of its resource prioritisation, not to apply the more stringent methods to this category that are required for key categories.

3.2.7.5.1 Category description (1.A.2.e)

This category includes only the sugar industry's process combustion. Plants generating their own power are not listed separately; they are reported under 1.A.2.g Other.

3.2.7.5.2 Methodological issues (1.A.2.e)

The calculation algorithms and special analyses for fuel inputs are described in detail in the final report for the research project "Substantiation of the data quality of activity data" ("Dokumentation der Datenqualität von Aktivitätsraten") (Juhrich & Wachsmann, 2007b).

The existing uncertainties, which were determined for all activity data for the first time in 2004, continue to apply. The relevant method is described in Annex Chapter 13.6 of the NIR (UBA, 2007).

3.2.7.5.3 Category-specific QA/QC and verification (1.A.2.e)

Due to limited resources and minimal relevance QA/QC for EF has not been conducted for this years reporting in this category.

For further information on quality assurance, cf. CRF 1.A.1.a (Chapter 3.2.4.4).

3.2.7.5.4 Category-specific recalculations (1.A.2.e)

Table 39: Recalculations for CRF 1.A.2.e, in [kt] and [%]

	CO_2 difference, absolute					CO_2 difference, relative
	Gaseous fuels	Liquid fuels	Solid fuels	Other fuels	Total	Total
2023	8.09	-9.98	-38.63	-	-40.52	-14.12%

Provisional figures for the year 2023 were replaced with figures from the now available final Energy Balance for that year. This has led to recalculations.

3.2.7.5.5 Category-specific planned improvements (1.A.2.e)

No improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

3.2.7.6 Manufacturing industries and construction – Non-metallic minerals industry (1.A.2.f)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
L/-	1 A 2 f, Non-metallic minerals	fossil fuels	CO_2	18507.38	1.44	9581.88	1.36	-48.23
-/-	1 A 2 f, Non-metallic minerals	0	CH_4	56.31	0.01	12.55	0.01	-77.71
-/-	1 A 2 f, Non-metallic minerals	0	N_2O	182.53	0.02	76.25	0.02	-58.23

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	NS	CS
CH_4	CS	NS	CS
N_2O	CS	NS	CS
NOX, CO, NMVOC, SO_2	CS/IE	NS/IE	CS/IE

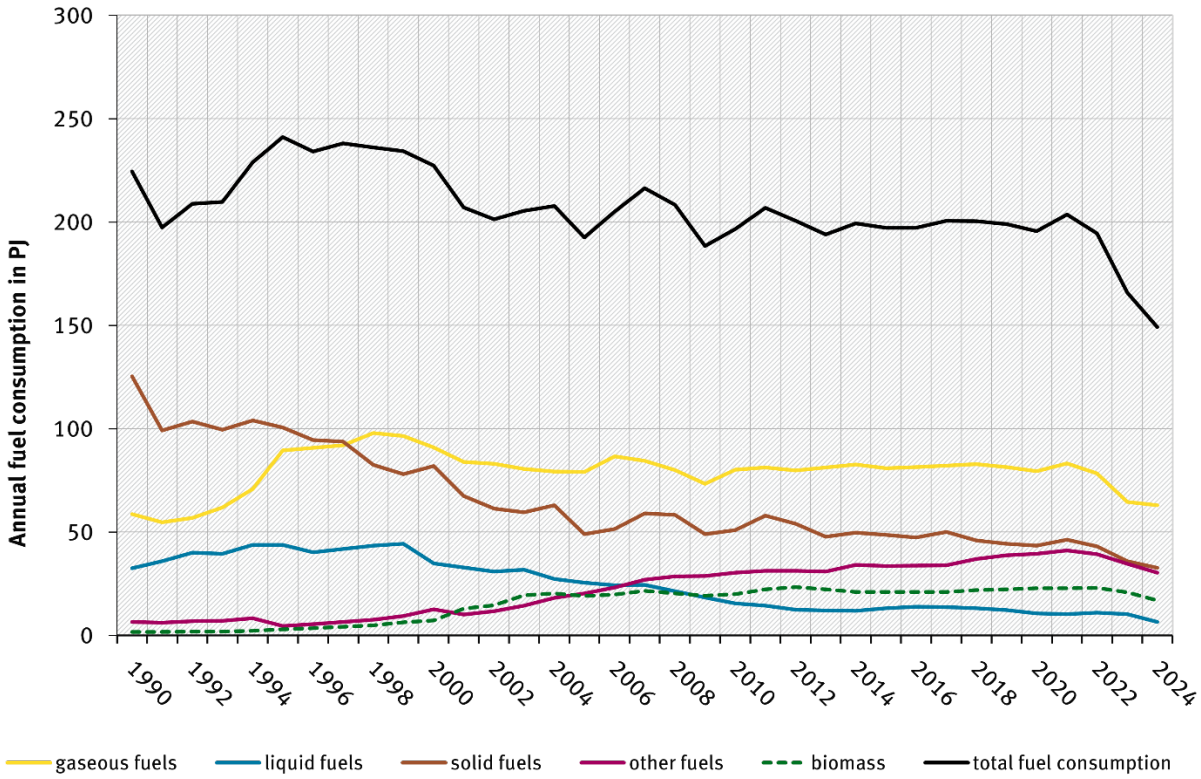
The category Manufacturing industries and construction – Non-metallic minerals industry (all subcategories) is a key category for CO_2 emissions in terms of emissions level.

In general in the inventory, those categories are listed separately in which combustion systems with a specific emissions behaviour – "process combustion" systems – are used.

3.2.7.6.1 Category description (1.A.2.f, Non-metallic minerals industry)

The areas listed in this category include process combustion from burning cement clinkers. The final step in cement production, i.e. grinding and mixing, is not included. As a power-intensive process, it is included in power production (1.A.1). In addition, process combustion in the brick industry and in the production of other structural ceramics are also taken into account. In the glass industry, process combustion includes production of flat glass, hollow glass and glass fibres; shaping and processing of flat glass; and the production and shaping of other types of glass and technical glassware. Process combustion in burnt lime production is also taken into account. Any electricity generation by the sector's own installations is also included in 1.A.2.gviii "Other".

Figure 25: Development of fuel inputs in category 1.A.2.f Non-metallic minerals



Source: own illustration, German Environment Agency

Several changes of fuels occurred in the area of the non-metallic minerals industry. In the mid-1990s, for example, gaseous fuels (natural gases) increasingly replaced solid fuels. These two fuel groups currently dominate this source category.

In the 2000s, the majority of liquid fuels (petroleum products) began to be replaced – first by waste and secondary fuels – and then also by biomass.

In recent years, solid fuels have been replaced to an ever greater extent by secondary fuels. The development of fuel inputs is in line with the industrial development in these sectors.

3.2.7.6.2 Methodological issues (1.A.2.f, Non-metallic minerals industry)

The inputs of conventional fuels are included in the Balance of Emission Sources (BEU). The fuel input data for energy-related process combustion are obtained from the manufacturing sector's own statistics. The following numbers from the WZ classification of industrial sectors are relevant: Melde-Nr. (reporting number) 26.51alt (old) (WZ 2003, (Statistisches Bundesamt, 2003)) → 23.51neu (new) (WZ 2008, (Statistisches Bundesamt, 2008)): Production of cement, Melde-Nr. 26.40 alt (WZ 2003) → 23.32 neu (WZ 2008): Brickyards, production of other structural ceramics, Melde-Nr. 26.1 alt (WZ 2003) → 23.1 neu (WZ 2008): Production of glass and glass products, and Melde-Nr. 26.52 alt (WZ 2003) → 23.52 neu (WZ 2008): Lime production. Due to the change in reporting numbers, it is no longer possible to distinguish between lime and gypsum. This is now done using a split factor that was determined on the basis of old individual statistics. For differentiation from heat and electricity production, Statistik 067 is used (Statistisches Bundesamt, 2025b).

Since 2002, the data of Statistik 067 have been available only in the three-digit reporting number (Meldenummer) range. This means that only (more highly aggregated) data for reporting number 26.5 old (WZ 2003, (Statistisches Bundesamt, 2003)) → 23.5 new (WZ 2008, (Statistisches Bundesamt, 2008)): (production of cement, lime and burnt plaster) can be used.

The relevant calculation algorithms are described in detail in the final report for the research project "Documentation of the quality of activity data" ("Dokumentation der Datenqualität von Aktivitätsraten" (Juhrich & Wachsmann, 2007b) and in the NIR (UBA et al., 2013), Chapters 3.2.9.7 through 3.2.9.10.

The fuel inputs for the new German federal states in 1990 were calculated on the basis of specific fuel consumption in 1989 and production in 1990.

The cement industry uses significant amounts of substitute fuels that do not appear in national statistics and in the Energy Balance. Production figures and fuel use quantities are taken from data of the relevant industry associations (in addition to the cement industry, this also applies to the lime industry). The procedure used to compile activity data for the old and new German federal states as of 1990 and to all of Germany as of 1995 is described in the final report of the research project "Inputs of secondary fuels" ("Einsatz von Sekundärbrennstoffen") Lechtenböhmer, Nanning, et al. (2006b), FKZ 204 42 203/02). In a first step, fuel inputs were allocated to the groups "Biomass" or "Other fuels (waste)" in accordance with IPCC procedures. In a second step, biogenic fractions were derived for mixed fuels and then incorporated into the calculations using split factors. In addition, CO_2 emission factors were derived on the basis of data on carbon content, water content and calorific values.

3.2.7.6.3 Uncertainties and time series consistency (1.A.2.f, Non-metallic minerals industry)

In 2004, uncertainties were determined for all fuels and for the aforementioned substitute fuels. The methods are explained in Annex Chapter 13.6 of the NIR (UBA, 2007) and in the final report of the research project Lechtenböhmer, Nanning, et al. (2006b). The uncertainties for the activity data were updated in the research project "Substantiation of the data quality of activity data" ("Dokumentation der Datenqualität von Aktivitätsraten" (Juhrich & Wachsmann, 2007b) and included in the relevant final report.

3.2.7.6.4 Category-specific QA/QS and verification (1.A.2.f, Non-metallic minerals industry)

General quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

For further information on quality assurance, cf. CRF 1.A.1.a (Chapter 3.2.4.4).

3.2.7.6.5 Category-specific recalculations (1.A.2.f, Non-metallic minerals industry)

Table 40: Recalculations for CRF 1.A.2.f, in [kt] and [%]

	CO_2 difference, absolute					CO_2 difference, relative
	Gaseous fuels	Liquid fuels	Solid fuels	Other fuels	Total	Total
2023	-102.66	-61.09	-99.62	0.00	-263.37	-2.43%

For the year 2023, recalculations for all conventional fuels were carried out to take account of the fact that provisional data were replaced by figures from the final Energy Balance.

3.2.7.6.6 Category-specific planned improvements (1.A.2.f, Non-metallic minerals industry)

No improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

3.2.7.7 Manufacturing industries and construction – Other energy production (1.A.2.g viii)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2023 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2023
L/T	1 A 2 g, Other Manufacturing Industries and Construction	fossil fuels	CO_2	125527.76	9.71	56437.66	7.98	-55.04
-/-	1 A 2 g, Other Manufacturing Industries and Construction	0	CH_4	146.88	0.02	202.46	0.03	37.85
-/-	1 A 2 g, Other Manufacturing Industries and Construction	0	N_2O	831.54	0.07	411.25	0.06	-50.54

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	NS	CS
CH_4	CS	NS	CS
N_2O	CS	NS	CS
NO_X, CO, NMVOC, SO_2	CS	NS	CS

The stationary and mobile sources in 1.A.2.g are grouped together for assignment to key categories. The category 1.A.2.g Manufacturing industries and construction – Other energy production is a key category for CO_2 emissions, in terms of both emissions level and trend.

As a result of its function as a collective category for fuel inputs that cannot be disaggregated to the individual sector level, this subcategory is particularly significant; it contributes substantially to the entire energy sector's CO2 emissions.

3.2.7.7.1 Category description (1.A.2.g viii)

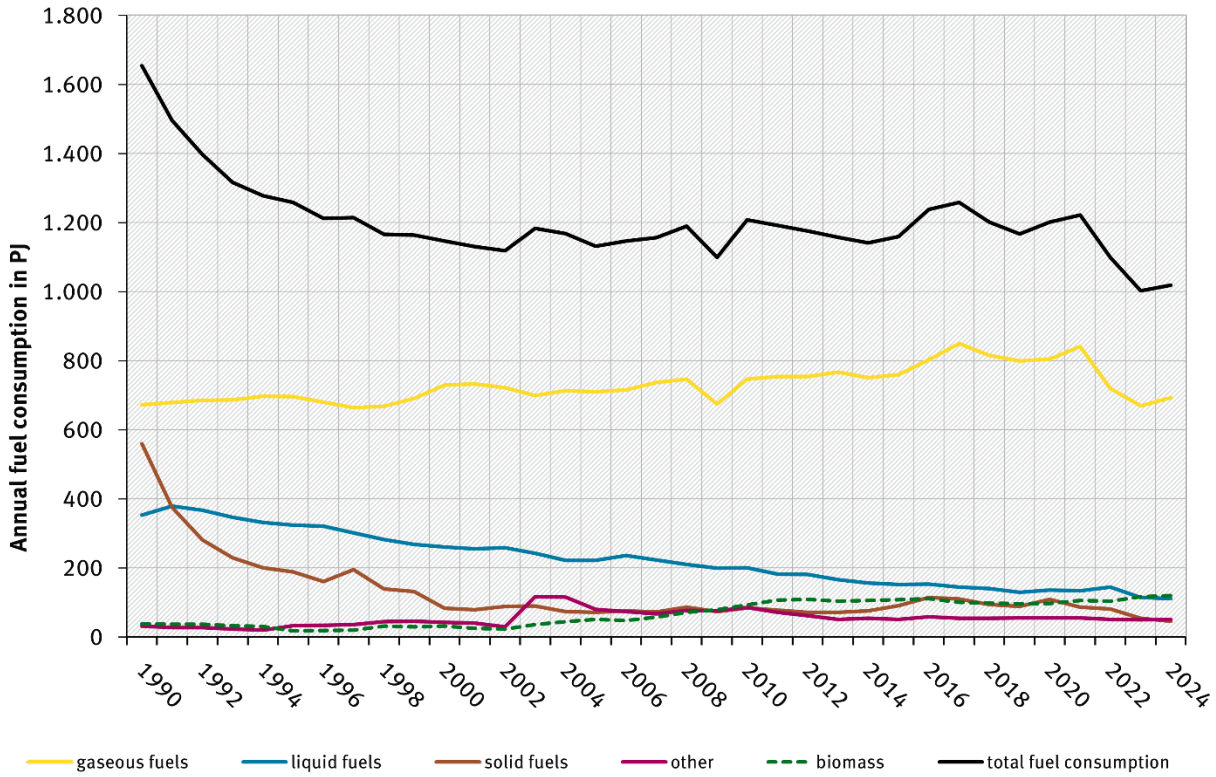
In this subcategory 1.A.2.g, all those emissions are reported for which the relevant energy inputs cannot be disaggregated in accordance with the categories in 1.A.2. This subcategory is responsible for about 65% of all CO_2 emissions of category 1.A.2.

All electricity and heat generation in industrial power stations and boilers is listed in this subcategory, because these systems can justifiably be grouped together in this subcategory given their emissions behaviour. Since the chemical industry, and systems in category 1.A.2.c primarily use CHP systems and boilers, these emissions are reported not in that category but in subcategory 1.A.2.gviii "Other." Any further subdivision of industrial power stations and boilers, among the planned subcategories, would not lead to higher data quality, since such systems' emissions behaviour does not depend on the industrial sector. In addition, preparation of time series in an additional subcategory would entail considerable difficulty, since in 1990 Germany still consisted of two countries, with two different statistical systems. Those statistical systems were merged in a transition phase lasting through 1994. Apart from that, considerable efforts were made to provide the required documentation and data quality for the base year 1990. Also, the 2003 amendment of the Act on Energy Statistics (Energiestatistikgesetz) considerably improved data collection, especially for CHP systems. These data cannot be retroactively collected for the period 2002 – 1990. By and large, while time series consistency was achieved at the aggregated level, further disaggregation would lead to discontinuity in the time series. Nevertheless, the possibility of further disaggregation has been extensively reviewed, but so far without a successful solution. Also, many energy data in Germany are subject to confidentiality restrictions, and thus often must be aggregated (aggregation safeguards confidentiality). In some sectors that have been listed separately to date, data for certain fuels now have to be combined for reasons of confidentiality and reported in category 1.A.2.gviii "Other". This considerably reduces the conclusiveness of the data in various individual sectors. The 2017 amendment of the Act on Energy Statistics (Energiestatistikgesetz) brought no improvements in the possibilities for disaggregating data on industrial power stations and boilers.

Furthermore, the boundary between the various individual industrial sectors and the public supply sector cannot ultimately be unambiguously drawn. The "autoproducers" described in the IPCC Guidelines hardly exist in reality in the clear-cut form outlined. Different companies manage their electricity and heat generation in different ways. Some companies operate power stations of their own that often also feed electricity into the public grid. Other companies draw electricity and/or heat from the public grid. In addition, frequent structural changes occurred in the course of energy market liberalisation. For example, energy generation installations were unbundled from legal groupings of companies, which led to changes in patterns of reporting for purposes of energy statistics. Since national statistics serve as the basis for inventory preparation, the inventory adopts those statistics' sectoral allocations of the various kinds of installations and plants involved. Furthermore, in the past, power stations assigned to the industrial sector were reclassified as public power stations. This is reflected in various energy statistics and would lead to distortions. These allocations do not remain constant throughout the time series and are not thoroughly consistent with the corresponding allocations in the emissions trading sector. As a result, they cannot be harmonised in the existing data records.

International comparisons of those subcategories in which industrial power stations play the primary role are not feasible, since the supply structures differ considerably from country to country.

Figure 26: Development of fuel inputs in category 1.A.2.gviii



Source: own illustration, German Environment Agency

This category exhibits marked shifts in fuel inputs.

Particularly striking is the decline in the use of solid fuels up to 2013, especially a significant reduction in the use of lignite. The decrease was especially pronounced in the 1990s. Since the 2000s, the use of natural gases has shaped the overall energy input trend. From the end of the 1990s until the early 2010s, the trend included a growing reliance on biomass. In the area of biomass, the quantities have been completely recorded only since the introduction of the Act on Energy Statistics in 2003. In earlier years, statistical surveys covered biomass use for energy generation either only partly or not at all. The use of waste fuels has grown in comparison to the levels in the 1990s. Since about 2010, it has remained at a roughly constant level. The development in the most recent previous year is largely due to the development in temperature.

3.2.7.7.2 Methodological issues (1.A.2.g viii)

The fuel inputs for electricity generation in industrial power stations are shown in Energy Balance line 12. The difference resulting after deduction of the fuel inputs for refinery power stations, mine power stations, power stations in the hard coal mining sector and, for the period until 1999, for the power stations of Deutsche Bahn (German Railways) consists of the activity data for other industrial power stations. These data cannot be further differentiated at present.

Allocation of fuel inputs to heat production in industrial power stations and boiler systems is possible only with additional data from the Federal Statistical Office. Fuel inputs for heat production in CHP systems can be determined from the statistics. The activity data for boiler systems are calculated as the difference.

For both electricity generation and heat generation, the data are broken down into the categories steam turbines, gas turbines, gas-and-steam (combined cycle) systems and gas

engines, since these different combustion technologies differ especially in terms of their methane emissions. This breakdown, which was extensively revised in the 2015 submission, is described under 1.A.1.a.

A detailed description of the calculation algorithms is provided in the final report for the research project "Documentation of the quality of activity data" ("Dokumentation der Datenqualität von Aktivitätsraten"; (Juhrich & Wachsmann, 2007b).

Emission factors

A list of the CO_2 emission factors used and a description of the method are provided in the Annex 6.6.

All other emission factors for greenhouse gases and precursor substances, for power stations and other boiler combustion for production of steam and hot/warm water, in category 1.A.2.gviii/all other, have been taken from Rentz et al. (2002) and Fichtner et al. (2011). A detailed description of the procedure is provided in Chapter 3.2.4.2. The research projects break down the relevant sector into industrial power stations and other boiler combustion systems for production of steam and hot/warm water.

3.2.7.7.3 Uncertainties and time series consistency (1.A.2.g viii)

Activity data

The uncertainties were determined for the first time for 2004. The relevant method is described in Annex Chapter 13.6 of the NIR 2007. The activity data were updated in the research project "Documentation of the quality of activity data" ("Dokumentation der Datenqualität von Aktivitätsraten" and included in the relevant final report (Juhrich & Wachsmann, 2007b)).

Emission factors

The procedure for determining uncertainties is described in Chapter 3.2.4.3.1.

Result for NO_2: The results of Chapter 3.2.4.3.2 apply accordingly.

Result for CH_4: The results of Chapter 3.2.4.3.3 apply accordingly.

The results of the time series consistency analysis in Chapter 3.2.4.3.4 apply accordingly.

3.2.7.7.4 Category-specific QA/QC and verification (1.A.2.g viii)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents, while for ED they were carried out by the Single National Entity.

For further information on quality assurance, cf. 1.A.1.a (Chapter 3.2.4.4).

Activity data

The quality of the data was reviewed in the research project "Documentation of the quality of activity data" ("Dokumentation der Datenqualität von Aktivitätsraten" (Juhrich & Wachsmann, 2007b) and improved by the use of statistics of the Federal Statistical Office. No other data sources with long-term availability have been identified.

Emission factors

The results obtained in Chapter 3.2.4.2 in the general procedure for source-specific quality assurance/control and verification apply accordingly.

3.2.7.7.5 Category-specific recalculations (1.A.2.g viii)

Table 41: Recalculations for 1.A.2.g viii by fuel, in [kt] and [%]

	CO_2 difference, absolute					CO_2 difference, relative
	Gaseous fuels	Liquid fuels	Solid fuels	Other fuels	Total	Total
2003	-19.40	-1.03	0.00	0.00	-20.44	-0.03%
2004	-36.45	-0.99	0.00	0.00	-37.44	-0.06%
2005	-52.41	-1.56	0.00	0.00	-53.97	-0.08%
2006	-55.64	-2.46	0.00	0.00	-58.10	-0.09%
2007	-88.12	-2.05	0.00	0.00	-90.17	-0.13%
2008	-60.64	-8.46	0.00	0.00	-69.09	-0.10%
2009	-53.00	-1.33	0.00	-0.09	-54.42	-0.09%
2010	-38.11	-16.83	0.00	-0.04	-54.99	-0.08%
2011	-96.99	-11.20	0.00	0.07	-108.12	-0.16%
2012	-93.22	-2.02	0.00	-0.52	-95.76	-0.15%
2013	-37.50	-1.46	0.01	-0.03	-38.98	-0.06%
2014	-36.93	-1.16	0.00	0.03	-38.06	-0.06%
2015	-66.30	-0.79	0.00	-0.04	-67.13	-0.10%
2016	-68.59	-2.99	0.00	-0.03	-71.61	-0.10%
2017	-69.54	-4.55	0.00	0.02	-74.07	-0.10%
2018	-75.67	-3.73	0.00	0.05	-79.35	-0.12%
2019	-73.08	-3.16	0.00	-0.13	-76.37	-0.12%
2020	-62.56	1.50	0.00	-0.06	-61.12	-0.09%
2021	-50.06	-8.22	0.00	-0.03	-58.31	-0.09%
2022	-68.03	-23.38	0.00	0.07	-91.34	-0.15%
2023	-755.63	-702.02	-922.08	-327.85	-2707.59	-4.80%

Provisional values for the year 2023 were replaced when the figures from the final Energy Balance for 2013 became available. This led to recalculations. Since 2023, AGEB has been providing revisions to the time series every two years starting from 2003. Revisions were again made for the 2026 reporting year, resulting in slight recalculations for previous years.

3.2.7.7.6 Category-specific planned improvements (1.A.2.g viii)

At present, no improvements are planned, neither relating to the activity data nor relating to the emission factors.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

3.2.7.8 Construction sector transport (1.A.2.g vii)

3.2.7.8.1 Category description (1.A.2.g vii)

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1[a], CS	NS/M	CS, D[a]
CH_4	CS (Tier 2)	NS/M	CS (M)
N_2O	CS (Tier 2)	NS/M	CS (M)
NO_X, CO, NMVOC, SO_2	CS (Tier 2)	NS/M	CS (M)

[a] Biodiesel: pursuant to (IPCC (2006a): Vol. 2, Tab. 2.4)

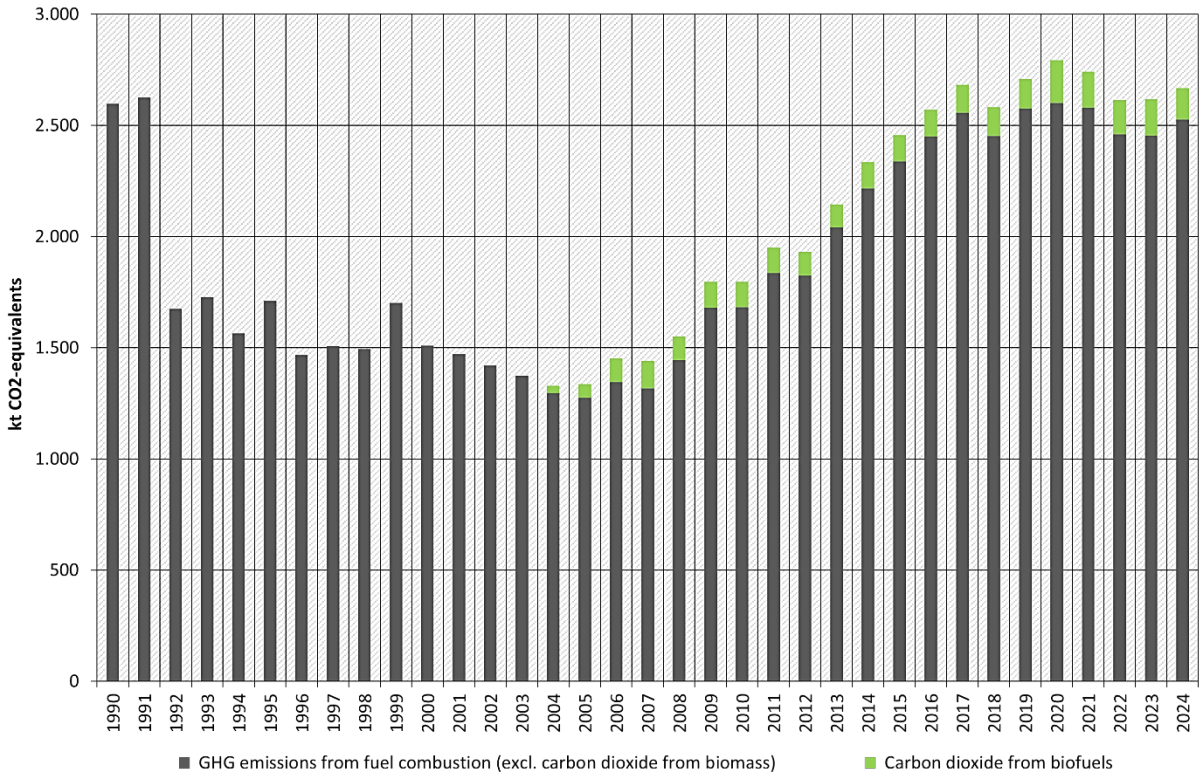
The stationary and mobile sources in 1.A.2.g are grouped together for assignment to key categories. (Overview cf. Chapter 3.2.7.7.). Accordingly, the category 1.A.2.g vii – Other: Offroad vehicles and other machines, in which emissions from construction sector transport are taken into account is a key category for CO_2 in terms of emissions level and trend.

3.2.7.8.2 Methodological issues (1.A.2.g vii)

Pursuant to the IPCC 2006 Guidelines (IPCC (2006a): page 3.33; Equation 3.3.2), the emissions are calculated using a Tier 2 method as products of consumed fuels and technology-specific emission factors.

The CO_2 emissions from the fossil fractions of the biofuels used are listed separately, and allocated to the total national emissions (cf. the explanatory remarks in Annex 7.1.4).

Figure 27: GHG emissions from vehicles and mobile construction sector machinery, since 1990



Source: own illustration, German Environment Agency

The activity data for fossil diesel fuel and gasoline are calculated, following deduction of energy inputs for military transports, from the data in Energy Balance lines 79 (until 1994) and 67 "Commercial and Institutional" ("commerce, trade, services and other consumers").

Finer allocation of fuel quantities to mobile sources in the construction sector, commerce & trade (1.A.4.a ii) and agriculture and forestry (1.A.4.c ii) is achieved with the help of annually fluctuating split factors modelled in TREMOD-MM (Transport Emission Model-Mobile Machinery (Heidt et al., 2025).

The emission factors are based on the results of various German Environment Agency research projects and expert opinions.

With regard to carbon dioxide, we refer in general to Annex 6.6. Both country-specific and default values (biodiesel) are used. Further information regarding co-combustion of lubricants in particular is provided in Chapter 4.5.1.

For methane and nitrous oxide, country-specific values from (Heidt et al., 2025) are used. The development of these values reflects the gradual phasing-in of emissions standards since the mid-1990s for construction sector machinery.

With regard to releases of methane and nitrous oxide from the co-combustion of lubricants, it is assumed that such emissions are already taken into account in the emission factors for the fuels used and thus are to be reported as IE (*included elsewhere*).

Table 42: Emission factors used for report year 2024, in kg/TJ

	CH_4	N_2O	Origin
Diesel & biodiesel	0.32 (4.15)	2.97 (28.6)	pursuant to(Heidt et al., 2025)
Gasoline & bioethanol	17.7 (50)	1.41 (2.00)	pursuant to(Heidt et al., 2025)

In parentheses: defaults pursuant to IPCC (2006a): Volume 2 – Energy, Chapter 3 – Mobile , Tab. 3.3.1: Industry

3.2.7.8.3 Uncertainties and time series consistency (1.A.2.g vii)

The uncertainty data for specific energy inputs, which are dominated by the mathematical uncertainty of the distribution key developed in TREMOD MM (cf. above: Methodological issues) are based on experts' assessments. The same is true for the carbon dioxide emission factors used. While the emission factors for methane are based on results from Knörr et al. (2009), the emission factors for nitrous oxide – for the time being – have to be oriented to guideline values pursuant to the IPCC.

For the specific energy inputs calculated as described above for diesel fuel and gasoline, uncertainties of ±10% are assumed.

The uncertainties assumed for the emission factors used are shown in the following table.

Table 43: Percentage uncertainties for emission factors*

	CO_2	CH_4	N_2O
Gasoline	±0.4%	±34%	-40%/140%
Diesel	±3%	±34%	-40%/+140%

* Upper and lower bounds of the 95% percentile

3.2.7.8.4 Category-specific QA/QC and verification (1.A.2.g vii)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

Quality reports of the Working Group on Energy Balances (AG Energiebilanzen – AGEB) have been submitted to the German Environment Agency for the purposes of quality assurance of the Energy Balances.

Table 44: Overview of relevant data comparisons

	Comparison with...	Explanation
CO_2	Alternative emissions inventories for Germany	No comparable data sets
CO_2	Default pursuant to IPCC (2006a): Volume 2, Chapter 3, Table 3.3.1: Industry	cf. Table 45
CH_4, N_2O	Default pursuant to IPCC (2006a): Volume 2, Chapter 3, Tab. 3.3.1: Industry	cf. Table 42
CO_2, CH_4, N_2O	IEFs of other countries	cf. Table 46

Table 45: Comparison of the EF (CO_2) used and default values, in kg/TJ

	Inventory values [a]	Default [b]	Lower bound	Upper bound
Diesel fuel	74,027	74,100	72,600	74,800
Gasoline	72,782	69,300	67,500	73,000
Biodiesel	70,800		59,800	84,300
Bioethanol	71,607	70,800	59,800	84,300

[a] for report year 2024; [b] pursuant to IPCC (2006a): Volume 2, [c] Chapter 3, Tab. 3.3.1; [d] Chapter 2, Tab. 2.4

The following table allows a comparison with specific implicit emission factors of other countries, which is difficult, however, due to the heterogeneous source group structure.

Table 46: International comparison of IEFs for liquid fossil fuels, in kg/TJ

	CO_2	CH_4	N_2O
Germany	74,029	2.83	2.92
Belgium	74,001	6.98	5.15
Denmark	73,631	1.99	3.46
France			
Italy			
Netherlands	72,276	1.33	0.70
Spain	73,318	0.60	3.17
EU-27			
United Kingdom	74,137	13.0	2.92

Germany: IEF for report year 2024; all other countries: IEF for 2021, pursuant to 2023 CRF submission

3.2.7.8.5 Category-specific recalculations (1.A.2.g vii)

As described above, the activity data for construction sector transport are part of the primary data provided in Energy Balance line 67. For the year 2023, the provisional data in the 2025 submission has been replaced by figures from the final Energy Balance. In addition, the biofuel admixture quotas were adjusted (from 2004 onwards).

Table 47: Revised primary activity data for 2004-2023, in terajoules

	2004	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023
Diesel fuel												
2026 submission	86,802	85,271	89,724	103,913	105,767	106,896	103,499	106,106	105,611	106,135	102,375	101,113
2025 submission	86,802	85,271	89,724	103,914	105,768	106,894	103,495	106,054	104,452	106,457	102,720	101,133
Absolute change	0.00	0.00	0.18	-0.50	-1.38	1.96	3.66	51.1	1,160	-322	-345	-20.7
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.05%	1.11%	-0.30%	-0.34%	-0.02%
Gasoline												
2026 submission	13,193	14,151	9,873	8,640	8,357	8,211	8,290	8,606	8,553	8,752	8,626	8,584
2025 submission	13,193	14,151	14,923	12,227	11,588	10,895	10,806	11,040	10,489	10,833	10,872	10,769
Absolute change	0.00	0.00	-5,050	-3,586	-3,230	-2,684	-2,516	-2,434	-1,937	-2,080	-2,246	-2,184
Relative change	0.00%	0.00%	-33.8%	-29.3%	-27.9%	-24.6%	-23.3%	-22.0%	-18.5%	-19.2%	-20.7%	-20.3%
Biodiesel												
2026 submission	2,983	5,446	6,945	5,699	5,656	5,707	5,975	6,028	8,742	7,368	7,084	7,522
2025 submission	3,164	5,681	7,018	5,772	5,733	5,827	5,840	6,016	8,543	7,465	7,126	7,496
Absolute change	-181	-235	-72.7	-73.1	-77.1	-120	136	12.3	198	-97.4	-42.3	26.9
Relative change	-5.73%	-4.14%	-1.04%	-1.27%	-1.35%	-2.05%	2.33%	0.20%	2.32%	-1.31%	-0.59%	0.36%
Bioethanol												
2026 submission	14	96.1	356	363	352	339	362	360	379	404	399	408
2025 submission	15	98	357	495	473	445	468	455	470	510	504	509
Absolute change	-0.50	-1.94	-1.81	-132	-121	-106	-106	-95	-91.6	-107	-105	-101
Relative change	-3.43%	-1.98%	-0.51%	-26.7%	-25.6%	-23.8%	-22.7%	-20.8%	-19.5%	-20.9%	-20.9%	-19.8%

Source: 2022 Energy Balance(AGEB, 2025d) and own calculations based on Heidt et al. (2025)

At the same time, the split factors generated in TREMOD-MM for allocating the diesel primary activity data to the small consumers subsumed in Energy Balance line 67 were corrected for all years. The percentage shares of construction-related transport changed as follows:

Table 48: Revised percentage shares of Energy Balance line 67

	2004	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023
Diesel fuels												
2026 submission	0.15	0.16	0.22	0.27	0.27	0.28	0.28	0.28	0.29	0.28	0.28	0.28
2025 submission	0.15	0.16	0.22	0.26	0.26	0.26	0.24	0.25	0.25	0.24	0.22	0.20
Absolute change	0.00	0.00	0.00	0.01	0.01	0.02	0.04	0.03	0.04	0.05	0.06	0.08
Relative change	-0.21%	-0.36%	-0.16%	4.79%	5.10%	7.00%	14.7%	13.3%	14.9%	19.4%	28.2%	28.2%

Own calculations based on Heidt et al. (2025)

In sum, the adjustments described above result in the following changes in the activity data most recently assigned to construction-related transport:

Table 49: Resulting revision of activity data 2004-2023, in terajoules

	2004	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023
	Diesel fuel											
2026 submission	12,939	12,784	19,158	27,623	28,923	30,072	28,694	30,110	30,387	30,104	28,649	28,384
2025 submission	12,966	12,831	19,188	26,360	27,518	28,105	25,008	26,566	26,159	25,287	22,417	20,495
Absolute change	-26.9	-47.5	-30.0	1,264	1,406	1,968	3,686	3,544	4,228	4,817	6,231	7,889
Relative change	-0.21%	-0.37%	-0.16%	4.79%	5.11%	7.00%	14.7%	13.3%	16.2%	19.0%	27.8%	38.5%
	Gasoline											
2026 submission	4,405	4,271	3,276	3,572	3,764	4,032	4,017	4,249	4,274	4,290	4,158	4,333
2025 submission	4,405	4,284	6,532	6,071	6,112	5,992	5,769	5,881	5,537	5,645	5,607	5,756
Absolute change	0.08	-12.9	-3,256	-2,499	-2,349	-1,960	-1,752	-1,632	-1,264	-1,355	-1,449	-1,423
Relative change	0.00%	-0.30%	-49.9%	-41.2%	-38.4%	-32.7%	-30.4%	-27.8%	-22.8%	-24.0%	-25.8%	-24.7%
	Biodiesel											
2026 submission	445	815	1,483	1,515	1,547	1,605	1,657	1,711	2,515	2,090	1,982	2,112
2025 submission	473	853	1,501	1,464	1,491	1,532	1,411	1,507	2,140	1,773	1,555	1,519
Absolute change	-28.0	-38.2	-17.9	50.8	55.1	73.3	246	204	376	317	427	593
Relative change	-5.92%	-4.48%	-1.19%	3.47%	3.70%	4.79%	17.4%	13.5%	17.6%	17.9%	27.5%	39.0%
	Bioethanol											
2026 submission	4.69	29.0	110	150	159	167	175	178	189	198	192	206
2025 submission	4.86	29.7	110	246	250	242	250	242	248	266	260	272
Absolute change	-0.17	-0.67	-0.57	-96.1	-91.0	-75.1	-74.5	-64.5	-59.1	-68.0	-67.7	-66.1
Relative change	-3.43%	-2.26%	-0.51%	-39.1%	-36.5%	-31.0%	-29.8%	-26.6%	-23.8%	-25.6%	-26.0%	-24.3%

Source: Own calculations based on Heidt et al. (2025)

In addition, the carbon dioxide emission factor for gasoline will be updated in 2023:

Table 50: Revised carbon dioxide emission factor 2023 for fossil-based gasoline

	EF
2026 submission	72,782
2025 submission	72,787
Absolute change	-4.16
Relative change	-0.01%

The totality of the corrections and adjustments described results in a comprehensive recalculation of the reported emissions for all years from 2004 onwards:

Table 51: Revised emission quantities 2004-2023, in kt and kt CO_2-equivalents

	2004	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023
	Carbon dioxide[a]											
2026 submission	1,281	1,261	1,663	2,312	2,422	2,527	2,424	2,546	2,571	2,550	2,432	2,426
2025 submission	1,283	1,266	1,902	2,400	2,489	2,524	2,278	2,402	2,349	2,291	2,075	1,943
Absolute change	-2.10	-4.60	-239	-88.7	-67.2	2.82	146	144	222	259	357	482
Relative change	-0.16%	-0.36%	-12.6%	-3.70%	-2.70%	0.11%	6.40%	5.99%	9.46%	11.3%	17.2%	24.8%
	Methane											
2026 submission	0.118	0.114	0.095	0.101	0.104	0.108	0.104	0.107	0.105	0.101	0.094	0.093
2025 submission	0.119	0.114	0.160	0.151	0.151	0.147	0.138	0.138	0.128	0.126	0.119	0.117
Absolute change	0.000	0.000	-0.065	-0.050	-0.047	-0.039	-0.033	-0.031	-0.023	-0.024	-0.025	-0.024
Relative change	-0.11%	-0.39%	-40.3%	-33.0%	-31.1%	-26.4%	-24.2%	-22.4%	-18.0%	-19.5%	-21.2%	-20.3%
	Nitrous oxide											
2026 submission	0.046	0.046	0.066	0.092	0.096	0.100	0.096	0.100	0.104	0.102	0.097	0.097
2025 submission	0.046	0.047	0.071	0.091	0.095	0.097	0.087	0.092	0.092	0.088	0.079	0.074
Absolute change	0.000	0.000	-0.005	0.000	0.001	0.003	0.009	0.009	0.012	0.013	0.018	0.023
Relative change	-0.35%	-0.58%	-6.68%	0.27%	0.95%	3.30%	10.5%	9.50%	12.8%	14.9%	22.2%	31.3%
	Total greenhouse gases[a]											
2026 submission	1,296	1,276	1,683	2,339	2,450	2,556	2,452	2,576	2,602	2,580	2,460	2,454
2025 submission	1,299	1,281	1,926	2,429	2,519	2,554	2,305	2,430	2,377	2,318	2,099	1,966
Absolute change	-2.14	-4.69	-242	-90.1	-68.3	2.58	147	145	225	262	361	488
Relative change	-0.17%	-0.37%	-12.6%	-3.71%	-2.71%	0.10%	6.39%	5.98%	9.45%	11.3%	17.2%	24.8%

Own calculations; [a]including fossil CO_2 from use of biofuels

3.2.7.8.6 Category-specific planned improvements (1.A.2.g vii)

No further improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

3.2.8 Transport (1.A.3)

3.2.8.1 Transport – Civil aviation (1.A.3.a)

3.2.8.1.1 Category description (1.A.3.a)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
-/-	1 A 3 a, Civil Aviation	fossil fuels	CO_2	2310.48	0.18	1087.32	0.16	-52.94
-/-	1 A 3 a, Civil Aviation	0	CH_4	3.48	0.01	1.52	0.01	-56.28
-/-	1 A 3 a, Civil Aviation	0	N_2O	20.68	0.01	9.70	0.01	-53.11

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS (Tier 3a)	NS/IS/M	D[a], CS[b]
CH_4	CS (Tier 3a)	NS/IS/M	CS[c] (M)
N_2O	CS (Tier 3a)	NS/IS/M	CS[c] (M)

Gas	Method used	Source for the activity data	Emission factors used
NO_X, CO, NMBVOC	CS (Tier 3a)	NS/IS/M	CS[c] (M)
SO_2	Tier 1	NS/IS/M	D

[a] Aviation gasoline: pursuant to IPCC (2006a), Chapter 3.6 – Civil Aviation, Table 3.6.4

[b] Derived from the default value of 3,150 kg/t kerosene pursuant to Houghton et al. (1997) and from the specific calorific value pursuant to AGEB (2025d)

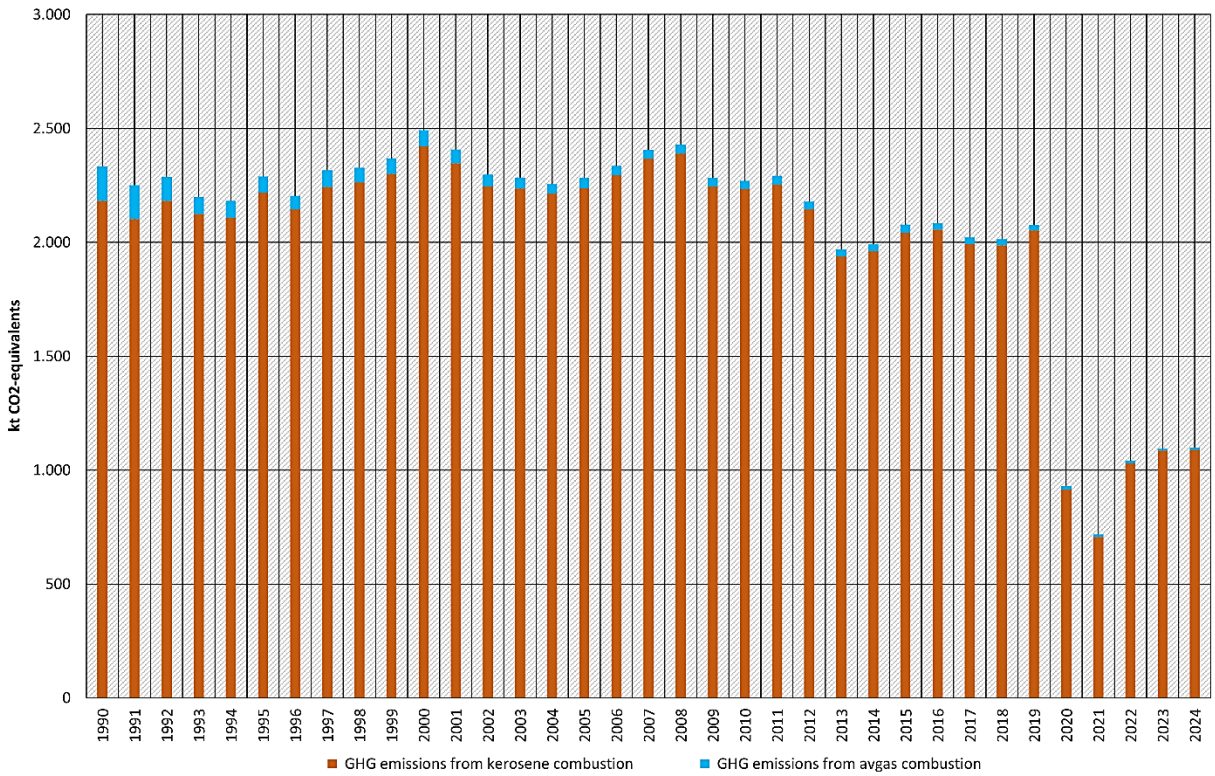
[c] Derived from Tier 3 default values pursuant to EMEP/EEA (2023)

The category "Civil aviation" is not a key category.

In terms of their climate impacts, aviation emissions differ considerably from emissions from land and water transport. This is because the climate impact of emissions changes under atmospheric conditions that differ from those near the ground and are also subject to change. The main influencing factors in this regard include atmospheric pressure, ambient temperature and humidity – all of which vary considerably with flight altitude.

Apart from carbon dioxide (CO_2), the debate on the climate impacts and environmental impacts of aviation caused by airborne emissions focuses mainly on water vapour, nitrogen oxides (NO_X) and particulates, as well as on hydrocarbons, carbon monoxide (CO) and sulphur dioxide (SO_2). Consequently, the remarks below refer to the following emissions that are considered within the framework of emissions reporting: (CO_2), methane (CH_4), nitrous oxide (N_2O), (NO_X, i.e. NO and NO_2), non-methane volatile organic compounds (NMVOC), CO and SO_2.

Figure 28: Development of GHG emissions in national civil air transport since 1990



Source: own illustration, German Environment Agency

3.2.8.1.2 Methodological issues (1.A.3.a)

Air transport emissions are calculated in accordance with Tier 3a, i.e. taking account of the annual flight mileages logged by the relevant individual aircraft types, broken down by national

and international flights, and taking account of the operational states LTO cycle (landing/take-off cycle, i.e. aircraft movements to an elevation of 3,000 feet/about 915 m) and cruise (cruising flight at elevations above 3,000 feet).

Emissions are generally determined on the basis of the Energy Balance data for consumption of kerosene and aviation gasoline (AGEB, 2025c). For years for which no data are yet available, data from the Federal Office for Economic Affairs and Export Control (BAFA, 2025a) are used. The breakdown into intra-German or international flights, which is carried out within the model (TREMOD Aviation) (Knörr et al., 2015), is crucial for reporting. The flight data are collected by the Federal Statistical Office.

For reporting, emissions are determined, in each case by multiplying fuel consumption for the respective flight phase by the specific emission factor. CO_2 and SO2 emissions figures do not depend on what method is used; they depend solely on the quantities and characteristics of the fuel consumed. On the other hand, emissions of CH_4 and N_2O depend on engines, flight altitudes, flight phases, etc., and are thus described more accurately by higher-Tier methods.

In a departure from this approach, as proposed in (IPCC (2006a): Volume 2, Chapter 3: Mobile Combustion), the emissions caused by use of aviation gasoline are calculated separately, with adjusted emission factors and calorific values.

The activity data (energy inputs) correspond to the aviation fuel sold in Germany pursuant to (AGEB (2025c); currently, for the period through 2024) and the Official mineral oil data for the Federal Republic of Germany (Amtliche Mineralöldaten für die Bundesrepublik Deutschland) that are published by the Federal Office for Economic Affairs and Export Control (BAFA, 2025a).

The calculations made within TREMOD AV with regard to kerosene take account of the numbers of flights for the various aircraft types and great circle distances for national and international air transport. In the process, the commercial flights recorded by the Federal Statistical Office are included for certain airports. The Federal Statistical Office breaks down flights from “other airfields” and non-commercial flights only by weight or aircraft classes, but not by destinations. The vast majority of these flights are operated by small aircraft powered by aviation gasoline.

Table 52: Domestic flights’ annual shares of domestic fuel deliveries, in [%]

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024
Kerosene	15.3	12.9	11.0	8.8	8.4	7.6	6.2	3.7	3.6	3.7	3.8
Aviation gasoline	86.0	85.9	86.1	86.2	86.3	86.2	97.5	92.8	92.8	79.2	80.5

TREMOD AV (Knörr, Allekotte, et al., 2025)

Fuel consumption is broken down in accordance with the two flight phases landing/take-off (LTO cycle) and cruise on the basis of data of the Federal Statistical Office and TREMOD-AV calculations. These results make it possible to extract fuel consumption figures for the LTO flight phase for both domestic and international flights. Consumption in cruise flight is obtained as the following difference: total sales according to the NEB, less the LTO consumption.

The quantities of co-combusted lubricants are derived, pursuant to (Wallfarth, 2014) from the relevant annual fuel quantities (cf. Chapter 4.5.1).

With regard to the emission factors used for carbon dioxide, we refer to Annex 6.6.

The emission factor for carbon dioxide from the use of kerosene was derived from the carbon content of kerosene; it is 3,150 g/kg. This value, which has been substantiated by numerous publications, is used for the entire aviation sector.

Nitrous oxide (laughing gas) is a product of nitrogen oxidation in the combustion chamber, and it can occur in traces. The available data for this substance are generally poor. Since the emission factors have to be broken down in accordance with the two flight phases, the emission factors for both nitrous oxide and methane have been taken from the IPCC emission factor database (EFDB) (cf. Table 495). For methane, it is assumed that emissions occur only during the LTO cycle (cf. IPCC (2006a)): Vol. 2, Chapter 3.6, Tab. 3.6.5). On the other hand, N_2O emissions are also calculated for cruising flight.

The other emissions are calculated separately for each flight phase on the basis of the relevant emission factors. Different sources are used in the process.

The implied emission factors used for NO_x, CO and NMVOC are quotients obtained by dividing the aircraft-type-specific emissions calculated and aggregated in TREMOD AV by the applicable annual kerosene consumption. The detailed emissions data calculated for this purpose in TREMOD AV are based on aircraft type-specific emission factors from the EMEP/EEA database.

Information on the other air pollutants analysed can be found in the Annex 7.1.2.1.

The emission factors expressed in the units [g/kg] are converted to the units [g/TJ] on the basis of a calorific value of 43,000 (AGEB, 2025c).

For the calculation of CO_2 emissions from the use of aviation gasoline, the standard value pursuant to IPCC (2006a): Volume 2, Chapter 3: Mobile Combustion is used. In these guidelines (pages 3-64), the emission factors for methane and nitrous oxide are explicitly defined as equal to the values specified for kerosene use. This assumption has been adopted here.

As described above for kerosene, the implied emission factors used for NO and CO are derived from aircraft-type-specific emissions calculated and aggregated in TREMOD AV and from the applicable annual avgas consumption.

CO_2 emissions from unintentional co-combustion of lubricants are reported in CRF 2.D.1. With regard to releases of methane and nitrous oxide, it is assumed that these emissions are already taken into account in the emission factors for the fuels used and thus are to be reported as IE (*included elsewhere*).

Table 53: Emission factors used for report year 2024, in kg/TJ

	CH_4	N_2O	Origin
Kerosene: LTO	12.3 (0.50)	2.80 (2.00)	pursuant to TREMOD AV; derived from EFDB defaults in kg/LTO
Kerosene: Cruise	0.00 (0.50)	2.34 (2.00)	pursuant to TREMOD AV; derived from EFDB defaults in kg/t kerosene
Avgas: LTO	162 (-)	2.30 (-)	pursuant to TREMOD AV
Avgas: Cruise	0 (-)	2.30 (-)	pursuant to TREMOD AV
Lubricants	IE	IE	Included in the EF for fuels

Knörr, Allekotte, et al. (2025); in (): Defaults pursuant to IPCC (2006a): Vol. 2, Chapter 3.6, Tab. 3.6.5

3.2.8.1.3 Uncertainties and time series consistency (1.A.3.a)

To determine uncertainties, the individual components that are included in the calculation of emissions are identified and their uncertainties (U_1 to U_n) are quantified. The total uncertainty U_{total} is obtained via additive linking of squared partial uncertainties as explained in *IPCC (2006a)*: Volume 1, Chapter 3, page 3.28, formula 3.1.

The uncertainties were determined for primary activity data (PAD); their distribution parameters (split factors, SF); the resulting specific activity data; and the emission factors used. The uncertainties for the primary activity data taken from the national Energy Balances and for the carbon dioxide emission factors were estimated by experts. All other uncertainties were derived as part of a study Allekotte et al. (2022). All uncertainties figures apply for the entire time series in each case.

The following table provides an overview of the specific uncertainties.

Table 54: Specific uncertainties used

Parameter		Distribution	Lower bound	Upper bound
Primary Activity Data (PAD)	Kerosene	normal	-5.00%	5.00%
	Aviation gasoline	normal	-5.00%	5.00%
Domestic use: percentage shares of PAD	Kerosene, national	Log normal	-7.06%	7.44%
	Avgas, national	normal	-16.2%	16.2%
	Kerosene, national: L/TO	Log normal	-7.42%	7.85%
	Avgas, national: L/TO	Log normal	-85.1%	250%
Activity Data	Kerosene – L/TO	normal	-4.10%	4.10%
	Kerosene – cruise	normal	-9.91%	9.91%
	Avgas – L/TO	Log normal	-81.8%	221%
	Avgas - cruise	normal	-39.9%	39.9%
Emission Factors	CO_2 Kerosene	normal	-5.00%	5.00%
	CO_2 Avgas	normal	-5.00%	5.00%
	CH_4 Kerosene: L/TO	Log normal	-59.6%	81.4%
	CH_4 Kerosene: Cruise		NA	
	N_2O Kerosene: L/TO	normal	-38.0%	38.0%
	N_2O Kerosene: Cruise	normal	-24.0%	24.0%
	CH_4 Avgas: L/TO	Log normal	-71.4%	156%
	CH_4 Avgas: Cruise		NA	
	N_2O Avgas: L/TO	normal	-44.8%	44.8%
	N_2O Avgas: Cruise	normal	-43.5%	43.5%

Source: Expert estimate or Allekotte et al. (2022)

3.2.8.1.4 Category-specific QA/QC and verification (1.A.3.a)

General quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

For a growing share of aircraft types for which no specific data are available, emission factors have to be obtained using regressions carried out on the basis of take-off weight. Use of more current and more complete aircraft type-specific data would further improve the quality of the calculations. Expanding the TREMOD calculation to differentiate between the types of engines used would also represent a further improvement.

Except for the emission factors for sulphur dioxide, international standard values were used that were taken from the IPCC emission-factors database, the EMEP-EEA database and EMEP/EEA (2023). Country-specific consumption and emissions data provided by Eurocontrol are currently being used only for verification purposes.

Table 55: Overview of relevant data comparisons

	Comparison with...	Explanation
CO_2, CH_4, N_2O	Alternative emissions inventories for Germany	No comparable data sets
CO_2	Specific Tier 1 default EF pursuant to (IPCC, 2006a): Vol. 2, Chapter 3.6, Tab. 3.6.4	cf. Table 53
CH_4, N_2O	Specific Tier 1 default EF pursuant to (IPCC, 2006a): Vol. 2, Chapter 3.6, Tab. 3.6.5	cf. Table 50
CO_2, CH_4, N_2O	Specific IEFs of other countries	cf. Table 57

Table 56: Comparison of the EF (CO_2) used in the inventory with default values, in kg/TJ

	Inventory value	Default	Lower bound	Upper bound
Kerosene	73,256	71,500	69,700	74,400
Aviation gasoline	71,199	70,000	67,500	73,000

[a] pursuant to IPCC (2006a): Volume 2, Chapter 2, Table 2.4

The following table provides a comparison with specific implied emission factors of other countries.

Table 57: International comparison of reported IEFs, in kg/TJ

	Kerosene			Aviation gasoline		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Germany	73,256	3.43	2.47	71,199	28.8	2.30
Belgium	72,153	4.54	6.61	72,237	35.1	272
Denmark	71,866	0.40	3.20	72,606	7.75	2.00
France	73,492	0.56	2.00	70,500	13.5	2.00
Italy	71,500	1.11	2.00	70,000	4.87	1.98
Netherlands	71,500	0.50	2.00	72,000	0.50	2.00
EU-27	72,735	1.23	2.09	70,586	8.40	5.26
UK	71,704	1.08	2.28	70,314	58.1	2.25

Germany: current IEF for report year 2022; all other countries: IEF for 2021, pursuant to 2023 CRF submission

3.2.8.1.5 Category-specific recalculations (1.A.3.a)

Compared with the 2024 submission, the recalculations result from the revision of the energy balances for 2003 to 2023 and the update to the TREMOD Aviation model (Allekotte et al., 2023).

Table 58: Revised domestic sales 1990-2023, in terajoules TJ

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Aviation gasoline/kerosene										
2026 submission	193,329	233,437	297,258	343,828	361,751	361,651	199,931	257,520	384,975	401,833
2025 submission	193,329	233,437	297,258	343,828	361,751	361,651	199,931	257,520	384,975	402,121
Absolute change	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-289
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.07%
Aviation gasoline										
2026 submission	2,438	1,142	1,120	697	567	569	214	159	175	133
2025 submission	2,438	1,142	1,120	698	568	570	214	159	175	130
Absolute change	0.00	0.00	0.00	-0.43	-0.35	-0.35	-0.13	-0.10	-0.11	3.05
Relative change	0.00%	0.00%	0.00%	-0.06%	-0.06%	-0.06%	-0.06%	-0.06%	-0.06%	2.34%

Table 59: Revised shares of domestic flights in domestic fuel deliveries in 2023, in %

	Kerosene	Aviation gasoline
2026 submission	3.652	79.2
2025 submission	3.650	79.2
Absolute change	0.003	0.00
Relative change	0.07%	0.00%

Source: TREMOD AV (Knörr, Allekotte, et al., 2025)

Table 60: Resulting revision of domestic consumption1990-2023, in terajoules TJ

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Aviation gasoline/kerosene										
2026 submission	29,501	29,989	32,746	30,260	30,210	27,605	12,354	9,541	13,914	14,676
2025 submission	29,501	29,989	32,746	30,260	30,210	27,605	12,354	9,541	13,914	14,676
Absolute change	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Aviation gasoline										
2026 submission	2,098	981	964	601	489	491	208	147	163	105
2025 submission	2,098	981	964	601	490	491	209	147	163	103
Absolute change	0.00	0.00	0.00	-0.37	-0.30	-0.31	-0.13	-0.09	-0.10	2.41
Relative change	0.00%	0.00%	0.00%	-0.06%	-0.06%	-0.06%	-0.06%	-0.06%	-0.06%	2.34%

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
TOTAL FUEL INPUTS										
2026 submission	31,599	30,970	33,710	30,861	30,699	28,096	12,563	9,688	14,076	14,781
2025 submission	31,599	30,970	33,710	30,861	30,699	28,096	12,563	9,688	14,076	14,779
Absolute change	0.00	0.00	0.00	-0.37	-0.30	-0.31	-0.13	-0.09	-0.10	2.41
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%

Source: Own calculations

This means that emissions will be recalculated for all years from 2023 onwards, although this will hardly have any impact for 2023 itself:

Table 61: Revised GHG emissions in 1990-2023, in kt or kt CO2-e

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Carbon dioxide - CO_2										
2026 submission	2,310	2,267	2,467	2,260	2,248	2,057	920	709	1,031	1,083
2025 submission	2,310	2,267	2,467	2,260	2,248	2,057	920	709	1,031	1,082
Absolute change	0.00	0.00	0.00	-0.03	-0.02	-0.02	-0.01	-0.01	-0.01	0.17
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%
Methane- CH_4										
2026 submission	0.124	0.100	0.109	0.096	0.091	0.096	0.073	0.078	0.087	0.055
2025 submission	0.124	0.100	0.109	0.096	0.091	0.096	0.073	0.078	0.087	0.055
Absolute change	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Relative change	0.00%	0.00%	0.00%	-0.01%	-0.01%	-0.01%	0.00%	0.00%	0.00%	0.15%
Nitrous oxide - N_2O										
2026 submission	0.08	0.08	0.08	0.08	0.08	0.07	0.03	0.02	0.03	0.04
2025 submission	0.08	0.08	0.08	0.08	0.08	0.07	0.03	0.02	0.03	0.04
Absolute change	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%
Total greenhouse gases										
2026 submission	2,335	2,290	2,492	2,282	2,270	2,078	930	718	1,043	1,094
2025 submission	2,335	2,290	2,492	2,282	2,270	2,078	930	718	1,043	1,094
Absolute change	0.00	0.00	0.00	-0.03	-0.02	-0.02	-0.01	-0.01	-0.01	0.18
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%

Source: Own calculations

3.2.8.1.6 Category-specific planned improvements (1.A.3.a)

Now that the TREMOD AV model has been extensively revised, no major work in this area is planned for the time being. Continuing work in this area will focus mainly on regular updating of the model based on the Advanced Emission Model (AEM)[23] operated by the European Organisation for the Safety of Air Navigation (Eurocontrol).

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

3.2.8.2 Transport – Road transportation (1.A.3.b)

3.2.8.2.1 Category description (1.A.3.b)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
L/T	1 A 3 b, Road transport	fossil fuels	CO_2	151889.81	11.75	139371.62	19.70	-8.24
-/-	1 A 3 b, Road transport	0	CH_4	1812.75	0.15	229.38	0.04	-87.35
-/-	1 A 3 b, Road transport	0	N_2O	1123.44	0.09	1306.82	0.19	16.32

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1 [a], CS (Tier 2)	NS/M	D [a], CS
CH_4	Tier 1 [b], CS (Tier 3)	NS/M	D [b], CS (M)
N_2O	Tier 1 [b], CS (Tier 3)	NS/M	D [b], CS (M)
NO_X, CO, NMVOC, SO2	CS (Tier 3)	NS/M	CS (M)

[a] Biodiesel, petroleum, lubricants co-combusted in two-stroke engines; [b] LP gas

The category “Road transport” is a key category for CO_2 emissions, in terms of both level and trend.

Emissions from motorised road transport in Germany are reported in this category. It includes transport on public roads within Germany, except for agricultural, forestry and military transports. Calculations are made for the vehicle categories of passenger cars (PCs), motorised two-wheelers (MTWs), light duty vehicles (LDVs), heavy duty vehicles (HDVs) and buses. For calculation purposes, the vehicle categories are broken down into “vehicle layers” with the same emissions behaviour. To that end, vehicle categories are also broken down by type of fuel used, vehicle size (utility vehicles and buses by weight class; motorised two-wheelers by engine displacement) and pollution control equipment used, as defined by EU directives for emissions control (“EURO norms”), and by regional traffic distribution (outside of cities, in cities and on motorways).

3.2.8.2.2 Methodological issues (1.A.3.b)

- cf. also Annex 7.1.2.2 -

Since 1990, emissions of CH_4, NO_x, CO, NMVOC and SO_2 from road transport have decreased sharply due to catalytic-converter use, engine improvements from stricter emissions laws and improved fuel quality.

[23] https://www.eurocontrol.int/model/advanced-emission-model

Between 1990 and 1993, the methane emission factor for gasoline dropped sharply, resulting in a sharp reduction in methane emissions. This was due especially to a massive reduction in the numbers of vehicles with two-stroke engines in the new German federal states. Further EF decreases resulted from stricter emissions standards.

For buses and heavy duty vehicles (over 3.5 t permissible total vehicle weight), maximum permissible levels of hydrocarbon (HC) emissions were lowered considerably (-40%) as a result of the introduction of the EURO III standard in 2000. Since EURO III vehicles were very quick to reach the market as of 2000, the emission factor for hydrocarbon emissions from diesel fuel – and the relevant emissions themselves – decreased considerably after 2000. This applies to methane, which is calculated as a fixed proportion of total HC emissions.

N_2O emissions result primarily from incomplete reduction of NO to N_2 in 3-way catalytic converters. They are not limited by law. Initially, growth in numbers of cars with catalytic converters caused increases in N_2O emissions in comparison to the 1990 level. Newer catalytic converters are optimised to produce only small amounts of N_2O, however. As a result, N_2O emissions decreased during the period 2000-2006. Since then, such emissions have been increasing again. This is due to the increasing use of selective catalytic reduction (SCR) equipment; under certain conditions, this equipment can produce N_2O as an undesired by-product.

CO_2 emissions depend directly on fuel consumption. From 1990 to 1999, these emissions increased, since growth in mileage travelled outweighed improvements in vehicle fuel efficiency. In the 2000-2009 period, road transport emissions from the consumption of fossil fuels decreased for the first time. The likely reasons for this trend include reductions in specific fuel consumption, the marked shift toward diesel vehicles in new registrations, continual increases in fuel prices, use of biofuels – and consumers' growing tendency to travel to other countries to buy fuel. The sharp increase in the number of electric vehicles since 2019 is also reducing the CO_2 emissions.

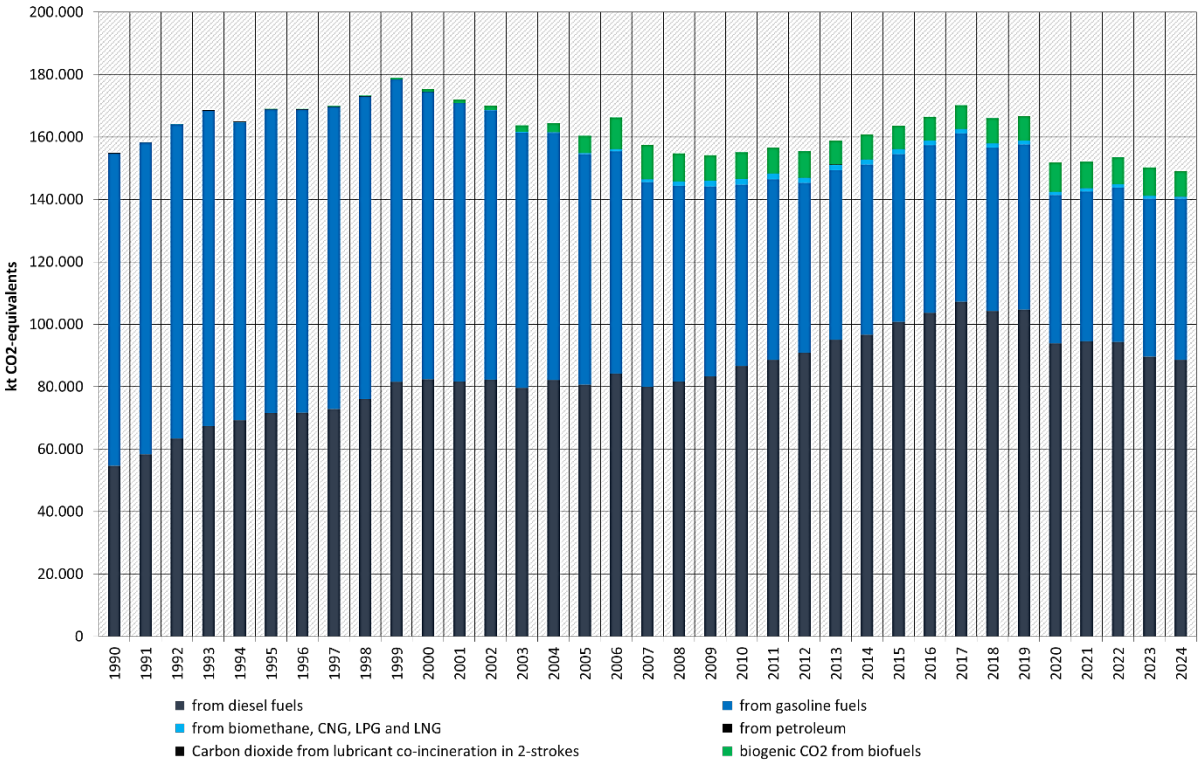
The CO_2 emissions from the fossil fractions of the biofuels used are allocated to the total national emissions (cf. explanations in the Annex 7.1.4).

However, the average engine power of newly registered cars has been increasing for years, and mileage has also been rising, with the result that by 2019 GHG emissions had risen again to a level that is around 6 million tonnes higher than in 1990.

The majority of the considerable reduction seen in 2020 and 2021can be attributed to the effects of the COVID-19 pandemic, including the changes in mobility behaviour brought about by the pandemic. Other emission reduction contributions – small ones, by comparison – came from an increase in electric vehicles' shares of new vehicle registrations and from an increase in the biofuel quota relative to 2019.

While 2021 was still marked by the pandemic, the year 2022 brought a societal and economic recovery that was reflected in a renewed increase in mileage levels. Also, those mileage increases were only partially offset by efficiency increases and by growing use of electric vehicles, with the result that GHG emissions grew by 1.2 million t with respect to 2021. At the same time, the resulting level was still considerably less (14 million t) below the 2019 level. Once again, this was primarily due to lower mileages in comparison with pre-pandemic years. As already observed for 2023, emissions declined again in 2024. However, at around 0.34 million t, the decline is considerably lower than in the previous year. This development continues to be largely due to the reduced use of diesel fuel, while there was a slight rise in the use of gasoline.

Figure 29: Development of GHG emissions in road transport since 1990



Source: own illustration, German Environment Agency

CO_2 emissions from motorised road transport in Germany is calculated using a Tier-2 "bottom-up" approach pursuant to (IPCC (2006a): Volume 2, Chapter 3.2, page 3.12): in the process, the fuels sold in Germany (gasoline, (bio-) ethanol fuel, diesel fuel, biodiesel, LP and natural gas, petroleum (until 2002), biogas) are allocated within the TREMOD ("Transport Emission Model") model to the individual vehicle layers (cf. Annex 7.1.2.2) (Knörr, Heidt, et al., 2025)[24]. The consumption data for each fuel type used in the model is taken from the Energy Balances. The actual emissions are calculated in the Central System of Emissions (CSE) after the specific fuel consumption data and emission factors have been imported.

The procedure for calculation of non-CO_2 emissions is based on a Tier-3 method, implemented in TREMOD, in which the mileage data for the relevant individual vehicle layers are multiplied by the specific emission factors. For PCs and LDVs, a "cold start surplus" is also added. The total consumption determined for each fuel type is cross-checked against consumption pursuant to the Energy Balance. The emissions as calculated in TREMOD are then corrected using correction factors obtained through cross-checking. For gasoline-powered vehicles, the VOC-evaporation emissions are calculated as a function of the pollution control technology used. From emissions and fuel consumption data for the individual TREMOD vehicle layers, fuel-based implied emission factors (IEFs) in [kg/TJ] are derived and entered into the Central System of Emissions (CSE). The IEFs are differentiated solely by fuel type and road type (motorway, country road, urban streets).

The actual emissions are calculated in the Central System of Emissions (CSE) after the specific fuel consumption data and implied emission factors have been imported.

[24] In order to derive and evaluate reduction measures, TREMOD also calculates the energy consumption and CO_2 emissions of individual vehicle categories. The values are then compared with the total consumption and total CO_2 emissions.

Table 62: Emissions from road transport, in kilotonnes

	CO_2		CH_4	N_2O	NO_X	CO	NMVOC [c]	SO_2
	Fossil [a]	Biogenic [b]						
1990	151,890	0.00	64.7	4.24	1,313	7,598	1,536	72.2
1995	166,452	106	31.9	5.9	1,140	4,332	703	69.3
2000	172,541	869	19.8	5.30	973	2,550	355	19.7
2005	153,734	5,589	13.2	2.9	783	1,635	208	0.81
2010	145,430	8,537	9.4	3.33	654	1,215	127	0.78
2015	154,675	7,487	8.6	4.5	598	1,090	100	0.82
2016	157,432	7,511	8.88	4.80	568	1,061	97.5	0.83
2017	160,958	7,657	9.11	5.16	536	1,029	94.8	0.85
2018	156,409	7,970	8.95	5.19	480	968	89.7	0.83
2019	157,196	7,889	8.96	5.32	433	931	87.8	0.83
2020	140,846	9,528	8.31	5.04	342	771	81.8	0.76
2021	142,075	8,524	8.16	5.10	318	750	79.7	0.76
2022	143,303	8,635	8.45	5.11	297	770	81.8	0.77
2023	139,702	9,008	8.18	4.95	271	776	80.6	0.75
2024	139,372	8,175	8.19	4.93	250	774	80.7	0.74

Source: Own calculations based on Knörr, Heidt, et al. (2025)

[a] Including CO_2 from the fossil fractions of consumed biofuels and of the lubricants co-combusted in two-stroke engines

[b] CO_2 emissions from the biogenic fractions of the biofuels consumed are reported (here solely for information purposes)

[c] Including emissions from fuel evaporation

For the calculation with TREMOD, extensive basic data from generally accessible statistics and special surveys are used, coordinated and supplemented. The main data sources used and key assumptions made are outlined only briefly here. A detailed description of the databases, including information on the sources used and the calculation methods used in TREMOD is provided in Knörr, Heidt, et al. (2025).

For western Germany from 1990 to 1993, and for Germany as a whole as of 1994, car fleet data are derived from the officially published fleet and new registration statistics of the Federal Motor Transport Authority (KBA). The car ownership analysis for East Germany in 1990 was based on a detailed analysis of the Adlershof car emissions testing agency in 1992 and the time series in the statistical annuals of the GDR. For the period between 1991 and 1993, it was necessary to estimate the figures based on a wide range of assumptions.

The fleet data for reference years as of 2001 are obtained for TREMOD from the database of the KBA. The supplied data include vehicle fleets for each reference year, broken down as required for emissions calculation in accordance with the following characteristics: type of engine (e.g. gasoline, diesel, other), size class, vehicle age and emissions standard. For each reference year, the mid-year fleet is assumed to be representative of the fleet's composition for the year.

Mileage data are updated on the basis of transport in kilometres, the BASt traffic barometer and data from Destatis and the Federal Motor Transport Authority Jamet and Knörr (2022). For heavy duty vehicles, the data are also cross-checked against road toll statistics.

With regard to the emission factors used for carbon dioxide, we refer to the Annex 6.6.

For petrol and natural gas, year-specific values, weighted in accordance with the fuel qualities produced in Germany, are available. For all other fuels, standardised values are used throughout all relevant years. Further information – in particular, with regard to carbon dioxide from lubricant co-combustion – is also provided in Chapter 4.5.1.

All other emission factors are listed in the "Handbook Emission Factors for Road Transport 3.2" (HBEFA), which was initially developed as part of a collaboration between Germany, Switzerland and Austria to derive emission factors for road transport. They are mainly based on measurement programmes conducted by TÜV Rheinland and RWTÜV, as well as basic studies for the reference years 1989/1990. In these studies, a new method was used for both passenger cars and heavy duty vehicles, whereby emission factors were derived on the basis of driving habits and traffic situations. Emission factors for passenger cars manufactured up to the year 1994 were updated using field monitoring data. Now France, Sweden and Norway are also participating in the development of the HBEFA. HBEFA version 4.2 (Notter et al., 2019), which is used for the current emissions calculations, draws on findings of the EU working group COST 346, of measurement programmes of the participating countries and of the ARTEMIS research programme.

With regard to unintentional co-combustion of lubricants, it is assumed that the non-CO_2 emissions are already included in the respective emission factors of the fuels used and thus have to be reported here as IE (*included elsewhere*). Carbon dioxide from unintentional co-combustion of lubricants is reported in 2.D.1, however, as emissions from product use. On the other hand, carbon dioxide from intentional co-combustion of lubricants, as part of the fuel mixtures used in road vehicle two-stroke engines, is also assigned to road transport and is reported in 1.A.3.b v in the CRT tables.

Shifting of fuel purchases to other countries

However, due to a sometimes significant price difference with several neighbouring countries, fuels that are purchased across the border and imported into Germany as grey imports have also been used in this country for some time.

At present, no precise data are available about this phenomenon, which is significant for truck and car traffic in Germany's border regions and which is referred to as "refuelling tourism" ("Tanktourismus"). Although several detailed studies have been carried out, no reliable overall picture of the situation is available(Lenk et al., 2004; Tietge et al., 2020). The sources that have documented shifting of consumers' fuel purchases to other countries (along with the resulting negative impacts on neighbouring countries' own emissions inventories) have included a study published by the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management (Molitor et al., 2004). On the one hand, the neighbouring countries profit from additional tax revenue from the energy taxes on such fuel; on the other hand the fuel sales are recorded in their greenhouse gas inventories.

3.2.8.2.3 Uncertainties and time series consistency (1.A.3.b)

The uncertainties for the activity data entering into TREMOD and for the emission factors generated therein for methane and nitrous oxide have been determined in a study (Allekotte et al., 2023). The uncertainties for the carbon dioxide emission factors, on the other hand, are based on experts' estimates and on fuel analyses.

Table 63: Relative uncertainties for carbon dioxide emission factors*

Fuel	Relative uncertainty
Diesel fuels	±3.00%
Gasoline	±0.40%
Natural gas (in the form of CNG & LNG)	±1.00%
LP gas (LPG)	±2.00%
Biodiesel	±5.00%
Bioethanol	±1.00%
Biomethane	±5.00%

* Upper and lower bounds of the 95% percentile; based on experts' estimates and fuel analyses

Table 64: Relative uncertainties of the activity data and IEFs for methane and nitrous oxide*, in %

	AD		IEF CH_4		IEF N_2O	
	U_{Min}	U_{Max}	U_{Min}	U_{Max}	U_{Min}	U_{Max}
1.A.3.b i – Passenger cars						
Diesel fuels	-18.5	27.0	-47.4	95.1	-36.5	74.7
Gasoline	-17.3	27.5	-36.2	53.0	-33.5	81.6
Natural gas	-30.2	52.2	-24.3	40.8	-31.8	50.7
Liquefied petroleum gas	-34.0	53.7	-36.7	77.7	-84.8	354.0
Biodiesel	-18.6	26.9	-47.5	95.6	-36.9	75.8
Bioethanol	-17.5	27.3	-36.1	52.4	-33.3	80.2
1.A.3.b ii – Light duty vehicles						
Diesel fuel	-14.0	18.2	-46.2	101	-35.8	67.5
Gasoline	-20.6	28.6	-30.1	37.8	-21.9	30.4
Natural gas	-21.7	36.4	-35.5	59.9	-23.3	31.5
Biodiesel	-14.3	18.8	-46.1	103.0	-35.8	68.2
Bioethanol	-20.8	28.8	-30.4	37.5	-21.9	30.7
1.A.3.b iii – Heavy duty vehicles (including buses)						
Diesel fuel	-25.8	34.1	-36.1	51.7	-28.8	51.4
Natural gas	-27.0	40.8	-18.8	34.7	NA	NA
LNG	-35.9	48.0	-14.2	11.4	NA	NA
Biodiesel	-25.8	33.9	-36.5	52.0	-28.9	52.8
1.A.3.b iv – Motorised two-wheelers (motorcycles and mopeds)						
Gasoline	-27.4	45.1	-22.5	29.4	-25.7	46.4
Bioethanol	-27.1	44.9	-22.5	29.9	-25.6	45.5

* Upper and lower bounds of the 95% percentile; modelled

3.2.8.2.4 Category-specific QA/QC and verification (1.A.3.b)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

Quality reports of the Working Group on Energy Balances (AGEB) have been submitted to the German Environment Agency for purposes of quality assurance of the National Energy Balances. In addition, documentation on revision of Energy Balances as of 2003 has been published on the Internet [25].

Table 65: Overview of relevant data comparisons

	Comparison with...	Explanation
CO_2, CH_4, N_2O	Alternative emissions inventories for Germany	No comparable data sets
CO_2	Specific Tier1 defaults pursuant to (IPCC, 2006a): Volume 2, Chapter 3, Table 3.2.1	No defaults for biofuels and petroleum
CO_2	Tier1 defaults pursuant to (IPCC, 2006a): Vol. 2, Chapter 3, Tab. 2.4	cf. Table 66
CH_4, N_2O	Specific Tier1 defaults pursuant to (IPCC, 2006a): Volume 2, Chapter 3, Table 3.2.2	Results are inconclusive
CH_4, N_2O	Tier1 defaults pursuant to (IPCC, 2006a): Volume 2, Table 2.4	Results are inconclusive
CO_2, CH_4, N_2O	Specific IEFs of other countries	cf. Table 67

Table 66: Comparison of the EF (CO_2) used and default values, in kg/TJ

	Inventory value [a]	Default [b]	Lower bound	Upper bound
Fossil-based diesel fuel	74,027	74,100	72,600	74,800
Fossil-based gasoline	72,782	69,300	67,500	73,000
Natural gas (CNG & LNG)	56,352	56,100	54,300	58,300
Liquefied petroleum gas	66,333	63,100	61,600	65,600
Petroleum	74,000	-	-	-
Co-combusted lubricants	73,300		71,900	75,200
Biodiesel	70,800		59,800	84,300
Bioethanol	71,607	70,800	59,800	84,300
Biomethane	56,352	54,600	46,200	66,000

[a]used for report year 2024; [b] pursuant to IPCC (2006a): Chapter 2, Table 2.4

Table 67: International comparison of CO2 emission factors used, in kg/TJ

	Gasoline	Diesel	LPG	CNG & LNG	Biomass	Biodiesel	Bioethanol	Biomethane
Germany	72,782	74,027	66,333	56,352		70,800	71,607	56,352
Belgium	72,270	74,240	64,930	57,150	71,950			
Denmark	72,990	74,090	63,100	56,800	74,449			

[25] AG Energiebilanzen (Working Group on Energy Balances): explanations about the revision of the Energy Balances 2003 – 2009; URL: http://www.ag-energiebilanzen.de/index.php?article_id=7&clang=0#revision_der_energiebilanzen_2003_bis_2009_05 (last accessed on 18 September 2013)

	Gasoline	Diesel	LPG	CNG & LNG	Biomass	Biodiesel	Bioethanol	Biomethane
France	74,890	74,840	65,250	56,350	70,120			
Italy	72,620	73,510	65,599	58,500	74,091			
Netherlands	72,200	72,450	66,700	56,400	72,097			
Spain	74,820	73,680	65,670	56,140	76,786			
EU-27	73,040	73,939	65,390	57,830	72,184			
UK	70,250	73,520	IE	IE	IE			

Germany: used for report year 2024; other countries pursuant to UNFCCC GHG Locator 2023

For a detailed comparison of the implied emission factors for methane and nitrous oxide, with the figures of other countries, and the values resulting for the EU (27), we refer to the Annex 7.1.2.3.3 of this report.

3.2.8.2.5 Category-specific recalculations (1.A.3.b)

With respect to the 2025 submission, recalculations have been carried out to take account of revised activity data and emission factors.

This involved a planned revision of the energy balances for 2003 to 2022, while the previously provisional figures for the 2023 energy balance were replaced by final values.

Table 68: Revised energy inputs for 2003-2023, in terajoules

	2003	2004	2005	2010	2015	2020	2021	2022	2023
Fossil diesel									
2026 submission	1,069,729	1,102,318	1,081,211	1,155,828	1,342,885	1,244,496	1,255,404	1,252,038	1,189,167
2025 submission	1,035,240	1,035,496	1,032,053	1,142,946	1,324,400	1,261,942	1,241,273	1,248,164	1,195,950
Absolute change	34,490	66,822	49,157	12,883	18,485	-17,446	14,131	3,874	-6,783
Relative change	3.33%	6.45%	4.76%	1.13%	1.40%	-1.38%	1.14%	0.31%	-0.57%
Biodiesel									
2026 submission	29,948	38,886	72,055	89,471	73,652	103,010	87,149	86,632	88,469
2025 submission	29,948	38,831	71,956	89,399	73,570	103,219	87,043	86,588	88,638
Absolute change	0.00	55.1	100	71.5	82.4	-209	106	44.3	-169
Relative change	0.00%	0.14%	0.14%	0.08%	0.11%	-0.20%	0.12%	0.05%	-0.19%
Fossil-based gasoline									
2026 submission	1,107,428	1,073,174	1,002,361	790,544	731,258	649,012	653,665	674,363	690,409
2025 submission	1,111,873	1,035,690	982,008	781,262	759,221	638,820	637,768	670,246	691,899
Absolute change	-4,446	37,484	20,353	9,282	-27,963	10,192	15,897	4,117	-1,490
Relative change	-0.40%	3.62%	2.07%	1.19%	-3.68%	1.60%	2.49%	0.61%	-0.22%
Bioethanol									
2026 submission		1,143	6,809	30,548	30,770	28,734	30,160	31,169	32,793
2025 submission		1,142	6,807	30,350	30,646	28,640	30,050	31,064	32,683
Absolute change		0.65	2.47	199	124	93.6	110	106	110
Relative change		0.06%	0.04%	0.66%	0.40%	0.33%	0.37%	0.34%	0.34%
Natural gas (CNG & LNG)									

	2003	2004	2005	2010	2015	2020	2021	2022	2023
2026 submission	2,488	2,774	3,127	5,491	5,837	4,727	8,047	7,858	6,943
2025 submission	2,488	2,774	3,127	8,498	4,595	2,881	7,144	7,749	6,886
Absolute change	0	0	0	-3,007	1,242	1,846	903	108	57.4
Relative change	0.00%	0.00%	0.00%	-35.4%	27.0%	64.1%	12.6%	1.40%	0.83%
LP gas (LPG)									
2026 submission	697	1,892	2,369	22,987	18,709	10,205	9,520	9,054	7,921
2025 submission	697	1,892	2,369	22,982	18,709	10,213	10,138	11,761	7,927
Absolute change	0.00	0.00	0.00	4.51	0.00	-7.53	-618	-2,706	-5.86
Relative change	0.00%	0.00%	0.00%	0.02%	0.00%	-0.07%	-6.10%	-23.0%	-0.07%
Biomethane									
2026 submission				270	1,242	3,181	3,474	4,796	7,035
2025 submission				270	1,242	3,181	3,474	3,821	5,218
Absolute change				0.00	0.00	0.00	0.00	975	1,817
Relative change				0.00%	0.00%	0.00%	0.00%	25.5%	34.8%
Lubricants (in fuel mixtures for two-stroke engines)									
2026 submission	72.8	72.4	79.3	82.5	80.4	82.6	73.0	78.1	68.9
2025 submission	72.8	72.4	77.7	81.6	83.3	81.6	72.2	78.6	69.5
Absolute change	0.00	0.00	1.60	0.95	-2.94	1.04	0.80	-0.52	-0.58
Relative change	0.00%	0.00%	2.06%	1.17%	-3.52%	1.28%	1.11%	-0.66%	-0.83%
TOTAL ENERGY INPUTS 1.A.3.b									
2026 submission	2,210,363	2,220,259	2,168,012	2,095,222	2,204,434	2,043,447	2,047,493	2,065,989	2,022,807
2025 submission	2,180,319	2,115,897	2,098,398	2,075,788	2,212,467	2,048,976	2,016,964	2,059,472	2,029,271
Absolute change	30,044	104,361	69,614	19,434	-8,033	-5,530	30,529	6,517	-6,464
Relative change	1.38%	4.93%	3.32%	0.94%	-0.36%	-0.27%	1.51%	0.32%	-0.32%

Source: Knörr, Heidt, et al. (2025) based on AGEB (2025c)

Lubricants: as part of 1:50 two-stroke fuel mixtures; burned in two-stroke gasoline engines

In addition, the carbon dioxide emission factor for petrol and liquefied petroleum gas has been corrected for 2023:

Table 69: Revised emission factors for 2023, in [kg/TJ]

	Gasoline	Liquefied petroleum gas
2026 submission	72,782	66,333
2025 submission	72,787	66,334
Absolute change	-4.16	-0.01
Relative change	-0.01%	0.00%

Changes have been made in the specific Tier 3 emission factors for methane and nitrous oxide in line with changes in TREMOD. It is not possible to provide the relevant revised data records here in any useful way.

The following table provides a comparison of current emission levels and those reported in the 2025 submission.

Table 70: Revised GHG emissions in 2003-2023, in kt CO_2-e

	2003	2004	2005	2010	2015	2020	2021	2022	2023
2026 submission	161,637	161,555	154,862	146,576	156,115	142,415	143,655	144,895	141,244
2025 submission	159,405	153,826	149,711	145,103	156,694	142,885	141,425	144,479	141,863
Absolute change	2,232	7,730	5,151	1,473	-578	-471	2,230	416	-619
Relative change	1.40%	5.03%	3.44%	1.02%	-0.37%	-0.33%	1.58%	0.29%	-0.44%

Source: Own calculations

3.2.8.2.6 Category-specific planned improvements (1.A.3.b)

Apart from annual regular revision of the TREMOD model, no category-specific improvements are planned.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

3.2.8.3 Transport – Railways (1.A.3.c)

3.2.8.3.1 Category description (1.A.3.c)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
L/T	1 A 3 c, Rail Transport	fossil fuels	CO_2	3133.05	0.25	742.99	0.11	-76.29
-/-	1 A 3 c, Rail Transport	0	CH_4	19.73	0.01	0.26	0.01	-98.66
-/-	1 A 3 c, Rail Transport	0	N_2O	6.83	0.01	1.64	0.01	-76.00

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1 [a], CS (Tier 2)	NS	D [a], CS
CH_4	CS (Tier 2)	NS	D [b, c, d]
N_2O	CS (Tier 2)	NS	D, CS
NO_x, CO, NMVOC, SO_2	CS (Tier 2)	NS	CS

[a] Biodiesel: pursuant to ((IPCC (2006a): Tab. 2.4);

[b] Diesel: pursuant to (EMEP/EEA (2023): 1.A.3.c – *Railways*; Tab. 3-2 to 3-4);

[c] Steinkohle & Steinkohlekoks: pursuant to (IPCC (2006a): Tab. 3.4.1);

[d] lignite: pursuant to (IPCC (2006a): Tab. 2.5)

The category "Railway transport" is a key category for CO_2 emissions in terms of emissions level and trend.

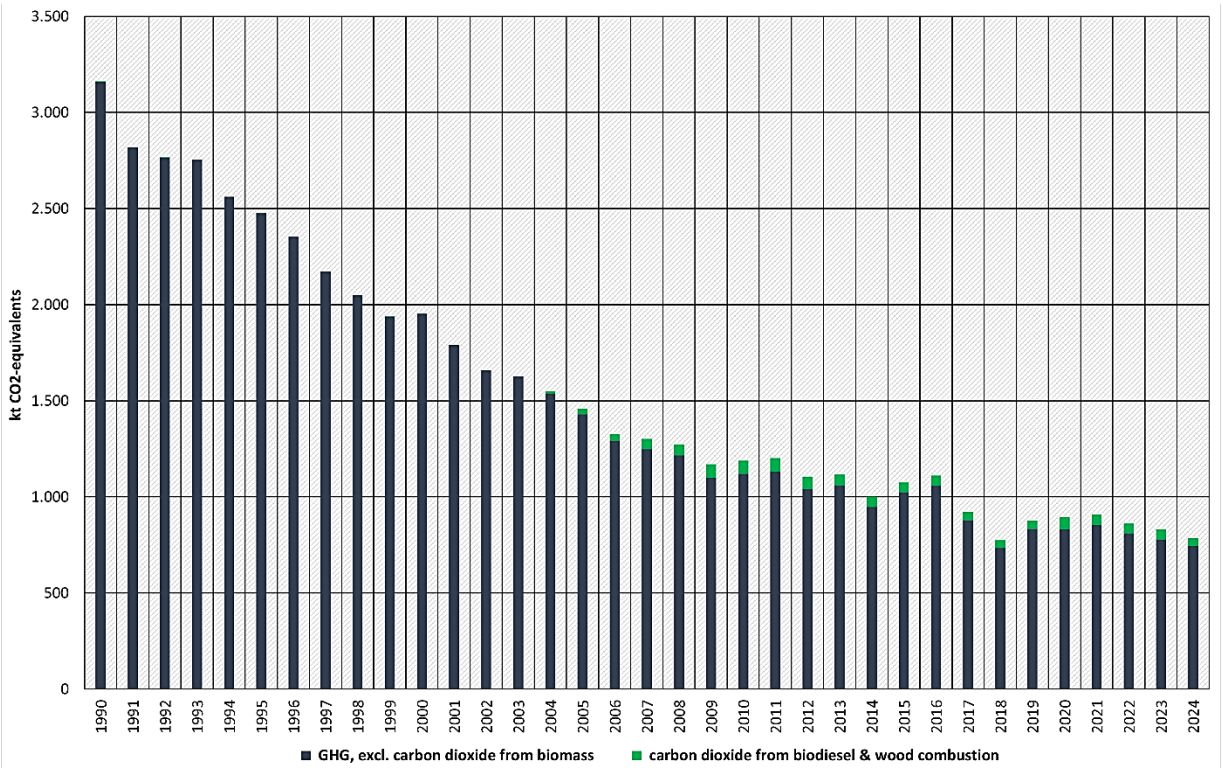
Germany's railway sector is undergoing a long-term modernisation process aimed at making electricity the main energy source for rail transport. Its share of final energy used for traction is currently about 81% (AGEB, 2025c). Railway power stations for the generation of required traction current are allocated to the stationary component of electricity generation in public power stations (1.A.1.a) and are not included in the following section.

Apart from electricity, diesel fuel is the only other significant source of energy. Since 2004, biodiesel has also been used, as an additive.

In historic vehicles, small quantities of solid fuels are also used.

Use of other fuels – such as vegetable oils or gas – in private narrow-gauge railway vehicles has not been included to date and may be considered negligible.

Figure 30: Development of GHG emissions in rail transport since 1990



* not including greenhouse gases from generation of traction current, and not including CO2 from unintentional co-combustion of lubricants

Source: own illustration, German Environment Agency

3.2.8.3.2 Methodological issues (1.A.3.c)

The relevant emissions are thus calculated as the product of fuel consumption and the relevant country-specific emission factors. This procedure conforms to the general Tier 2 method and the basic calculation rule pursuant to Equation 3.4.2 of the 2006 IPCC Guidelines (Volume 2, page 3.42).

The CO_2 emissions from the fossil fractions of the biofuels used are listed separately in this report and allocated to the total national emissions (cf. the explanatory remarks in Chapter Annex 7.1.4).

In general, the activity data (energy inputs) are taken from Energy Balance lines 74 (through 1994) and 61 (as of 1995) (AGEB, 2025c).

Consumption data for solid fuels that can be evaluated is only available in the official energy balances for lignite up to 2002 and for hard coal up to 2000. Interpolations and extrapolations, and the results of three surveys, carried out in 2012, 2016 and 2021 (Hasenbalg & Sohnke, 2021; Hedel & Kunze, 2012; Illichmann, 2016) are used as complementary sources

Table 71: Overview of the statistics and other sources used

Fuel	Source(s) used
Diesel	AGEB
Biodiesel	calculated based on official admixture quotas
Hard coal	until 1994: AGEB; 1995-2004: Interpolation, as of 2005: Survey: as of 2016: Continuation
Hard coal coke	until 1997: AGEB; 1998-2004: Interpolation; 2005-2010: Survey: as of 2011: Extrapolation
Crude lignite & briquettes	1990-2002: AGEB; not used thereafter

With regard to the emission factors used for carbon dioxide, we refer to Annex 6.6.

For methane and nitrous oxide, country-specific values pursuant to (Knörr, Heidt, et al. (2025): liquid fuels) or default values pursuant to (IPCC (2006a): solid fuels) are used. With regard to releases of methane and nitrous oxide from co-combustion of lubricants, it is assumed that these emissions are already taken into account in the emission factors for the fuels used and thus are to be reported as IE (*included elsewhere*).

Table 72: Emission factors used for report year 2024, in kg/TJ

	CH_4	N_2O	Origin
Diesel & biodiesel	0.83 (4.15)	0.56 (28.60)	CH_4: pursuant to Knörr, Heidt, et al. (2025); N_2O: tier 2 based on EMEP/EEA (2023)
Crude lignite & briquettes	300 (-)	1.50 (-)	Fuels not used in 2024
Hard coal& hard coal coke	2.00 (2.00)	1.50 (1.50)	Use of the sector-specific IPCC defaults for “sub-bituminous coal”
Firewood	100	1.00	derived from stationary small combustion systems
Lubricants	IE	IE	Already included in the EFs for liquid fuels

In parentheses: Sector-specific prescribed values pursuant to IPCC (2006a), Volume 2, Chapter 3.4 - Railways

3.2.8.3.3 Uncertainties and time series consistency (1.A.3.c)

In the framework of a study (Knörr et al., 2009), uncertainties were calculated for the activity data entered into TREMOD, for the implied emission factors modelled in TREMOD and for the emissions calculated in the Central System of Emissions (CSE).

Table 73: Percentage uncertainties for activity data and emission factors*

	AD	EF CO_2	EF CH_4	EF N_2O
Diesel fuels	±10%	±3%	±34%	-42.5%/75%
Lignite briquettes	±20%	±5%	-28.1%/40%	-42.5%/75%
Crude lignite	±20%	±3%	-28.1%/40%	-42.5%/75%
Hard coal	±20%	±2%	-28.1%/40%	-42.5%/75%
Hard coal coke	±20%	±2%	-28.1%/40%	-42.5%/75%
Firewood	±10%	±5%	-42.5%/75%	±75%
Biodiesel	±10%	±5%	-28.1%/40%	-42.5%/75%

* Upper and lower bounds of the 95% percentile

The activity rate time series for lignite briquettes, hard coal and hard coal coke exhibit inconsistencies resulting from statistical conversion as of 1994/1995; these inconsistencies cannot be eliminated at present.

3.2.8.3.4 Category-specific QA/QC and verification (1.A.3.c)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

Quality reports of the Working Group on Energy Balances (AGEB) have been submitted to the German Environment Agency for purposes of quality assurance of the National Energy Balances. In addition, documentation on revision of the Energy Balances as of 2003 has been published on the Internet.

Table 74: Overview of relevant data comparisons

	Comparison with...	Explanation
CO_2, CH_4, N_2O	Alternative emissions inventories for Germany	No comparable data sets
CO_2	Specific Default EF pursuant to IPCC (2006a): Volume 2, Chapter 3.4, Tab. 3.4.1	Not for all fuels
CO_2	Default EF pursuant to IPCC (2006a): Volume 2, Chapter 2, Table 2.4	cf. Table 75
CH_4, N_2O	Specific Default EF pursuant to IPCC (2006a): Volume 2, Chapter 3.4, Tab. 3.4.1	cf. Table 72
CH_4, N_2O	Default EF pursuant to IPCC (2006a): Volume 2, Chapter 2, Table 2.4	Results are of little significance
CO_2, CH_4, N_2O	IEFs of other countries	cf. Table 76

Table 75: Comparison of the EF (CO_2) used with default values [a], in kg/TJ

	Inventory value [b]	Default	Lower bound	Upper bound
Fossil-based diesel fuel	74,027	74,100	72,600	74,800
Lignite briquettes	100,979	97,500	87,300	109,000
Crude lignite	103,612	101,000	90,900	115,000
Hard coal	94,386	94,600	89,500	99,700
Hard coal coke	109,568	107,000	95,700	119,000
Biodiesel	70,800		59,800	84,300
Firewood	102,108	112,000	95,000	132,000

[a] for report year 2022; [b] pursuant to IPCC (2006a): Vol. 2, Tab. 2.4

The following table provides a comparison with specific implied emission factors of other countries as well as with the relevant values resulting for the EU(27).

Table 76: International comparison of reported IEFs, in kg/TJ

	Fossil liquid fuels			Fossil solid fuels		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Germany	74,027	0.83	0.56	94,426	3.05	1.50
Belgium	74,100	4.94	6.86	NO	NO	NO
Denmark	74,173	1.06	2.24	NO	NO	NO
France	74,247	10.60	2.95	IE	IE	IE
Italy	74,320	4.21	29.04	NO	NO	NO

	Fossil liquid fuels			Fossil solid fuels		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Netherlands	74,394	4.26	0.56	NO	NO	NO
Spain	74,467	4.15	0.56	NO	NO	NO
EU-27	74,541	2.95	10.80	94,991	49.77	1.10
UK	74,614	0.93	0.56	96,100	87.57	0.70

Sources: IEF for report year 2025; otherwise: IEF for 2021, pursuant to 2023 CRF submission

3.2.8.3.5 Category-specific recalculations (1.A.3.c)

Since the 2025 submission, recalculations have been carried out to take account of revised activity data. While only the most recent provisional value for fossil diesel was corrected to reflect the 2023 Energy Balance, adjustments were made to the entire time series for biodiesel.

Table 77: Revised activity data, in terajoules [TJ]

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Diesel fuel										
2026 submission	38,605	31,054	25,410	18,877	14,626	13,321	10,782	11,072	10,482	10,035
2025 submission	38,605	31,054	25,410	18,877	14,626	13,321	10,782	11,072	10,482	10,039
Absolute change	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-3.75
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.04%
Biodiesel										
2026 submission				416	966	729	892	769	725	747
2025 submission				434	976	738	882	776	727	744
Absolute change				-17.98	-9.97	-9.34	10.55	-7.81	-1.88	2.54
Relative change				-4.14%	-1.02%	-1.27%	1.20%	-1.01%	-0.26%	0.34%
TOTAL ENERGY INPUTS										
2026 submission	41,381	32,681	26,065	19,576	15,924	14,401	11,982	12,167	11,534	11,108
2025 submission	41,381	32,681	26,065	19,594	15,934	14,411	11,972	12,175	11,536	11,110
Absolute change	0.00	0.00	0.00	-17.98	-9.97	-9.34	10.55	-7.81	-1.88	-1.21
Relative change	0.00%	0.00%	0.00%	-0.09%	-0.06%	-0.06%	0.09%	-0.06%	-0.02%	-0.01%

Sources: AGEB (2025c); Knörr, Heidt, et al. (2025)

The adjustment to the carbon dioxide emission factor for firewood has no impact on the reported emissions.

The adjustments described above lead to the following recalculated emission quantities:

Table 78: Revised emission quantities, in [kt] and [kt CO_2 equivalents]

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Carbon dioxide – CO_2[a]										
2026 submission	3,133	2,458	1,945	1,426	1,118	1,022	830	853	810	777
2025 submission	3,133	2,458	1,945	1,426	1,118	1,022	830	853	810	777
Absolute change	0.00	0.00	0.00	-0.07	-0.04	-0.04	0.04	-0.03	-0.01	-0.27
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.03%

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Methane – CH_4										
2026 submission	0.70	0.47	0.19	0.04	0.02	0.01	0.01	0.01	0.01	0.01
2025 submission	0.70	0.47	0.19	0.04	0.02	0.01	0.01	0.01	0.01	0.01
Absolute change	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Relative change	0.00%	0.00%	0.00%	-0.08%	-0.06%	-0.06%	0.08%	0.03%	-0.02%	0.01%
Nitrous oxide – N_2O										
2026 submission	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2025 submission	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Absolute change	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Relative change	0.00%	0.00%	0.00%	-0.09%	-0.06%	-0.06%	0.08%	-0.06%	-0.02%	-0.01%
Total GHG[a]										
2026 submission	3,160	2,477	1,954	1,430	1,121	1,024	833	856	812	779
2025 submission	3,160	2,477	1,954	1,430	1,121	1,025	833	856	812	779
Absolute change	0.00	0.00	0.00	-0.07	-0.04	-0.04	0.04	-0.03	-0.01	-0.27
Relative change	0.00%	0.00%	0.00%	-0.01%	0.00%	0.00%	0.01%	0.00%	0.00%	-0.03%

Source: Own calculations; [a]including fossil CO_2 from the use of biofuels

3.2.8.3.6 Category-specific planned improvements (1.A.3.c)

No further improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

3.2.8.4 Transport – Shipping (1.A.3.d)

3.2.8.4.1 Category description (1.A.3.d)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
L/-	1 A 3 d, National Shipping	fossil fuels	CO_2	3013.77	0.24	1410.58	0.20	-53.20
-/-	1 A 3 d, National Shipping	0	CH_4	2.65	0.01	10.07	0.01	280.56
-/-	1 A 3 d, National Shipping	0	N_2O	18.68	0.01	10.42	0.01	-44.22

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS (Tier 2)	NS/IS/M	D[a]/CS
CH_4	CS (Tier 2)	NS/IS/M	CS (M)
N_2O	CS (Tier 2)	NS/IS/M	CS (M)
NO_X, CO, NMVOC, SO_2	CS (Tier 2)	NS/IS/M	CS (M)

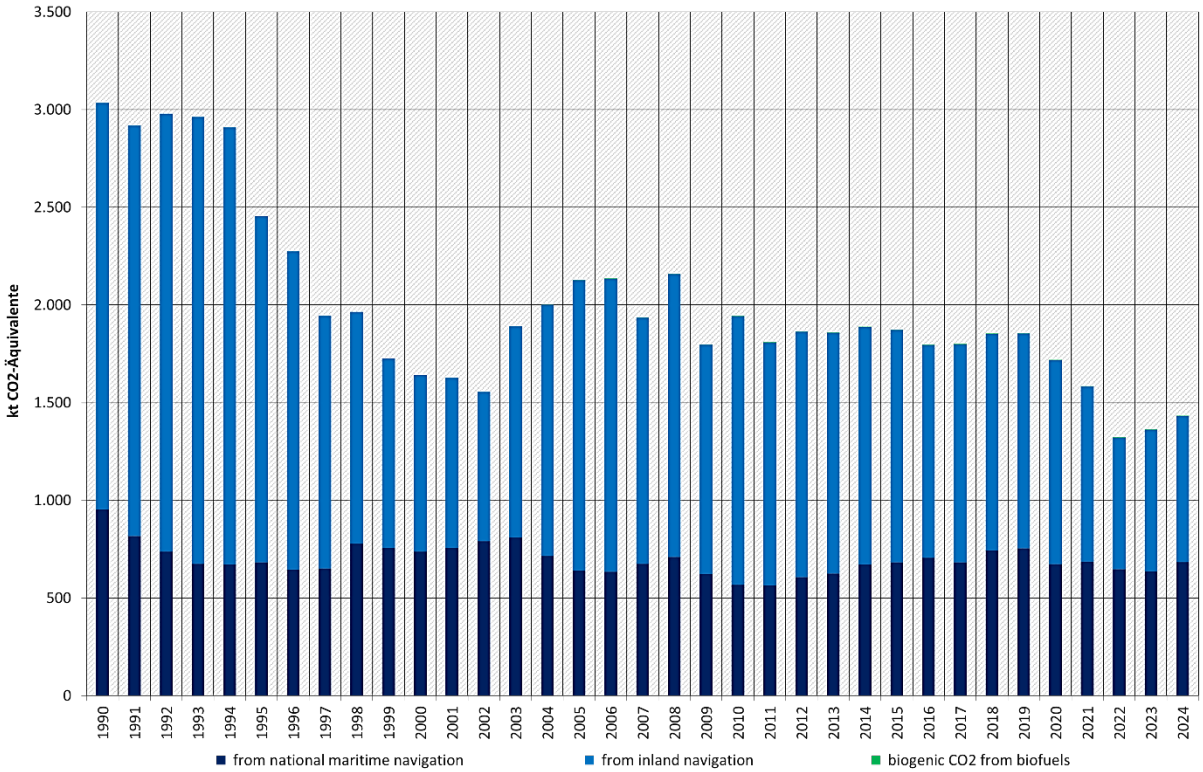
The category “National shipping” is a key category for carbon dioxide according to the Method 1 analysis.

Shipping is broken down into national (or domestic) maritime navigation, inland shipping and international maritime navigation. The emissions from international maritime navigation are reported for information purposes in the emissions inventories, but not included in the national total emissions.

In the CSE, both inland shipping and national maritime navigation, i.e. travel between German ports, are assigned to category 1.A.3.d – national shipping.

The following figure shows the development of GHG emissions from national shipping since 1990, broken down into inland shipping and national maritime navigation.

Figure 31: Development of GHG emissions in national maritime navigation since 1990



Source: own illustration, German Environment Agency

3.2.8.4.2 Methodological issues (1.A.3.d)

For the area of national maritime navigation, all primary input data are combined in a model operated by the Federal Maritime and Hydrographic Agency (BSH) accordance with the Tier 3 method pursuant to (EMEP/EEA (2023): Sectoral guidance chapters, 1.A.3.d Navigation (shipping)) (Deichnik, 2025). The underlying AIS data used in the process are currently available only as of the year 2012. For the period 1990 through 2011, the specific consumption fractions for national and military shipping and for fisheries were derived on the basis of annual trends in relevant indicators (including data on traffic volumes in the Kiel Canal and data on development of military and fishery fleets).

For inland shipping, primary data is consolidated in TREMOD using a Tier 2 approach (Knörr, Heidt, et al., 2025). The model integrates emission values from test bench measurements and data on specific energy consumption. The latter were linked to a traffic volume model based on inland shipping statistics from the Federal Statistical Office and can be differentiated according to ship type and size, as well as cargo and water body type.

In general, the source for the activity data, as for the entire sector 1.A, is (AGEB (2025c), based on BAFA).

Both AGEB and BAFA divide the data into *domestic* (AGEB: "Coastal and inland shipping" = BAFA: "an die Binnenschifffahrt" ("for inland shipping")) and *international* (AGEB: "high-seas bunkering" = BAFA: "Bunker int. Schifffahrt") based on the different taxation rates applied to different ship fuels.

With respect to ship transport, the NEB differentiates – on the basis of taxation aspects – between international marine bunkers (Energy Balance line 6) and coastal and inland shipping (Energy Balance line 64). Energy Balance line 6 lists the fuel quantities bunkered by ocean-going ships registered with the *International Maritime Organization* (IMO) as "sea-going ships" (IMO number). This category includes cargo, fishing and military ships that can operate on both domestic (between two German seaports) and international routes (from Germany to international ports). Energy Balance line 64, on the other hand, lists the fuel quantities that were a) taken on by inland vessels or b) bunkered by ocean vessels that have *not* been certified by the IMO (smaller ships that operate only on domestic routes). For the breakdown into national and international sea transport, therefore, the fuel quantities listed in Energy Balance line 6 have to be divided into those for domestically operating ships and those for internationally operating sea-going ships, which is done using modelling carried out by the Federal Maritime and Hydrographic Agency (BSH). In addition, those relevant specific quantities of fishing and military ships that are reported separately under 1.A.4.c iii and 1.A.5.b are deducted.

Table 79: Sources for the activity data used

Material	Source
Diesel fuel	Energy Balance lines 77 (through 1994) and 64 (as of 1995): Coastal and inland shipping; and line 6: International marine bunkers
Heavy fuel oil	Energy Balance, line 6: International marine bunkers
Light heating oil	Energy Balance, line 6: International marine bunkers
Gasoline	1990-2002: linear extrapolation, as of 2003: EBZ 64: Coastal and inland shipping
LP gas (LPG)	1990-2002: linear extrapolation, as of 2003: EBZ 64: Coastal and inland shipping
LNG	Not available to date in the NEB; instead modelled in (Deichnik, 2025)

The activity data for "national maritime navigation" are included in the annual figures listed in Energy Balance line 6 for domestic deliveries of diesel, light heating oil and heavy fuel oil. To determine these fractions, the specific consumption figures of the domestically operating seagoing vessels are calculated – in the aforementioned BSH model – on the basis of their AIS signals (currently, as of 2012; see above) and then aggregated into annual total quantities.

While use of LNG in national maritime navigation is currently not included in the Energy Balances, it is included in the inventories.

The fuel quantities refuelled each year by inland vessels in Germany correspond to the domestic deliveries of diesel, petrol and liquefied petroleum gas listed in Energy Balance line 64. The changing navigability of waterways results in highly fluctuating annual consumption, which has been on a downward trend since the mid-1990s, as many ships are refuelled abroad due to price advantages. The abrupt decrease that occurred in 1994/1995 was due to a change in the National Energy Balance.

As part of the UNFCCC's review process, Germany has been repeatedly encouraged (most recently during the 2016 In-Country Review) to report separately on emissions from fuels that

are refuelled by inland vessels in Germany but consumed abroad. As the available statistics and models do not allow this directly, it would require a very complex regular survey, which would also have to be used to develop data going back to 1990. However, assuming that inland vessels operating across borders only rarely refuel in Germany[26], this approach would appear questionable. Nevertheless, the request of the review boards will be followed up and a solution acceptable to all parties and scientifically sound will be sought.

With regard to the emission factors used for carbon dioxide, we refer to Annex 6.6. Further information – in particular, about carbon dioxide from lubricant co-combustion – is also provided in Chapter 4.5.1.

With regard to releases of methane and nitrous oxide from the co-combustion of lubricants, it is assumed that these emissions are already taken into account in the emission factors for the fuels used and thus are to be reported as IE (included elsewhere).

All other emission factors for the subsector domestic maritime navigation were taken from Deichnik (2025).

For the area of inland shipping, CH_4 emission factors from Knörr, Heidt, et al. (2025) are used. They are calculated on the basis of test bench measurements and of data on the required propulsion energy, broken down by ship type, size and cargo and water body type. With regard to N_2O, the emission factors follow the expert assessments based on the UBA study "Air Quality Control '88" ("Luftreinhaltung '88") and the analogous conclusion for heavy duty commercial vehicles without emissions control technology.

Table 80: Emission factors used for report year 2024, in kg/TJ

	CH_4	N_2O	Source
Inland waterways			
Diesel/ biodiesel	1.32 (-)	1.00 (-)	Country-specific value pursuant to (Knörr, Heidt, et al., 2025)
Gasoline	24.9	1.62	
LP gas (LPG)	5.63	3.45	
National maritime navigation			
Diesel/light heating oil	1.59 (-)	3.22 (2.00)	pursuant to(Deichnik, 2025)
Heavy fuel oil	3.47 (7.00)	3.38 (2.00)	
LNG	646	2.39	
Overarching			
Lubricants	IE	IE	Included in the EF for the individual fuels

In parentheses: defaults pursuant to IPCC (2006a): Volume 2, Chapter 3.5, p. 3.50, Table 3.5.3

The EFs for biodiesel correspond to the values for fossil-based diesel fuel

3.2.8.4.3 Uncertainties and time series consistency (1.A.3.d)

While uncertainties for national inland shipping could be taken from Knörr et al. (2009). reference values according to the IPCC must still be used for national shipping.

For the specific energy inputs calculated as described above, uncertainties of ±5% are assumed.

[26] Because fuel prices in other countries along the Rhine and Danube rivers are consistently lower than they are in Germany, and because large inland vessels can easily travel several thousand kilometres on one tank of fuel, it is assumed that inland vessels making international trips refuel in Germany only in exceptional cases.

The uncertainties assumed for the emission factors used are shown in the following table.

Table 81: Percentage uncertainties for emission factors*

	CO_2	CH_4	N_2O
Diesel: Inland vessels	±3%	±34%	-42.5%/75%
Diesel/light heating oil: seagoing vessels	±3%	±50%	-40%/140%
Heavy fuel oil	-4%/1%	±40%	-40%/140%
Gasoline	±1%	±34%	-42.5%/75%
LNG	±2%	-75%/150%	±50%
LPG	±2%	±34%	-42.5%/75%

* Upper and lower bounds of the 95% percentile

Due to the change in energy balances between 1994 and 1995, the time series of activity data for coastal and inland shipping also show inconsistencies that cannot currently be resolved.

The emission factor time series exhibit no inconsistencies.

3.2.8.4.4 Category-specific QA/QC and verification (1.A.3.d)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

Quality reports of the Working Group on Energy Balances (AGEB) have been submitted to the German Environment Agency for purposes of quality assurance of the National Energy Balances. In addition, documentation on the revision of the Energy Balances as of 2003 has been published on the Internet [27].

Table 82: Overview of relevant data comparisons

	Comparison with...	Explanation
CO_2, CH_4, N_2O	Alternative emissions inventories for Germany	No comparable data sets
CO_2	Specific Tier 1 defaults pursuant to (IPCC, 2006a)Vol. 2, Tab. 3.5.2	cf. Table 83
CH_4, N_2O	Sector-specific Tier1 defaults pursuant to (IPCC, 2006a): Vol. 2, Tab. 3.5.3	cf. Table 80 Maritime: no defaults
CH_4, N_2O	Tier 1 defaults pursuant to (IPCC, 2006a): Vol. 2, Tab. 2.4	Inland: Results are inconclusive
CO_2, CH_4, N_2O	Specific IEFs of other countries	cf. Table 84

Table 83: Comparison of the EF (CO_2) used for 2024 with IPCC defaults, in kg/TJ

	Inventory value	Default [a]	Lower bound	Upper bound
Diesel fuel/light heating oil	74,027	74,100	72,600	74,800
Gasoline	72,787	69,300	67,500	73,000
LP gas (LPG)	66,333	63,100	61,600	65,600
Heavy fuel oil	76,771	77,400	75,500	78,800
LNG	56,352	56,100	54,300	58,300
Biodiesel	70,800		59,800	84,300

[27] AG Energiebilanzen (Working Group on Energy Balances): explanations about the revision of the Energy Balances 2003 – 2009; URL: https://ag-energiebilanzen.de/wp-content/uploads/2021/01/revision_der_energiebilanzen_2003_bis_2009_05.pdf (last accessed on 23 October 2023)

[a] pursuant to IPCC (2006a): Volume 2, Table 2.4

The following table provides a comparison with specific implied emission factors of other countries and of the EU (27). For light heating oil, liquefied natural gas (LNG) and liquefied petroleum gas (LPG), no implied emission factors are available for comparison.

Table 84: International comparison of reported IEFs, in kg/TJ

	Diesel fuel			Heavy fuel oil			Gasoline		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Germany	74,027	1.17	2.05	76,771	3.47	3.38	72,782	24.9	1.62
Belgium	73,342	2.00	1.96	IE	IE	IE	NO	NO	NO
Denmark	74,050	1.95	1.81	78,000	1.36	1.95	69,300	5.00	0.60
France	74,704	7.05	1.91	78,000	7.00	2.00	72,477	58.0	1.53
Italy	74,048	6.95	1.86	77,400	7.31	1.95	73,081	70.3	1.86
Netherlands	72,454	7.00	2.00	NO	NO	NO	72,200	47.2	0.86
Spain	74,100	7.00	2.00	78,352	7.00	2.00	NO	NO	NO
EU-27	74,471	3.80	4.01	77,896	6.64	2.05	72,463	64.4	1.40
UK	75,151	0.81	3.41	76,116	1.25	3.63	70,249	38.1	1.79

Germany: Current IEF for report year 2024; all other countries: IEF for 2021, pursuant to 2023 CRF submission

3.2.8.4.5 Category-specific recalculations (1.A.3.d)

Compared to the 2025 submission, recalculations were made based on updated or newly recorded activity data as well as adjusted emission factors.

On the one hand, a planned revision of the energy balances for 2003 to 2023 was carried out, and on the other hand, the previously provisional energy quantities for 2023 were replaced by final values in accordance with AGEB:

Table 85: Revised energy inputs 2003-2023, in terajoules

	2003	2004	2005	2010	2015	2020	2021	2022	2023
Diesel fuels									
2026 submission	22,362	24,170	26,114	23,920	24,710	13,761	11,785	8,786	9,473
2025 submission	22,451	24,282	26,241	24,060	24,874	14,029	12,003	9,275	9,887
Absolute change	-89.4	-112	-127	-140	-163	-268	-218	-489	-414
Relative change	-0.40%	-0.46%	-0.48%	-0.58%	-0.66%	-1.91%	-1.82%	-5.27%	-4.18%
Gasoline									
2026 submission	272	273	275	271	276	281	285	287	286
2025 submission	272	273	275	271	275	281	286	288	289
Absolute change	0.00	-0.01	-0.04	-0.05	0.45	-0.15	-0.27	-0.72	-2.77
Relative change	0.00%	0.00%	-0.01%	-0.02%	0.16%	-0.05%	-0.09%	-0.25%	-0.96%
LP gas (LPG)									
2026 submission	7.03	7.02	7.02	7.08	7.10	7.36	7.49	7.23	7.53
2025 submission	7.03	7.02	7.02	7.08	7.10	7.40	7.51	7.55	7.61
Absolute change	0.00	0.00	0.00	0.00	0.00	-0.04	-0.02	-0.33	-0.08

	2003	2004	2005	2010	2015	2020	2021	2022	2023
Relative change	0.00%	0.00%	0.00%	0.01%	0.00%	-0.54%	-0.24%	-4.30%	-1.00%
Light heating oil									
2026 submission						8,329	8,475	7,879	7,922
2025 submission						8,329	8,475	7,879	7,922
Absolute change						0.00	0.00	0.00	0.00
Relative change						0.00%	0.00%	0.00%	0.00%
Heavy fuel oil									
2026 submission	2,607	2,298	2,054	1,810	108	378	392	235	203
2025 submission	2,607	2,298	2,054	1,810	108	378	392	237	237
Absolute change	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.72	-33.8
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.73%	-14.3%
Liquefied Natural Gas (LNG)									
2026 submission					22.0	276	293	513	382
2025 submission					22.0	276	293	513	382
Absolute change					0.00	0.00	0.00	0.00	0.00
Relative change					0.00%	0.00%	0.00%	0.00%	0.00%
TOTAL FUEL INPUTS									
2026 submission	25,248	26,747	28,450	26,009	25,123	23,031	21,237	17,708	18,274
2025 submission	25,337	26,859	28,577	26,149	25,286	23,299	21,456	18,199	18,724
Absolute change	-89.4	-112	-127	-140	-163	-268	-218	-492	-450
Relative change	-0.35%	-0.42%	-0.44%	-0.54%	-0.64%	-1.15%	-1.02%	-2.70%	-2.40%

Source: Own calculations based on Knörr, Heidt, et al. (2025) and Knörr, Heidt, et al. (2025)

This was followed by a consolidation of emission factors for carbon dioxide, primarily from heavy fuel oil (from 2022) and LNG (from 2014):

Table 86: Revised emission factors, in kg/TJ

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2020
Heavy fuel oil											
2026 submission	78,819	76,445	77,188	77,188	77,188	77,188	77,188	77,188	77,753	76,554	78,819
2025 submission	78,819	76,445	77,188	77,188	77,188	77,188	77,188	77,188	77,188	77,188	78,819
Absolute change	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	565	-634	0.00
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.73%	-0.82%	0.00%
LNG											
2026 submission	55,936	55,889	55,840	55,827	55,718	55,749	55,826	55,786	56,221	56,325	55,936
2025 submission	55,944	55,944	55,944	55,944	55,944	55,718	55,944	55,944	55,944	55,944	55,944
Absolute change	-7.63	-54.8	-103	-117	-226	31.0	-117	-158	277	381	-7.63
Relative change	-0.01%	-0.10%	-0.18%	-0.21%	-0.40%	0.06%	-0.21%	-0.28%	0.50%	0.68%	-0.01%
LPG											
2026 submission	65,461	66,346	66,333	66,333	66,333	66,333	66,333	66,333	66,333	66,333	65,461
2025 submission	65,461	66,346	66,334	66,334	66,334	66,334	66,334	66,334	66,334	66,334	65,461
Absolute change	-0.002	-0.001	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

The corrections described above lead to the following recalculated emissions quantities.

Table 87: Revised GHG emissions in 2003-2023, in kt CO_2-e

	2003	2004	2005	2010	2015	2020	2021	2022	2023
Carbon dioxide[a]									
2026 submission	1,877	1,987	2,112	1,930	1,859	1,700	1,567	1,301	1,345
2025 submission	1,884	1,995	2,122	1,940	1,871	1,720	1,583	1,337	1,379
Absolute change	-6.62	-8.28	-9.41	-10.4	-12.1	-19.9	-16.2	-36.1	-33.4
Relative change	-0.35%	-0.42%	-0.44%	-0.53%	-0.65%	-1.15%	-1.02%	-2.70%	-2.42%
Methane									
2026 submission	0.055	0.058	0.062	0.053	0.062	0.225	0.210	0.348	0.259
2025 submission	0.055	0.058	0.062	0.053	0.062	0.225	0.210	0.349	0.260
Absolute change	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.001	-0.001
Relative change	-0.30%	-0.35%	-0.37%	-0.44%	-0.37%	-0.17%	-0.15%	-0.20%	-0.28%
Nitrous oxide									
2026 submission	0.051	0.049	0.048	0.044	0.047	0.044	0.043	0.038	0.038
2025 submission	0.051	0.049	0.049	0.044	0.047	0.044	0.043	0.038	0.039
Absolute change	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.001
Relative change	-0.18%	-0.23%	-0.26%	-0.32%	-0.35%	-0.61%	-0.51%	-1.30%	-1.40%
TOTAL GREENHOUSE GASES[a]									
2026 submission	1,892	2,002	2,127	1,943	1,873	1,718	1,584	1,321	1,363
2025 submission	1,899	2,010	2,137	1,954	1,885	1,738	1,601	1,358	1,396
Absolute change	-7.02	-8.77	-9.98	-10.9	-12.6	-20.3	-16.6	-36.5	-33.8
Relative change	-0.37%	-0.44%	-0.47%	-0.56%	-0.67%	-1.17%	-1.04%	-2.69%	-2.42%

Source: Own calculations; [a]including fossil CO_2 from use of biofuels

3.2.8.4.6 Category-specific planned improvements (1.A.3.d)

With regard to national maritime navigation, model maintenance work will also be carried out as part of the annual model update, if necessary, although this cannot be specified in more detail at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

3.2.8.5 Transport – Other transportation (1.A.3.e)

3.2.8.5.1 Category description (1.A.3.e)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
-/-	1 A 3 e, Other Transport	fossil fuels	CO_2	1083.27	0.09	675.05	0.10	-37.68
-/-	1 A 3 e, Other Transport	0	CH_4	5.95	0.01	3.66	0.01	-38.43
-/-	1 A 3 e, Other Transport	0	N_2O	12.88	0.01	5.11	0.01	-60.34

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	ETS	CS
CH_4	Tier 2	ETS	CS
N_2O	Tier 2	ETS	CS

The category "1.A.3.e - Transport – other transportation" is not a key category.

Currently, only emissions from gas turbines in natural gas compressor stations of the transport network are reported here. Emissions from gas turbines of pumping stations are reported under 1.A.1.c, while fugitive emissions from compressors are reported under 1.B.2.b.iii & iv.

Gas compressors used in the chemical industry are reported in accordance with the relevant statistical structure under 1.A.2.g – Other.

3.2.8.5.2 Methodological issues (1.A.3.e)

As of the year 2005, the activity data are reported on the basis of the natural gas quantities reported in emissions trading and aggregated by the German Emissions Trading Office (DEHSt). The approach used to calculate the fuel inputs for the years 1990 to 2005 is described in the 2022 NIR (in the same section).

While the natural gas compressors of pumping stations are surveyed via energy statistics and are therefore already included in category 1.A.1.c, only those natural gas compressors that can be assigned to the transport network are considered here, thus preventing double counting.

The emission factors used are based on pollutant-specific results from various research projects and expert assessments by the German Environment Agency (UBA) research projects and expert opinions, specifically:

- For CO_2, please refer to the documentation in the Annex 6.6.
- The factors for CH_4 and N_2O were taken from the report Fichtner et al. (2011).

The approach used in the studies is described in Chapter 3.2.4.2.

3.2.8.5.3 Uncertainties and time series consistency (1.A.3.e)

Uncertainties for the activity data were determined for the first time in report year 2004 (Juhrich & Wachsmann, 2007b). The relevant approach is described in Annex 2 in the Chapter "Uncertainties for the activity data of stationary combustion systems" of the NIR 2007.

The procedure for determining uncertainties for the emission factors is described in Chapter 3.2.4.2. Results for N_2O are presented in Chapter 3.2.4.3.2 and for CH_4 in Chapter 3.2.4.3.3.

3.2.8.5.4 Category-specific QA/QC and verification (1.A.3.e)

General quality control and quality assurance by the relevant department and the National Coordination Office were carried out in accordance with the requirements of the QSE manual and its accompanying documents, while for ED they were carried out by the Single National Entity.

For verification purposes, it is not possible to compare activity data, as the emissions trading authority is the sole data source.

The results of Chapter 3.2.4.2 apply accordingly.

3.2.8.5.5 Category-specific recalculations (1.A.3.e)

No recalculations were carried out.

3.2.8.5.6 Category-specific planned improvements (1.A.3.e)

No improvements are planned at present. The intention is to use the methane emission values from the operator data in accordance with EU Methane Regulation 2024/1787.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

3.2.9 Other: Residential, commercial/institutional, agriculture, forestry and fisheries (1.A.4 Stationary)

3.2.9.1 Category description (1.A.4 stationary)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
L/T	1 A 4 a, Commercial/Institutional	fossil fuels	CO_2	64025.93	4.96	21323.69	3.02	-66.70
-/-	1 A 4 a, Commercial/Institutional	0	CH_4	1636.92	0.13	100.24	0.02	-93.88
-/-	1 A 4 a, Commercial/Institutional	0	N_2O	130.28	0.02	70.04	0.01	-46.24
L/T	1 A 4 b, Residential	fossil fuels	CO_2	128635.75	9.95	76863.21	10.87	-40.25
-/-/2	1 A 4 b, Residential	0	CH_4	2782.86	0.22	813.85	0.12	-70.76
-/-/2	1 A 4 b, Residential	0	N_2O	683.71	0.06	226.93	0.04	-66.81
L/T	1 A 4 c, Agriculture/Forestry/Fishing	fossil fuels	CO_2	11359.76	0.88	7263.37	1.03	-36.06
-/-	1 A 4 c, Agriculture/Forestry/Fishing	0	CH_4	272.15	0.03	203.52	0.03	-25.22
-/-	1 A 4 c, Agriculture/Forestry/Fishing	0	N_2O	66.84	0.01	71.36	0.02	6.77

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1*, CS	NS/M	CS, D*
CH_4	CS (Tier 2)	NS/M	CS (M)
N_2O	CS (Tier 2)	NS/M	CS (M)
NO_X, CO, NMVOC, SO_2	CS (Tier 2)	NS/M	CS (M)

* biodiesel and co-combusted lubricants

For category 1.A.4 “Other”, stationary and mobile sources are classified together in the key categories (for an overview, cf. Chapter 3.2.9.1). The category 1.A.4 “Other” is a key category for CO_2 emissions and trend in its subcategories 1.A.4.a, b & c in terms of both emissions level. For CH_4 emissions, category 1.A.4.b is a key category in terms of trend and Approach 2. Subcategory 1.A.4.b was also identified as a key category for N_2O using the Approach 2 analysis.

Category 1.A.4 Stationary comprises combustion systems in the areas *Commercial and Institutional, Residential and Agriculture*.

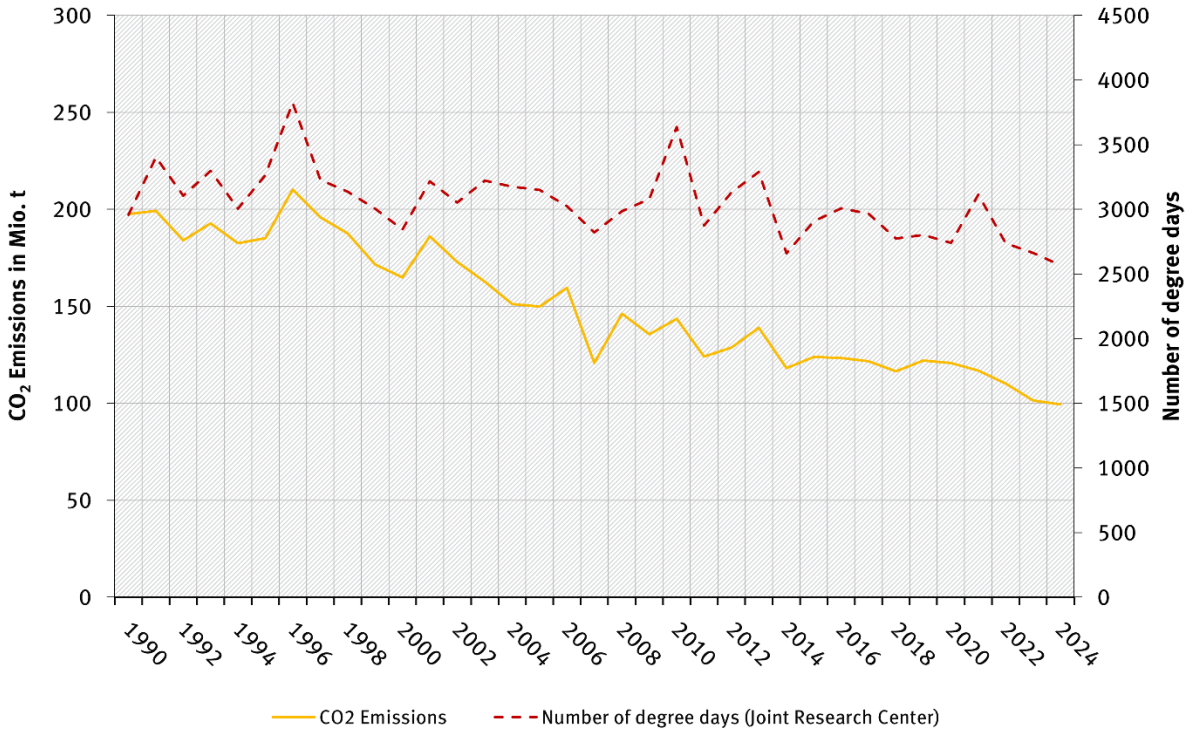
In subcategory 1.A.4.ai “Commercial and institutional (stationary)”, heat generation systems in small combustion systems of small commercial and institutional users are reported.

In subcategory 1.A.4.bi, emissions from stationary combustion systems in the residential sector are reported. Subcategory 1.A.4.ci comprises the stationary part of the areas agriculture, forestry

and fisheries. Reporting in this category includes emissions from heat generation in small and medium-sized combustion systems.

The group of combustion systems in the residential and commercial/institutional sectors is very diverse with regard to installation design and size. It covers a range that includes individual room furnaces for solid fuels with a rated thermal output of approximately 6 to 8 kW (e.g. fireplaces, ovens), oil and gas furnaces used for space heating and water heating (e.g. central heating boilers), hand-fed and automatically fed wood-burning furnaces in the commercial sector and combustion systems with a rated thermal output of 1 MW, to name a few examples. A total of nearly 33 million combustion systems were in service in Germany in 2022 in the residential and commercial/institutional sectors (small consumers) ((ZIV, 2024)[28]). Gas-fired combustion systems accounted for the largest share with some 15.1 million systems, followed by combustion systems for solid fuels (12.9 million systems) (of which 11.7 million were single-room combustion systems for solid fuels) and oil-fired furnaces (approximately 4.8 million systems).

Figure 32: Change in total emissions of 1.A.4 (stationary) depending on temperature

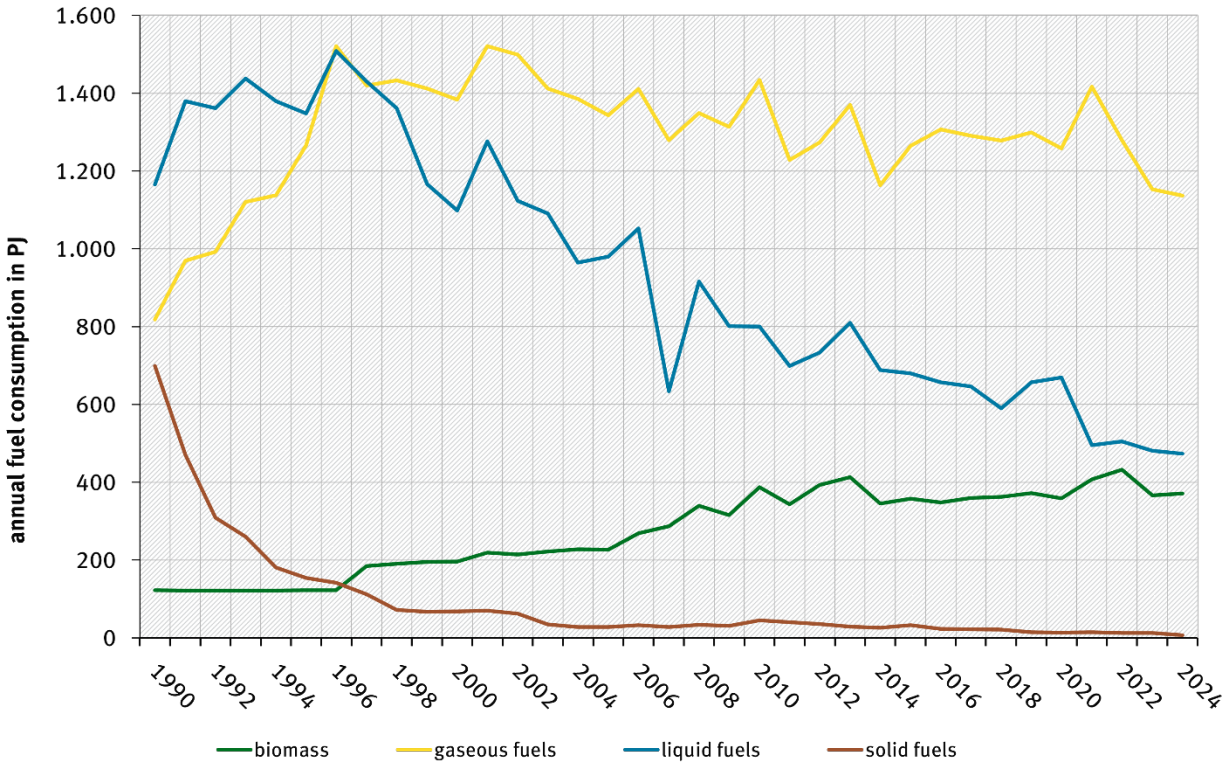


Source: own illustration, German Environment Agency

The development of CO_2 emissions and the number of degree days are shown in Figure 32. The main driver of CO_2 emissions in 1.A.4 is energy consumption for space heating. This means that fluctuations in consumption are very dependent on weather conditions. Over the years, these factors have caused energy use – especially use of light heating oil and natural gas – to fluctuate sharply. The trend towards lower CO_2 emissions is primarily due to energy efficient building renovations and the shift to more energy efficient heating technologies using fuels with lower CO_2 emissions, but also to higher standards for new buildings. CO_2 emissions arising from the power consumption of electrical heat pumps are not reported here but under 1.A.1.a.

[28] Zentralinnungsverband des Schornsteinfegerhandwerks (ZIV) https://www.schornsteinfeger.de/erhebungen.aspx

Figure 33: Trends in energy consumption in 1.A.4 (stationary) according to 4 fuel categories



Source: own illustration, German Environment Agency

Shifting from heating oil and coal to natural gas and biomass has brought about considerable CO_2 emissions reductions in the reporting period since 1990. Improvements in energy efficiency have also helped lower consumption. This long-term trend was overshadowed by short-term fluctuations in energy consumption, induced, for example, by price changes for energy sources whose quantities – such as light heating oil – are determined on the basis of sales rather than consumption.

3.2.9.2 Methodological issues (1.A.4, stationary)

Activity data

The activity data in category 1.A.4 are based on the Energy Balances for the Federal Republic of Germany, which are prepared by the Working Group on Energy Balances (AGEB). For the years prior to 1995 separate Energy Balances are used for the old and new German federal states. For years as of 1995, lines 66 (residential) and 67 (commercial and institutional and other consumers) are the standard.

Since the data in Energy Balance line 67 – commercial and institutional and other consumers – also include military consumption, these data must be deducted from the relevant positions in line 67 (cf. Chapter 3.2.11.2 with regard to stationary and mobile sources in the military sector).

As of the 2021 NIR (UBA et al., 2021), AGEB data has been used for the fossil fuels in the energy inputs in combustion plants in agriculture (1.A.4.ci) (energy inputs that are also included in line 67 of the Energy Balance). The AGEB data are available as a time series beginning with the year 2010. These data are determined using an estimation method based on energy expenditure in agriculture according to the "Statistisches Jahrbuch über Ernährung, Landwirtschat, und Forsten" (BMEL, 2024b) (Statistical yearbook on food, agriculture and forests). The structure of the energy sources is described in the study "Implementation of a procedure for regular, current

determination of energy consumption in areas not covered by official statistics" ("Umsetzung eines Verfahrens zur regelmäßigen und aktuellen Ermittlung des Energieverbrauchs in nicht amtlichen Statistik erfassten Bereichen") (AGEB, 2016). In the AGEB Evaluation Tables on the Energy Balance, the data are listed as a subset of the Energy Balance[29].

Data on wood consumption in the residential and commercial/institutional sectors – like data on consumption of other biofuels – are based on data provided by the Working Group on Renewable Energy Statistics (Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat)), which is responsible for providing renewable energy data to meet various national, EU-wide and international obligations of the Federal Government.[30]

The results for firewood in the residential sector are based on surveys of consumption carried out as part of the "Rohstoffmonitoring Holz" ("Monitoring of raw materials – wood")[31] project. In addition to firewood purchased through official channels, the quantities cut down by private individuals in forests, gardens or for landscape maintenance are also included. In addition, a regression model is applied that takes account of numbers of degree days; of the price indexes for conventional fuels; and of the heating systems, broken down by types, used in residential buildings. Volume units are converted into energy units in conformance with the accepted conversion conventions of AGEE-Stat.

Wood consumption in heat-generation-only systems of the commercial and institutional sector is derived using a remainder calculation. In the process, the data on total wood consumption (outside of private households), as determined using the "Rohstoffmonitoring Holz" surveys and using regression models, are combined with the relevant wood quantity data from official energy statistics and the applicable wood quantity data provided by other models. The wood consumption data derived using this approach that relate to data on heat generation by CHP systems are also part of the data on total wood consumption in the commercial and institutional sector.

Emission factors

A description and a list of the CO_2 emission factors used are available in Annex 6.6.

The data basis for the emission factors used for N_2O and CH_4 emissions of stationary combustion systems is provided by the research report "Ermittlung und Aktualisierung von Emissionsfaktoren für das nationale Emissionsinventar bezüglich kleiner und mittlerer Feuerungsanlagen der Haushalte und Kleinverbraucher" ("Determination and updating of emission factors for the national emissions inventory, with regard to small- and medium-sized combustion systems in the residential and commercial/institutional sectors") (Tebert et al., 2016). Within the context of this project, device-related and category-specific emission factors for combustion systems in the residential and commercial/institutional sectors were calculated with a high level of detail for all important emissions components for the reference years 2010 and 2015.

Determination of emission factors is based on a category-specific bottom-up approach that, in addition, to differentiating (sub-)categories and fuels, also differentiates system technologies in detail. In the process, several system-specific emission factors are aggregated in order to obtain mean emission factors for all systems within the categories in question. Use of system-specific/category-specific emission factors ensures that all significant combustion-related

[29] https://ag-energiebilanzen.de/daten-und-fakten/auswertungstabellen/

[30] cf. also https://www.erneuerbare-energien.de/EE/Navigation/DE/Service/Erneuerbare_Energien_in_Zahlen/Arbeitsgruppe/arbeitsgruppe_ee.html

[31] https://www.kiwuh.de/projekte-und-foerderung/projekte/holzbereitstellung/rohstoffmonitoring-holz/

characteristics of typical systems for the various categories are taken into account. The procedure is follows the Tier 2/3 method described in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006a).

The emission factors are structured along the lines of the fuels that account for significant shares of Germany's final energy consumption:

- Fuel oil EL
- Natural gas,
- Lignite (briquettes from the Rhine (Rheinisch) and Lusatian (Lausitz) coal fields; imported briquettes),
- Hard coal (coke, briquettes, anthracite) and
- Wood (unprocessed wood, wood pellets, residual wood).

In addition, emission factors for combustion systems are determined in accordance with installation design, installation age, output category and typical mode of operation. The emission behaviour of the combustion plants was documented on the basis of an extensive evaluation of the literature. Transfer factors were used to take account of the fact that emissions in a test bench environment tend to be lower than those of corresponding systems in real operation.

The description of the plant structure of the installed combustion plants was carried out by updating the data from Struschka et al. (2008) using sales statistics from the relevant industry associations. These data were used to estimate the energy inputs for various system types to make it possible to determine sectoral emission factors weighted by energy inputs. Table 88 shows the sectoral emission factors used.

Table 88: Sectoral emission factors for combustion systems in the residential and commercial/institutional sectors for reference year 2010, [kg/TJ]

1.A.4.bi – Residential	CH_4	N_2O
Hard coal	134	11.5
Hard coal briquettes	368	9.7
Hard coal coke	10	0.9
Lignite briquettes	237	5.2
Heating oil EL	0.05	0.55
Natural gas	3	0.25
1.A.4.ai & ci – Commercial and Institutional (Small Consumers) & Agriculture, Forestry, Fisheries		
Hard coal	100	8.5
Hard coal briquettes	-	-
Hard coal coke	20	0.8
Lignite briquettes	-	-
Heating oil EL	0.03	0.56
Natural gas	0.16	0.33

The emission factors for 2010 were updated to take into account the replacement of old combustion plants with new ones.

3.2.9.3 Uncertainties and time series consistency (1.A.4 stationary)

Annex 2, Chapter 13.6 in the NIR (UBA, 2007) describes how the uncertainties for the activity data were determined.

A complex procedure is required to calculate reliable emission factors in the installation sector. In addition to emission values, additional information must be determined, e.g. to take into account the operating mode (loads), the plant structure and the device-specific final energy consumption. This approach was largely followed when collecting data as part of the FE project mentioned above. Nevertheless, due to the large number of facilities, the wide variety of different types of combustion systems and the fuels used, it must be assumed that the data is subject to a relatively high degree of "basic uncertainty".

For some installation types, moreover, only inadequate data or no data at all were available on emissions behaviour when using certain fuels. It is important to remember that the law does not require the greenhouse gas emissions of combustion systems of residential and commercial/institutional users to be measured. As a result, only a few results from individual measurements at selected installations could generally be used to determine the emission factors (with the exception of CO_2, which is largely independent of the type of combustion system). Gaps in the data were closed by applying emission factors of comparable combustion systems.

The uncertainties listed for the emission factors for CH_4 and N_2O for stationary combustion systems were determined by expert estimates pursuant to IPCC-GPG (Penman et al. (2000): Chapter 6). This assessment, which is based on the emissions data obtained for the aforementioned research project, was carried out as part of that project by experts of the University of Stuttgart's Institute of Process Engineering and Power Facility Technology (Institut für Verfahrenstechnik und Dampfkesselwesen). Uncertainties were estimated separately for all combustion technologies and fuels. The following sources of error were included in the estimates for N_2O and CH_4:

- Measuring errors when determining pollutant concentrations;
- Uncertainties when estimating transfer factors (systematic differences between test bench and field measurements);
- Uncertainties resulting from too little emissions data;
- Uncertainties resulting from the use of different measuring procedures;
- Uncertainties in the installation data used (overall group structure in terms of type, age and performance and fuel consumption)

In gas-fired systems, another error occurs when determining startup/shutdown emissions. During startup/shutdown processes, some unburned CH_4 is emitted from natural gas. These emissions, which occur upstream and downstream from the actual combustion process, cf. Chapter 3.3.2.2 (natural gas), are a significant reason why CH_4 emission factors for gas combustion systems are subject to high levels of uncertainties.

As for the distribution of uncertainties, a log normal distribution is assumed for N_2O emission factors. It can be assumed that the deviations towards larger values are significantly more pronounced than those towards smaller values. The emission factors for CH_4 and N_2O were

determined for the year 2005 as part of the aforementioned research project and are assumed to have remained constant since then.

3.2.9.4 Category-specific QA/QC and verification (1.A.4 stationary)

Emission factors: General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

Emissions data: General and category specific quality control and quality assurance, have been carried out in conformance with the requirements of the QSE-manual and its associated applicable documents, by the Single National Entity.

Activity data: General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

Quality assurance for the activity data was carried out as described in Chapter 3.2.4.4. For further information on quality assurance, cf. Annex 6.4.1. Since all available data are used for compiling the activity data, there are no other data sources for a comparison.

For the purposes of quality assurance for data related to the emission factors of stationary combustion systems, in the context of the aforementioned research and development project, all the input data taken from literature and from the research contractor's own surveys were reviewed for validity. To describe the emissions behaviour of combustion systems, emissions data were included in subsequent calculations only if the relevant literature contained complete, undisputed data on the fuel used, the design of the furnace and the furnace's operating mode during measurements. The contractor has documented all materials essential for the inventory.

As part of a quality review carried out by German Environment Agency experts, the country-specific emission factors for CH_4 and N_2O, determined in accordance with the Tier 2 standard, were compared with the IPCC Tier 2 default factors in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 2006a). The values for most fuels were largely consistent (deviations within a certain range), with the default values for CH_4 tending to be higher than the country-specific values.

As part of quality assurance, in addition to determining emissions according to Tier 2/3, a calculation using Tier 1 default values was carried out for the residential and commercial/institutional sectors for the year 2015. The results are documented in Table 89. The emissions of the agriculture, forestry and fisheries sectors are also included in the commercial and institutional (small consumers) sector.

Table 89: Emissions calculation with country-specific Tier 2/3 emission factors and with the Tier 1 default emission factors pursuant to IPCC et al. (2006)

	CH_4 [t]				N_2O [t]			
	Residential		Commercial and institutional		Residential		Commercial and institutional	
Emission factors	Tier 1 default	Country-specific EF	Tier 1 default	Country-specific EF	Tier 1 default	Country-specific EF	Tier 1 default	Country-specific EF
Heating oil EL	4,694	76	1,723	6	277	256	101	97
Fuel gases	4,223	2,534	1,763	55	84	212	35	115
Coal fuels	7,388	5,776	44	85	37	177	2	7

Emission factors	CH_4 [t]				N_2O [t]			
	Residential		Commercial and institutional		Residential		Commercial and institutional	
	Tier 1 default	Country-specific EF	Tier 1 default	Country-specific EF	Tier 1 default	Country-specific EF	Tier 1 default	Country-specific EF
Wood	66,780	21,074	9,011	1,465	890	352	120	25
Total	83,085	29,459	12,541	1,611	1,289	997	258	244

For N_2O, the results of the emissions calculation obtained with both methods were largely consistent. Larger discrepancies were seen when determining the CH_4 emissions. Presumably, this is due to the fact that methane emissions of combustion systems depend significantly on the combustion technology used. Country-specific differences in plant structures (i.e. in sector composition) thus manifest themselves much more in total emissions (as determined) than they do in nitrous oxide emissions. Emissions of natural gas are also included in 1.B.2.b.vi. As a result, Germany's IEFs seem very low here. Most importantly, the default emission factor for heating oil is very high. The technology-specific emission factor provided in (IPCC, 2006a) for boilers exhibits considerably better agreement with the country-specific factor for Germany.

No data sources are known that would support a comparison with the data reported here for mobile emissions sources of the residential, agricultural transport and fisheries sectors. In addition, the country-specific IEFs were compared with those of other countries. Due to the heterogeneous composition of the subcategories involved, however, that comparison is largely of limited significance – especially for methane and nitrous oxide.

3.2.9.5 Category-specific recalculations (1.A.4, stationary)

Provisional figures for the year 2023 were replaced with figures from the now available final Energy Balance for that year. This made recalculations necessary for nearly all energy sources. (cf. Table 90). Since 2023, AGEB has been providing revisions to the time series every two years starting from 2003. Revisions were again made for the 2026 reporting year, resulting in recalculations for previous years.

Table 90: Recalculations for CRF1.A.4 (stationary) by fuel, in [kt] and [%]

	CO_2 difference, absolute					CO_2 difference, relative
	Gaseous fuels	Liquid fuels	Solid fuels	Other fuels	Total	Total
2003	0.00	2857.22	0.00	-	2857.22	1.79%
2004	0.00	-748.88	0.00	-	-748.88	-0.49%
2005	0.00	-6034.34	0.00	-	-6034.34	-3.87%
2006	0.00	-3046.43	0.00	-	-3046.43	-1.87%
2007	0.00	224.51	0.00	-	224.51	0.19%
2008	0.00	90.72	0.00	-	90.72	0.06%
2009	0.00	-106.76	0.00	-	-106.76	-0.08%
2010	0.00	2097.54	0.00	-	2097.54	1.48%
2011	0.00	219.26	0.00	-	219.26	0.18%
2012	0.00	-761.68	0.00	-	-761.68	-0.59%

	CO_2 difference, absolute					CO_2 difference, relative
	Gaseous fuels	Liquid fuels	Solid fuels	Other fuels	Total	Total
2013	0.00	1112.08	0.00	-	1112.08	0.81%
2014	0.00	-1638.52	0.00	-	-1638.52	-1.37%
2015	0.00	-1479.30	0.00	-	-1479.30	-1.18%
2016	0.00	2624.36	0.00	-	2624.36	2.17%
2017	0.00	1813.16	0.00	-	1813.16	1.51%
2018	0.00	1513.19	0.00	-	1513.19	1.32%
2019	0.00	1131.65	0.00	-	1131.65	0.94%
2020	0.00	-999.28	0.00	-	-999.28	-0.82%
2021	-717.28	-666.61	0.00	-	-1383.89	-1.17%
2022	572.88	125.59	0.02	-	698.49	0.64%
2023	-1431.08	864.83	0.01	-	-566.24	-0.56%

3.2.9.6 Category-specific planned improvements (1.A.4, stationary)

No improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

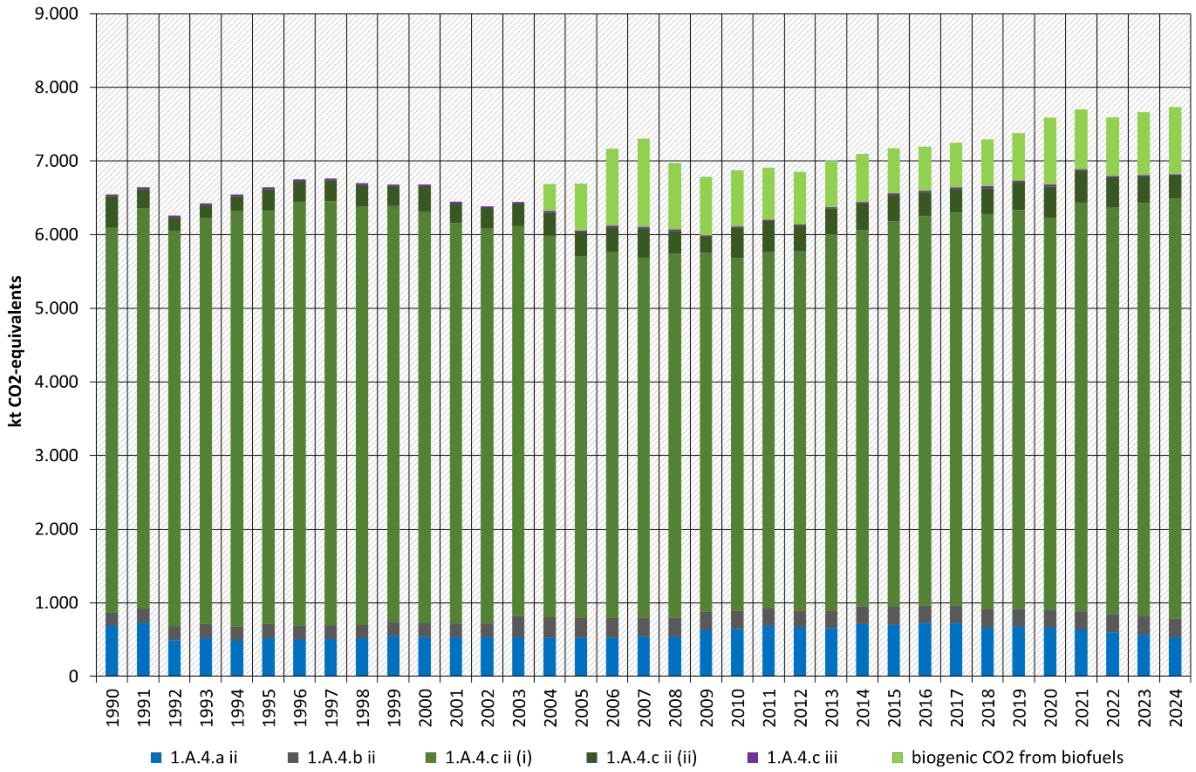
3.2.10 Other: Residential, commercial/institutional, agriculture, forestry and fisheries (1.A.4 mobile)

3.2.10.1 Category description (1.A.4 mobile)

The stationary and mobile sources categories in 1.A.4 are grouped together for assignment to key categories (for an overview, cf. Chapter 3.2.9.1). The category 1.A.4 Other is a key category for CO_2 emissions in all of its subcategories in terms of both emissions level and trend. For CH_4 emissions, categories 1.A.4.a & b are a key category in terms of trend.

Category 1.A.4 – mobile comprises various mobile sources in subcategories 1.A.4.a ii – Commercial and Institutional (commerce, trade and services), 1.A.4.b ii – Residential, 1.A.4.c ii – Agriculture and forestry and 1.A.4.c iii – Fisheries.

Figure 34: Development of GHG emissions in the relevant subsectors since 1990



Source: own illustration, German Environment Agency

3.2.10.2 Methodological issues (1.A.4 mobile)

The activity data in source group 1.A.4 mobile, like those for stationary combustion systems, are taken from AGEB AGEB (2025a).

The quantities of gasoline fuels listed in "Energy Balance line 66 – Residential" are all allocated to mobile sources (1.A.4.b ii).

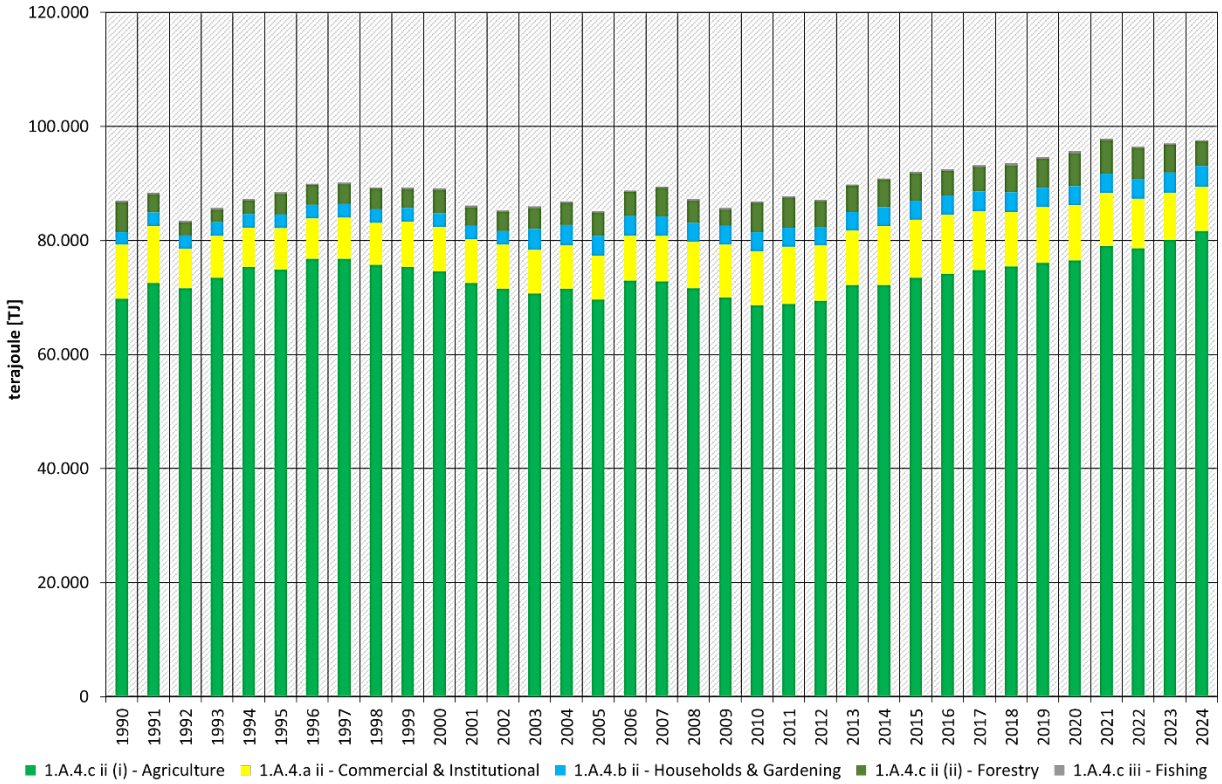
"NEB line 67 – Commercial and Institutional also includes fuel consumption areas of the military sector that are that are separately recorded in (BAFA, 2025a) statistics; those areas can thus be deducted here (cf. Chapter 3.2.12 regarding mobile sources in the military sector). The additional breakdown into mobile sources in Agriculture (1.A.4.c ii (i)) and Forestry (1.A.4.c ii (ii)), Construction vehicles and machinery (1.A.2.g vii), and mobile sources in "1.A.4.a ii (primarily forklifts), is carried out on the basis of an annual distribution key generated in Heidt et al. (2025).

The activity data for the coastal and high-seas fisheries included under "1.A.4.c (iii) – Fisheries" are calculated in the BSH model described in 1.A.3.d, on the basis of AIS data (data of the IMO's Automatic Identification System (AIS)). The development of energy use reflects the development of the number of fishing vessels classified as such based on their AIS signal, for which consumption data was modelled.

The quantities of unintentionally co-combusted lubricants are generally derived, pursuant to Wallfarth (2014), from the relevant annual fuel quantities. For two-stroke gasoline engines (residential and forestry sectors), on the other hand, those quantities, as part of the lubricants co-combusted with fuel mixtures, are obtained as a two-percent addition to the quantities of gasoline used for refuelling (cf. also Chapter 4.5.1).

The CO_2 emissions from the fossil fractions of the biofuels used are allocated to the total national emissions (cf. the explanations in Annex 7.1.4).

Figure 35: Development of fuel consumption in the relevant subsectors since 1990



Source: own illustration, German Environment Agency

With regard to the emission factors used for carbon dioxide, we refer in the Annex 6.6. Further information – in particular, with regard to carbon dioxide from lubricant co-combustion – is also provided in Chapter 4.5.1.

For methane and nitrous oxide, country-specific values from (Heidt et al., 2025) and Deichnik (2025) are used. With regard to releases of methane and nitrous oxide from co-combustion of lubricants, it is assumed that these emissions are already taken into account in the emission factors for the fuels used and thus are to be reported as IE (*included elsewhere*).

Table 91: Emission factors used for report year 2024, in kg/TJ

	CH_4	N_2O	Note
1.A.4.a ii – Mobile sources in the Commercial and Institutional (commerce, trade and services) sector			
Diesel & biodiesel	0.62 (4.15)	2.90 (28.6)	pursuant to (Heidt et al., 2025)
Liquefied petroleum gas	5.63 (-)	3.45 (-)	
1.A.4.b ii – Mobile sources of the residential sector			
Gasoline: Machinery/equipment, two-stroke	196 (180)	0.46 (0.40)	pursuant to (Heidt et al., 2025)
Gasoline: Machinery/equipment, four-stroke	24.4 (120)	1.33 (2)	
Gasoline: Recreational boats, two-stroke	47.1 (-)	0.29 (-)	
Gasoline: Recreational boats, four-stroke	24.9 (-)	1.62 (-)	

	CH_4	N_2O	Note
1.A.4.c ii (i) – Mobile sources of the agricultural sector			
Diesel & biodiesel	1.16 (4.15)	2.94 (28.6)	pursuant to (Heidt et al., 2025)
1.A.4.c ii (ii) – Mobile sources of the forestry sector			
Diesel & biodiesel	0.13 (4.15)	3.12 (28.6)	pursuant to (Heidt et al., 2025)
Gasoline: Two-stroke engines	219 (170)	0.46 (0.40)	
1.A.4.c iii – Fisheries (here: High-seas fisheries)			
Diesel	1.17 (-)	3.32 (-)	pursuant to (Deichnik, 2025)
Heavy fuel oil	NA	NA	Use ended in 2014
Overarching			
Lubricants	IE	IE	Included in the EFs for the individual fuels

In parentheses: defaults pursuant to IPCC (2006a): Volume 2, Chapter 3.3 – *Off-road transportation*, p. 3.36, Table 3.3.1
The EFs for biodiesel and bioethanol correspond to the values for their fossil-based counterparts.

3.2.10.3 Uncertainties and time series consistency (1.A.4 mobile)

The uncertainty data for specific energy inputs, which are dominated by the mathematical uncertainty of the distribution key developed in TREMOD MM (cf. above: 3.2.10.2), are based on experts' assessments. The same is true for the carbon dioxide emission factors used. While the emission factors for methane are based on results from Knörr et al. (2009), the emission factors for nitrous oxide – for the time being – have to be based on guideline values pursuant to the IPCC.

For the specific energy inputs, calculated as described above, for diesel fuel and gasoline, uncertainties of ±20% are assumed, while for modelled quantities of the LP gas used in 1.A.4.a ii, uncertainties of ±5% are assumed.

The uncertainties assumed for the emission factors used are shown in the following table.

Table 92: Percentage uncertainties for emission factors*

	CO_2	CH_4	N_2O
Gasoline	±0.4%	-28%/+40%	±50%
Diesel	±3%	±50%	-40%/+140%
Liquefied petroleum gas	±2%	±50%	±75%
Gasoline (bio)	±1%	±50%	-40%/+140%
Diesel (bio)	±3%	±50%	-40%/+140%

* Upper and lower bounds of the 95% percentile

3.2.10.4 Category-specific QA/QC and verification (1.A.4 mobile)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

Table 93: Overview of relevant data comparisons

	Comparison with...	Explanation
CO_2, CH_4, N_2O	Alternative emissions inventories for Germany	No comparable data sets
CO_2	Specific Tier 1 defaults pursuant to (IPCC, 2006a): Volume 2, Chapter 3, Tab. 3.3.1 and 3.5.3 (1.A.4.c iii)	cf. Table 94
CH_4, N_2O	Specific Tier 1 defaults pursuant to (IPCC, 2006a): Volume 2, Chapter 3, Tab. 3.3.1 and 3.5.3 (1.A.4.c iii)	cf. Table 91
CO_2, CH_4, N_2O	Specific IEFs of other countries	cf. Table 95

Table 94: Comparison of the EF (CO_2) used in the inventory with default values*, in kg/TJ*

	Inventory values [a]	Default [b]	Lower bound	Upper bound
Diesel fuel	74,027	74,100	72,600	74,800
Gasoline		69,300	67,500	73,000
Two-stroke engines [b]	72,797			
Four-stroke engines	72,782			
Liquefied petroleum gas	66,333	63,100	61,600	65,600
Heavy fuel oil	n.a.	77,400	75,500	78,800
Lubricants	73,300		71,900	75,200
Biodiesel	70,800		59,800	84,300
Biogasoline	70,800		59,800	84,300
Two-stroke engines [c]	*71,641*			
Four-stroke engines	71,607			

[a] Inventory values for 2024; [b] pursuant to IPCC (2006a): Volume 2, Chapter 2, Table 2.4

[c] including 2% lubricants (EF = 73,300 kg/TJ) in 1:50 two-stroke fuel mixtures

The following table allows a comparison with specific implicit emission factors (IEF) of other countries and the resulting values for the EU (27), which is difficult, however, due to the extremely heterogeneous source group structure.

Table 95: International comparison of reported IEFs, in kg/TJ

	1.A.4.a ii			1.A.4.b ii			1.A.4.c ii		
	Liquid fuels						Diesel fuel		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Germany	68,534	2.61	3.12	69,717	54.2	1.21	74,027	1.16	2.94
Belgium	NO	NO	NO	75,901	36.4	1.42	74,163	2.52	16.8
Denmark	73,036	11.90	2.80	73,000	52.4	1.16	74,098	0.79	3.58
France							74,840	0.78	28.70
Italy				73,081	190.0	0.47	73,510	3.98	27.90
Netherlands	72,040	2.61	0.81	73,200	46.8	0.6	72,454	1.11	0.60
Spain	75,920	406	0.40	IE	IE	IE	73,318	0.68	3.22

EU-27				IE	IE	IE	73,830	2.13	17.4
UK	63,966	0.08	0.04	70,531	9.49	0.9	74,938	0.41	3.26
	1.A.4.c ii			**1.A.4.c iii**					
	Gasoline			**Heavy fuel oil**			**Diesel/light heating oil**		
	CO_2	**CH_4**	**N_2O**	**CO_2**	**CH_4**	**N_2O**	**CO_2**	**CH_4**	**N_2O**
Germany	72,797	219	0.46	NO	NO	NO	74,027	1.17	3.32
Belgium	72,405	280	0.46	NO	NO	NO	74,100	10.0	0.60
Denmark	72,989	175	1.31	78,000	1.4	1.95	73,930	1.69	1.64
France	74,892	165	0.55	NO	NO	NO	74,523	7.00	2.00
Italy	73,081	139	0.89	NO	NO	NO	73,510	4.21	1.45
Netherlands	72,200	282	0.60	NO	NO	NO	72,454	7.00	2.00
Spain	75,920	202	0.47	NO	NO	NO	74,100	7.00	2.00
EU-27	73,282	169	0.75	77,400	7.00	2.00	73,925	5.94	1.92
UK	NO	NO	NO	76,120	1.52	3.8	75,313	1.03	3.41

Germany: IEF for report year 2024; otherwise: IEF for 2021, pursuant to 2023 CRF submission

3.2.10.5 Category-specific recalculations (1.A.4 mobile)

As described above, the activity data for the emissions sources considered here are part of the primary activity data listed in Energy Balance line 67. For the year 2023, the provisional data in the 2024 submission were replaced by final figures. In addition, the admixture quotas for biofuels were corrected.

The same is true for the primary activity data of the residential sector listed in Energy Balance line 66.

Table 96: Revised primary activity data for 2003-2023, in terajoules

	2003	**2004**	**2005**	**2010**	**2015**	**2020**	**2021**	**2022**	**2023**
Diesel fuel									
2026 submission	89,685	86,802	85,271	89,724	103,913	105,611	106,135	102,375	101,113
2025 submission	89,685	86,802	85,271	89,724	103,914	104,452	106,457	102,720	101,133
Absolute change	0.00	0.00	0.00	0.18	-0.50	1,160	-322	-345	-20.7
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	1.11%	-0.30%	-0.34%	-0.02%
Gasoline									
2026 submission	14,200	13,193	14,151	9,873	8,640	8,553	8,752	8,626	8,584
2025 submission	14,200	13,193	14,151	14,923	12,227	10,489	10,833	10,872	10,769
Absolute change	0.00	0.00	0.00	-5,050	-3,586	-1,937	-2,080	-2,246	-2,184
Relative change	0.00%	0.00%	0.00%	-33.8%	-29.3%	-18.5%	-19.2%	-20.7%	-20.3%
Liquefied petroleum gas									
2026 submission	15,397	13,916	22,317	11,765	17,325	17,638	16,953	14,750	12,998
2025 submission	23,027	18,339	25,297	11,432	18,702	18,598	18,139	13,962	10,117
Absolute change	-7,629	-4,423	-2,980	333	-1,377	-959	-1,186	789	2,881
Relative change	-33.1%	-24.1%	-11.8%	2.91%	-7.36%	-5.16%	-6.54%	5.65%	28.5%
Biodiesel									

	2003	2004	2005	2010	2015	2020	2021	2022	2023
2026 submission		2,983	5,446	6,945	5,699	8,742	7,368	7,084	7,522
2025 submission		3,164	5,681	7,018	5,772	8,543	7,465	7,126	7,496
Absolute change		-181	-235	-72.7	-73.1	198	-97.4	-42.3	26.9
Relative change		-5.73%	-4.14%	-1.04%	-1.27%	2.32%	-1.31%	-0.59%	0.36%
Bioethanol									
2026 submission		14.0	96.1	356	363	379	404	399	408
2025 submission		14.5	98.1	357	495	470	510	504	509
Absolute change		-0.50	-1.94	-1.81	-132	-91.6	-107	-105	-101
Relative change		-3.43%	-1.98%	-0.51%	-26.7%	-19.5%	-20.9%	-20.9%	-19.8%

Source: Revised Energy Balance 2023 (AGEB, 2025c)and own calculations

At the same time, an annual adjustment was made to the distribution factors used to allocate primary activity data in accordance with TREMOD MM.

Table 97: Revised percentage shares of primary data pursuant to Energy Balance line 67

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Energy Balance line 67 - diesel fuel										
1.A.2.g vii										
2026 submission	0.297	0.189	0.170	0.156	0.216	0.267	0.288	0.284	0.281	0.282
2025 submission	0.297	0.189	0.170	0.156	0.216	0.255	0.251	0.238	0.219	0.203
Absolute change	0.000	0.000	0.000	-0.001	0.000	0.012	0.037	0.046	0.062	0.078
Relative change	0.01%	0.01%	0.00%	-0.36%	-0.16%	4.79%	14.9%	19.4%	28.2%	38.5%
1.A.4.a ii										
2026 submission	0.060	0.040	0.037	0.036	0.051	0.057	0.056	0.055	0.055	0.055
2025 submission	0.060	0.040	0.037	0.037	0.051	0.054	0.049	0.046	0.043	0.040
Absolute change	0.000	0.000	0.000	0.000	0.000	0.003	0.007	0.009	0.012	0.015
Relative change	-0.03%	-0.02%	-0.01%	-0.37%	-0.16%	4.79%	14.9%	19.4%	28.2%	38.5%
1.A.4.c ii (i)										
2026 submission	0.624	0.766	0.785	0.797	0.718	0.658	0.630	0.636	0.639	0.640
2025 submission	0.624	0.766	0.785	0.796	0.718	0.674	0.678	0.695	0.718	0.740
Absolute change	0.000	0.000	0.000	0.001	0.000	-0.016	-0.048	-0.059	-0.079	-0.100
Relative change	0.00%	0.00%	0.00%	0.09%	0.06%	-2.32%	-7.07%	-8.52%	-11.1%	-13.5%
1.A.4.c ii (ii)										
2026 submission	0.019	0.006	0.009	0.011	0.016	0.018	0.025	0.026	0.025	0.023
2025 submission	0.019	0.006	0.009	0.011	0.016	0.017	0.022	0.021	0.020	0.017
Absolute change	0.000	0.000	0.000	0.000	0.000	0.001	0.003	0.004	0.006	0.006
Relative change	-0.03%	-0.02%	-0.01%	-0.37%	-0.16%	4.79%	14.9%	19.4%	28.2%	38.5%

Source: Heidt et al. (2025)

Table 98: Revised energy inputs of the relevant subsectors, in terajoules

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
1.A.4.a ii										
2026 submission	9,480	7,317	7,748	7,713	9,471	10,423	10,582	10,258	9,995	9,906
2025 submission	9,482	7,318	7,749	7,733	9,482	10,144	9,680	9,270	8,689	8,239
Absolute change	-1.77	-0.86	-0.47	-20.4	-11.2	278	902	988	1,306	1,667

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Relative change	-0.02%	-0.01%	-0.01%	-0.26%	-0.12%	2.74%	9.31%	10.7%	15.0%	20.2%
1.A.4.b ii										
2026 submission	2,177	2,395	2,395	3,475	3,321	3,348	3,345	3,392	3,459	3,353
2025 submission	2,177	2,395	2,395	3,475	3,321	3,352	3,349	3,396	3,458	3,523
Absolute change	0.00	0.00	0.00	-0.18	0.02	-4.15	-4.43	-4.65	1.18	-170
Relative change	0.00%	0.00%	0.00%	-0.01%	0.00%	-0.12%	-0.13%	-0.14%	0.03%	-4.82%
1.A.4.c ii (i)										
2026 submission	69,792	74,870	74,621	69,542	68,656	71,760	71,960	72,071	69,688	69,319
2025 submission	69,792	74,870	74,621	69,662	68,660	73,512	76,515	79,073	78,635	80,158
Absolute change	0.000	0.000	0.000	-121	-3.79	-1,752	-4,555	-7,003	-8,947	-10,839
Relative change	0.00%	0.00%	0.00%	-0.17%	-0.01%	-2.38%	-5.95%	-8.86%	-11.4%	-13.5%
1.A.4.c ii (ii)										
2026 submission	5,226	3,619	4,155	4,019	3,352	2,009	3,011	5,492	5,222	2,620
2025 submission	5,227	3,620	4,155	4,035	5,150	4,822	5,819	5,853	5,485	4,892
Absolute change	-0.782	-0.420	-0.295	-16.0	-1,798	-2,813	-2,808	-361	-263	-2,271
Relative change	-0.01%	-0.01%	-0.01%	-0.40%	-34.9%	-58.3%	-48.3%	-6.17%	-4.79%	-46.4%

Source: Own calculations based on AGEB (2025c) and Heidt et al. (2025)

At the same time, the implied emission factors modelled for the various individual mobile emitters were updated. These updates have affected the emissions of all subsectors (cf. also Chapter 3.2.8.4.5).

The totality of the adjustments described results in the following recalculated emission quantities:

Table 99: Revised emissions quantities, in kt CO2 equivalents

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
1.A.4.a ii										
2026 submission	687	519	540	526	646	726	727	709	691	683
2025 submission	688	520	541	527	647	707	665	641	600	567
Absolute change	-0.87	-0.67	-0.70	-1.58	-1.40	19.1	61.4	68.8	91.0	116
Relative change	-0.13%	-0.13%	-0.13%	-0.30%	-0.22%	2.71%	9.23%	10.7%	15.2%	20.4%
1.A.4.b ii										
2026 submission	180	192	188	269	246	243	240	243	248	240
2025 submission	178	191	187	267	245	242	240	243	247	252
Absolute change	2.20	1.45	0.99	1.58	1.21	0.60	0.45	0.43	0.57	-11.8
Relative change	1.23%	0.76%	0.53%	0.59%	0.49%	0.25%	0.19%	0.18%	0.23%	-4.68%
1.A.4.c ii										
2026 submission	5,653	5,906	5,930	5,240	5,052	5,249	5,203	5,467	5,281	5,028
2025 submission	5,654	5,910	5,934	5,240	5,202	5,596	5,753	5,991	5,937	5,977

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Absolute change	-1.34	-3.10	-3.33	-0.11	-150	-346	-550	-524	-657	-949
Relative change	-0.02%	-0.05%	-0.06%	0.00%	-2.89%	-6.19%	-9.56%	-8.74%	-11.1%	-15.9%
1.A.4.c iii										
2026 submission	25.43	20.02	19.86	18.84	18.89	21.29	26.87	19.87	16.53	16.90
2025 submission	25.47	20.05	19.89	18.86	18.92	21.32	26.91	19.90	16.55	16.92
Absolute change	-0.04	-0.03	-0.03	-0.03	-0.03	-0.03	-0.04	-0.03	-0.02	-0.02
Relative change	-0.14%	-0.14%	-0.14%	-0.14%	-0.14%	-0.14%	-0.14%	-0.14%	-0.14%	-0.14%
1.A.4 - MOBILE EMITTERS, TOTAL										
2026 submission	6,546	6,638	6,679	6,054	5,963	6,239	6,197	6,439	6,236	5,968
2025 submission	6,546	6,640	6,682	6,054	6,113	6,566	6,685	6,894	6,801	6,813
Absolute change	-0.04	-2.34	-3.07	-0.13	-150	-327	-488	-455	-565	-845
Relative change	0.00%	-0.04%	-0.05%	0.00%	-2.46%	-4.97%	-7.30%	-6.60%	-8.31%	-12.4%

Source: Own calculations; including fossil CO_2 from use of biofuels

3.2.10.6 Category-specific planned improvements (1.A.4 mobile)

No concrete improvements are currently planned, apart from the regular review and revision of the models used.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

3.2.11 Other sectors (1.A.5.a stationary)

Category 1.A.5 comprises the combustion-related emissions of the military sector. It is divided into the categories 1.A.5.a “Stationary” and 1.A.5.b “Mobile”.

3.2.11.1 Category description (1.A.5.a stationary)

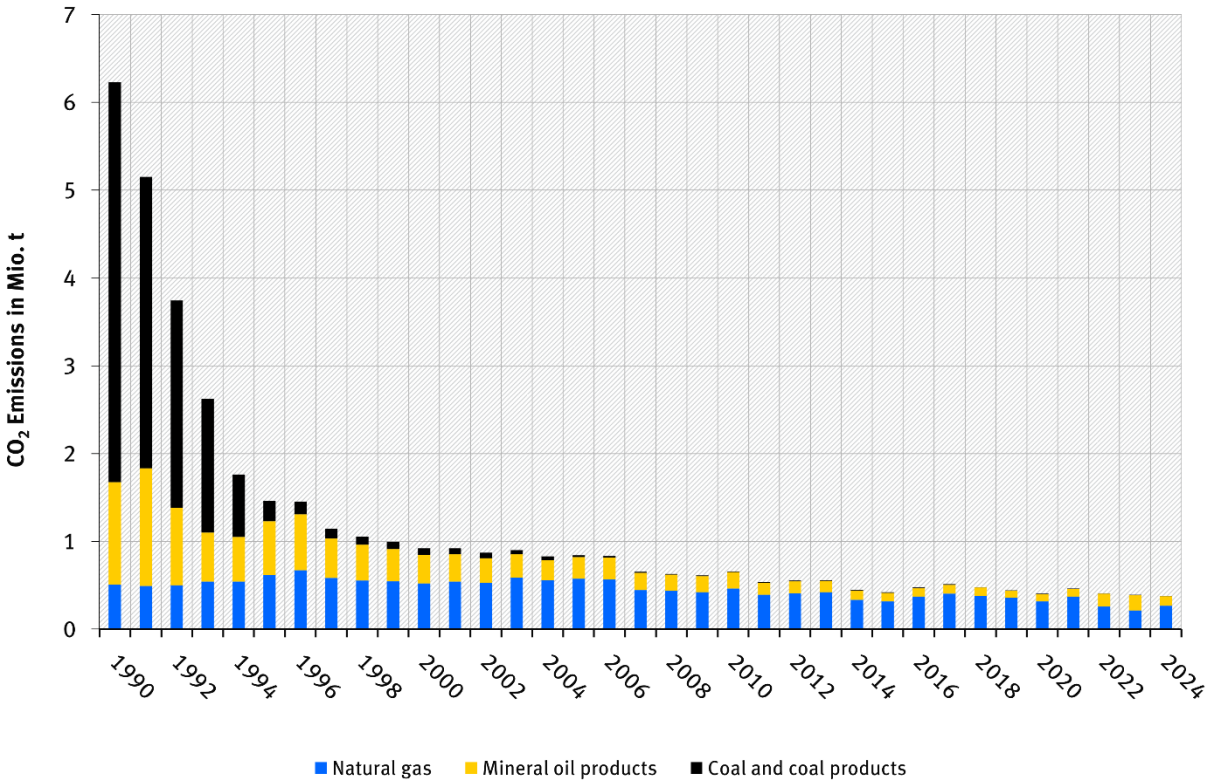
KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
L/T	1 A 5, Military	fossil fuels	CO_2	11764.62	0.91	597.06	0.09	-94.92
-/-	1 A 5, Military	0	CH_4	312.97	0.03	1.51	0.01	-99.52
-/-	1 A 5, Military	0	N_2O	54.14	0.01	1.51	0.01	-97.21

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS, Tier 1	NS	CS/D
CH_4	CS, Tier 1, Tier 3	NS/M	CS/D/M
N_2O	CS, Tier 1, Tier 3	NS/M	CS/D/M

The stationary and mobile sources in 1.A.5 are grouped together for assignment to key categories. Consequently, category 1.A.5 Other is a key category for CO_2 emissions in terms of both emissions level and trend.

The following Figure 36 shows the emissions trend since 1990. The particularly large emissions reduction results from the closure of numerous military agencies, as well as from a clear trend toward less use of solid fuels.

Figure 36: Development of CO_2 emissions of category 1.A.5.a



Source: own illustration, German Environment Agency

3.2.11.2 Methodological issues (1.A.5.a stationary)

Activity data

The National Energy Balance (NEB) provides the basis for the activity data used. As of 1995, the NEB no longer lists the final energy consumption of military agencies separately, and instead includes that consumption in line 67, under "Commercial and Institutional" (commerce, trade, services and other consumers), data from the Federal Ministry of Defence (BMVg) is used, which reports the energy used for heat generation in the armed forces to the UBA based on fuel type. These figures are also published annually in the sustainability report of the Federal Ministry of Defence and the German Armed Forces (BMVg, 2024). These figures are subtracted from the data of Energy Balance line 67 (Commercial and Institutional and other consumers) and reported not in 1.A.4, but in 1.A.5. As of report year 2008, use of wood in category 1.A.5.a is also reported. For the time series as of 2003, the data are provided by the Working Group on Renewable Energy Statistics (Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat)).

Emission factors

A description and a list of the CO_2 emission factors used are available in the Annex 6.6.

The data basis for the emission factors used for methane and nitrous oxide consists of the results of a research project carried out by the University of Stuttgart commissioned by the German Environment Agency (Struschka et al., 2008). Within that project, device-related and category-specific emission factors for combustion systems in military agencies were calculated, with a

high level of detail, for all important emissions components for the reference year 2005. The method used to determine the factors corresponds to the method described for category 1.A.4. Table 100 shows the sectoral emission factors used.

Table 100: Sectoral emission factors for military agencies, with reference year 2005; updated for the current reporting, in [kg/TJ]

	CH_4	N_2O
Hard coal	2.0	4.8
Lignite briquettes	242	0.37
Heating oil EL	0.03	0.56
Natural gas	0.042	0.29

3.2.11.3 Uncertainties and time series consistency (1.A.5.a stationary)

Information about the uncertainties for the emission factors is provided in the description for category 1.A.4. Annex 2 Chapter 13.6 in the NIR (UBA, 2007) describes how the uncertainties for the activity data were determined.

3.2.11.4 Category-specific QA/QC and verification (1.A.5.a stationary)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents, while for ED they were carried out by the Single National Entity.

As no other data sources for Germany are known, a comparative verification of the emissions reported here is currently not possible.

3.2.11.5 Category-specific recalculations (1.A.5.a, stationary)

Table 101: Recalculations for CRF1.A.5 (stationary) by fuel, in [kt] and [%]

	CO_2 difference, absolute					CO_2 difference, relative
	Gaseous fuels	Liquid fuels	Solid fuels	Other fuels	Total	Total
2023	0.00	0.00	-0.09		-0.09	-0.02%

Provisional figures for the year 2023 were replaced with figures from the now available final Energy Balance for that year, which resulted in minimal recalculations.

3.2.11.6 Category-specific planned improvements (1.A.5.a stationary)

No improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

3.2.12 Other areas (1.A.5.b mobile)

3.2.12.1 Category description (1.A.5.b mobile)

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1[a], CS	NS/M [b]	D [a], CS
CH_4	CS, Tier 1, Tier 3	NS/M [b]	CS (M)
N_2O	CS, Tier 1, Tier 3	NS/M [b]	CS (M)
NO_x, CO, NMVOC, SO_2	CS, Tier 1, Tier 3	NS/M [b]	CS (M)

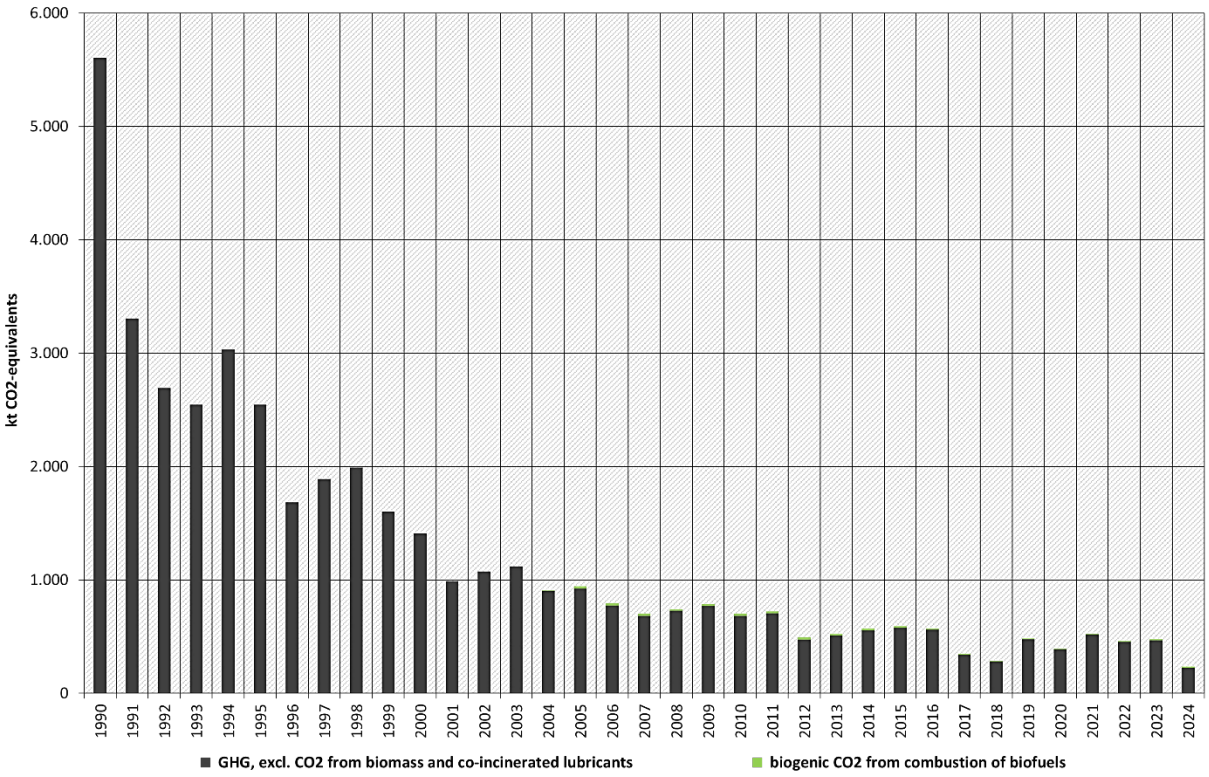
[a] for biodiesel and aviation gasoline: Default EF pursuant to IPCC (2006a): Volume 2, Chapter 2, Table 2.4

[b] military maritime transport: calculated in (Deichnik, 2025)

The key category analysis for 1.A.5 – Other is carried out on an overarching basis, for both stationary and mobile sources (cf. Chapter 3.2.11.1). Consequently, the source group 1.A.5 is a key category for CO_2 emissions in terms of both emissions level and trend.

The following figure shows the development of GHG emissions since 1990.

Figure 37: Development of GHG emissions of mobile sources in the military sector since 1990



Source: own illustration, German Environment Agency

3.2.12.2 Methodological issues (1.A.5.b mobile)

Activity data

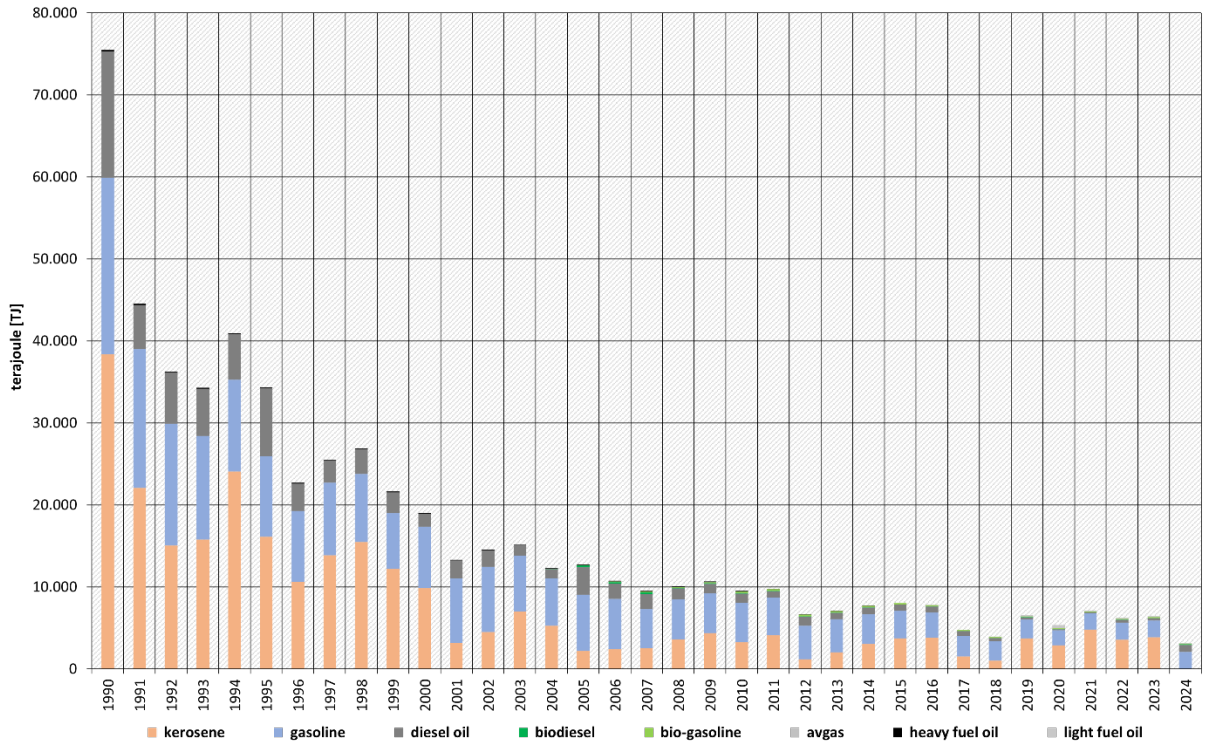
The activity data used are based on the Energy Balance of the Federal Republic of Germany (AGEB), which provides directly usable fuel input data for military air and ground transport (diesel fuel and gasoline – including any biogenic admixtures – and kerosene and avgas) only for the period until 1993. As of 1994, (BAFA, 2025a) is used. The consumption figures in that source, which are expressed in units of 1000 t, are converted into terajoules on the basis of the

listed calorific values (AGEB, 2025d). On the other hand, the fuel inputs in the naval sector are only a subquantity of the quantities listed in Energy Balance line 6 – International marine bunkers. They are thus calculated separately as described in Chapter 3.2.8.4.4.

In addition, the quantities of co-combusted lubricants are derived from the total quantities of fuels used in subcategories 1.A.5.b i to iii using co-combustion rates according to Wallfarth (2014) (cf. also Chapter 4.5.1).

The CO_2 emissions from the fossil fractions of the biofuels used are allocated to the total national emissions (cf. the explanations in Annex Annex 7.1.4).

Figure 38: Development of fuel inputs since 1990



Source: own illustration, German Environment Agency

Emission factors

With regard to the emission factors for carbon dioxide, we refer here to Annex 6.6. Both country-specific and default values (biodiesel, avgas) are used. Further information regarding co-combustion of lubricants in particular is provided in Chapter 4.5.1.

For methane and nitrous oxide, country-specific values are also used for ground transports and for the use of aviation gasoline. For kerosene, IPCC default figures are used as the aircraft used by the sector are very different from those used in civil aviation. The emission factors used for the naval sector are taken from Deichnik (2025). With regard to releases of methane and nitrous oxide from co-combustion of lubricants, it is assumed that these emissions are already taken into account in the emission factors for the fuels used and thus are to be reported as IE (*included elsewhere*).

Table 102: Emission factors used for report year 2024, in kg/TJ

	CH_4	N_2O	Source
1.A.5.b i – Military ground vehicles and machinery			
Diesel & biodiesel	2.97 (-)	0.81 (-)	IEF derived from 1.A.3.b: heavy duty vehicles
Gasoline & bioethanol	7.04 (-)	0.72 (-)	IEF from 1.A.3.b
1.A.5.b ii – Military air transport [a]			
Kerosene	0.50 (0.50)	2.00 (2.00)	Tier 1 defaults pursuant to IPCC (2006a)
Aviation gasoline	20.4 (-)	2.30 (-)	cf. 1.A.3.a
1.A.5.b iii – Military maritime transport/navy [b]			
Diesel & light heating oil	0.85 (7.00)	4.15 (2.00)	pursuant toDeichnik (2025)
Heavy fuel oil	n.a.	n.a.	Use ended in 2014
Overarching			
Lubricants	IE	IE	Included in the EF for fuels

In parentheses: defaults pursuant to IPCC (2006a): Volume 2, Chapter 3: a Tab. 3.6.5; b Tab. 3.5.3
The EFs for biodiesel and bioethanol correspond to the values used for their fossil-based counterparts.

3.2.12.3 Uncertainties and time series consistency (1.A.5.b mobile)

Within subsectors 1.A.5.b i and ii, default uncertainties pursuant to IPCC are used. In a departure from this method, specific uncertainties for activity data and emission factors for military maritime transports were derived in (Deichnik, 2025).

For the specific energy inputs calculated as described above, uncertainties of ±5% are assumed.

The uncertainties assumed for the emission factors used are shown in the following table.

Table 103: Percentage uncertainties for emission factors*

	CO_2	CH_4	N_2O
Gasoline	±0.4%	-28%/+40%	-40%/+140%
Diesel/light heating oil	±3%	±50%	-40%/+140%
Kerosene	±1%	-57%/+100%	-70%/+150%
Aviation gasoline	±1%	-57%/+100%	-70%/+150%
Heavy fuel oil	±5%	±50%	-40%/+140%

* Upper and lower bounds of the 95% percentile

3.2.12.4 Category-specific QA/QC and verification (1.A.5.b mobile)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

Table 104: Overview of relevant data comparisons

	Comparison with...	Explanation
CO_2	Alternative emissions inventories for Germany	No comparable data sets
CO_2	Specific Tier 1 default EF pursuant to IPCC (2006a): Volume 2, Chapter 2, Table 2.4	for 1.A.5.b ii & iii: cf. Table 105
CO_2	Tier 1 default EF pursuant to IPCC (2006a): Volume 2, Chapter 2, Table 2.4	for 1.A.5.b i: cf. Table 105
CH_4, N_2O	Specific Tier 1 default EF pursuant to IPCC (2006a):	for 1.A.5.b ii & iii: cf. Table 102
CH_4, N_2O	Tier 1 default EF pursuant to IPCC (2006a): Volume 2, Chapter 2, Table 2.4	1.A.5.b i: cf. Table 102
CO_2, CH_4, N_2O	Specific IEFs of other countries	No comparable data sets

Table 105: Comparison of the EF (CO_2) used and default values, in kg/TJ

	Inventory values[a]	Default[b]	Lower bound	Upper bound
Diesel & light heating oil	74,027	74,100	72,600	74,800
Gasoline	72,782	69,300	67,500	73,000
Kerosene	73,256	71,500	69,800	74,400
Aviation gasoline	71,199	70,000	67,500	73,000
Biodiesel	70,800		59,800	84,300
Bioethanol	71,607	70,800	59,800	84,300

[a] for report year 2024; [b] pursuant to IPCC (2006a): Volume 2, Chapter 2, Table 2.4

Table 106: International comparison of reported IEFs, in kg/TJ

	Fossil liquid fuels		
	CO_2	CH_4	N_2O
Germany	73,402	5.86	0.91
Belgium	72,520	4.27	2.46
Denmark	72,520	2.17	2.53
France	IE	IE	IE
Italy			
Netherlands	74,010	6.54	3.95
Spain	C	C	C
EU-27			
UK	72,630	1.93	2.57

Germany: IEF for report year 2024; all other countries: IEF for 2021, pursuant to 2023 CRF submission

3.2.12.5 Category-specific recalculations (1.A.5.b Mobile)

Compared with the 2025 submission, there are significant recalculations due to consolidated calorific values for gasoline fuel as a result of the revision of the energy balances for 2003 to 2022. In addition, the 2023 energy balance was finalised. The consumption figures for military maritime transport modelled in (Deichnik, 2025) remain unaffected by this and are therefore unchanged.

Table 107: Revised energy quantities 2003-2023, in terajoules

	2003	2004	2005	2010	2015	2020	2021	2022	2023
Military road transport & mobile machines									
2026 submission	7,870	6,761	10,323	6,023	4,140	2,050	2,219	2,586	2,447
2025 submission	7,868	6,761	10,304	6,028	4,044	1,995	2,160	2,562	2,487
Absolute change	2.17	-0.13	19.2	-5.84	96.1	55.1	59.2	24.1	-40.1
Relative change	7,870	6,761	10,323	6,023	4,140	2,050	2,219	2,586	2,447
Military air transport									
2026 submission	7,029	5,281	2,200	3,286	3,726	2,904	4,810	3,551	3,875
2025 submission	7,029	5,281	2,200	3,286	3,726	2,904	4,810	3,551	3,369
Absolute change	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	506
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	15.0%
MILITARY MOBILE EMITTERS, TOTAL									
2026 submission	15,158	12,291	12,762	9,518	8,021	5,345	7,148	6,268	6,457
2025 submission	15,156	12,291	12,743	9,524	7,925	5,289	7,089	6,244	5,991
Absolute change	2.17	-0.13	19.2	-5.84	96.1	55.1	59.2	24.1	466
Relative change	0.01%	0.00%	0.15%	-0.06%	1.21%	1.04%	0.83%	0.39%	7.77%

Source: Own calculations

In addition, the carbon dioxide emission factor for gasoline will be updated in 2023:

Table 108: Revised carbon dioxide emission factor 2023 for fossil-based gasoline

	EF
2026 submission	72,782
2025 submission	72,787
Absolute change	-4.16
Relative change	-0.01%

These adjustments lead to changes in the reported greenhouse gas emissions for all years considered.

Table 109: Revised emissions data 2022 – by GHG, in kt CO_2-equivalents

	2003	2004	2005	2010	2015	2015	2020	2021	2022	2023
Military road transport & mobile machines										
2026 submission	582	496	744	425	292	144	156	181	171	582
2025 submission	582	496	742	425	285	140	151	180	174	582
Absolute change	0.16	0.15	2.12	-0.29	6.43	3.93	4.28	1.71	-2.86	0.16
Relative change	0.03%	0.03%	0.29%	-0.07%	2.25%	2.81%	2.83%	0.95%	-1.64%	0.03%
Military air transport										
2026 submission	519	390	162	243	275	214	355	262	286	519
2025 submission	519	390	162	243	275	214	355	262	249	519
Absolute change	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	37.3	0.00
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	15.0%	0.00%
MILITARY MOBILE EMITTERS, TOTAL										
2026 submission	1,120	905	925	683	578	388	520	453	467	1,120
2025 submission	1,120	905	923	683	572	384	515	452	433	1,120
Absolute change	0.16	0.15	2.12	-0.29	6.43	3.93	4.28	1.71	34.5	0.16
Relative change	0.01%	0.02%	0.23%	-0.04%	1.12%	1.02%	0.83%	0.38%	7.96%	0.01%

Source: Own calculations; including fossil CO_2 from use of biofuels

3.2.12.6 Category-specific planned improvements (1.A.5.b Mobile)

No specific improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

3.2.13 Military

The German emissions inventories do not record emissions from international missions of the German Armed Forces, under NATO or UN mandates; instead, they list them as n*ot estimated* (NE) memo items. The reason for this is a lack of information regarding the fuel quantities (activity data) required/used for these mandates.

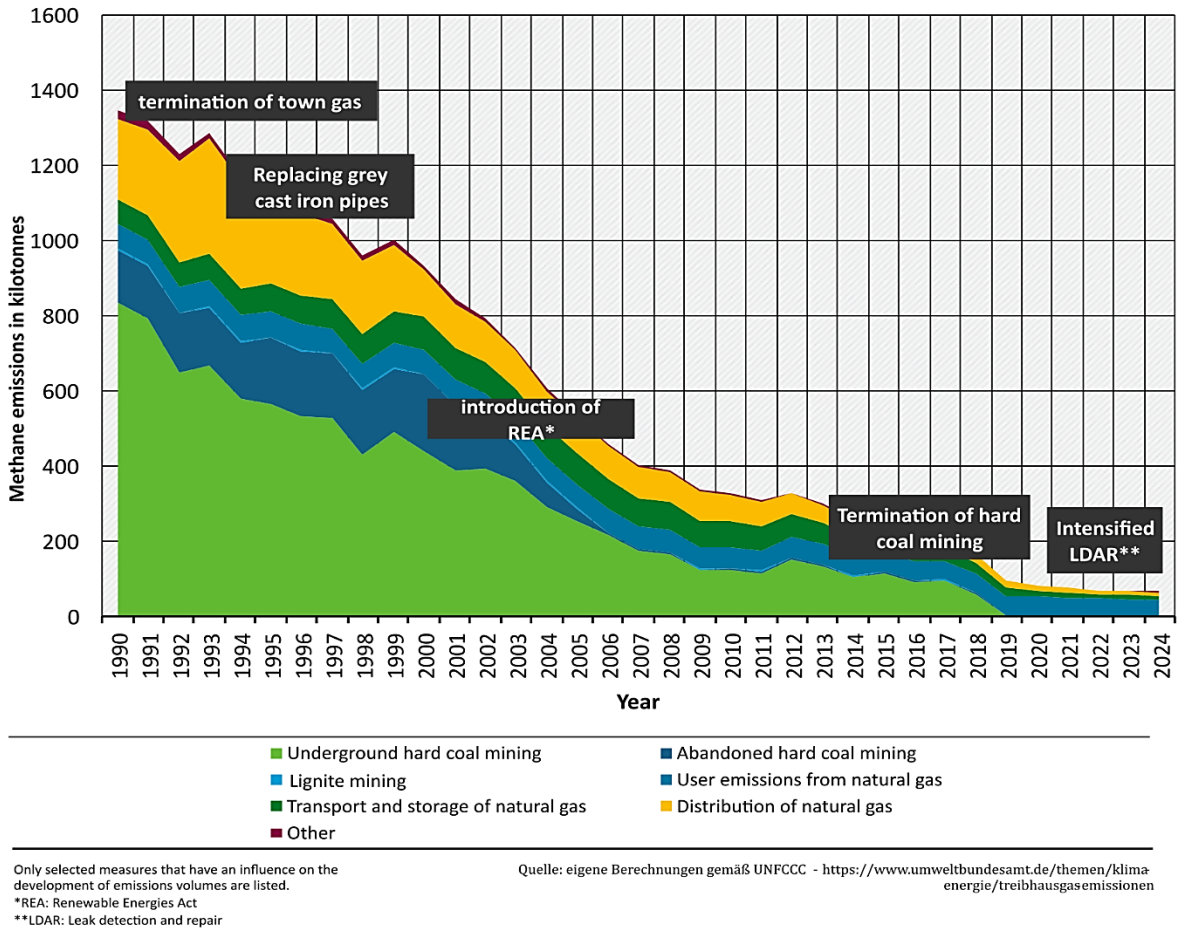
Emissions from stationary combustion systems of military agencies and from domestic operation of military vehicles and machinery are recorded and described in the German emissions inventories, however – under category 1.A.5 – Other (cf. Chapters 3.2.11 and 3.2.12).

3.3 Fugitive emissions from fuels (1.B)

During all stages of fuel production and use, from extraction of fossil fuels to their final use, fuel components can escape or be released as fugitive emissions. While methane emissions are the most important emissions within the source category areas of fugitive emissions from solid fuels and fugitive emissions from natural gas, fugitive emissions of oil and natural gas also include substantial amounts of NMVOC. Carbon dioxide plays a role in category 1.B in processing solid fuels and sour gas, with refinery processes and as a component of natural gas leaks. Source category 1.B. is not a source for fluorinated gases.

Figure 39 shows the development of methane emissions in category 1.B. This trend is explained in the various subcategories. Overall, methane emissions have declined by 95% since 1990.

Figure 39: Development of methane emissions in category 1.B



Source: own illustration, German Environment Agency

3.3.1 Solid fuels – coal mining and handling (1.B.1)

KC	Category	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
-/-/2	1 B 1, Solid Fuels	CO_2	1832.80	0.15	699.81	0.10	-61.82
L/T	1 B 1, Solid Fuels	CH_4	28579.16	2.21	78.09	0.02	-99.73

The category Coal mining and handling is a key category for CH_4 emissions in terms of emissions level and trend and a key category for CO_2 emissions pursuant to Approach 2 analysis.

In mining, a distinction is made between surface mining, in which deposits are extracted from pits open to the surface, and underground mining, in which deposits are extracted from sites underground. Since 2003, lignite has been mined in Germany only in open-pit mines. Hard coal mining was terminated in 2018.

This category is subdivided as follows:

Source category		Included emissions
1.B.1.a. Coal mining		
i.	Underground mining	
	Mining activities	Total emissions from active hard coal mines, consisting of emissions from mine ventilation and mine gas extraction, less the quantity of mine gas recovered and used. Since 2019, no more mining has taken place; for this reason, “NO” is reported here.
	Follow-up mining activities	Emissions from processing, storage and transport of hard coal. Since 2019, no more mining has taken place; for this reason, “NO” is reported here.
	Decommissioned coal mines	Emissions from decommissioned hard coal mines
	Flaring of mine gas	Such flaring (along with the relevant carbon dioxide emissions) occurred in Germany only in the period 2009 to 2012; otherwise, “NO” is reported here.
ii.	Open-pit mining	
	Mining activities	Emissions from active open-pit lignite mining. Here, the entire potential methane content of German lignite is used as the basis – this methane is assumed to be emitted in its entirety during mining. Any subsequent emissions of methane are thus already taken into account during further processing. No mine gas collection or use takes place in open-pit mining.
	Follow-up mining activities	No separate listing – the emissions are already included in “mining activities”
iii.	Coal exploration	No exploratory drilling for discovery of coal deposits takes place in Germany. For this reason, “NO” is reported here.
1.B.1.b. Fuel transformation		
	Charcoal production	The production emissions are included in 1.A.1.a. The use of charcoal is summarised under 2.G.4. For this reason, “IE” is reported here.
	Vegetable carbon production	In Germany, vegetable carbon is produced only in very small quantities, and it is not used as a fuel. For this reason, “NA” is reported here.
	Wood pellet production	No data are available on fugitive greenhouse gas emissions from wood pellets; for this reason, “NA” is reported here.
	Coke production and refined coal products	This area takes account of specific emissions that occur in hard coal processing. Methane emissions from lignite processing are already included in 1.B.1.a.ii “Mining activities”.
	Transformation of coal into liquid fuels	Coal dehydration has not taken place in Germany since 1987. For this reason, “NO” is reported here.
	Synthesis gas production	Production emissions are taken into account under 1.A. For this reason, “IE” is reported here.
	Town gas production	Town gas has not been used in Germany since 1998. Fugitive emissions from processing, distribution and use for the period through 1997 are reported 1.B.2.b. For the period thereafter, they are reported as “NO”.
1.B.1.c. Other		No emissions are currently being reported in this category.

3.3.1.1 Underground mining – hard coal

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 3	AS, M	CS
CO_2	Tier 3	AS, M	CS

3.3.1.1.1 Category description (1.B.1.a.ii)

Mining activities

No hard coal has been mined in Germany since the end of 2018.

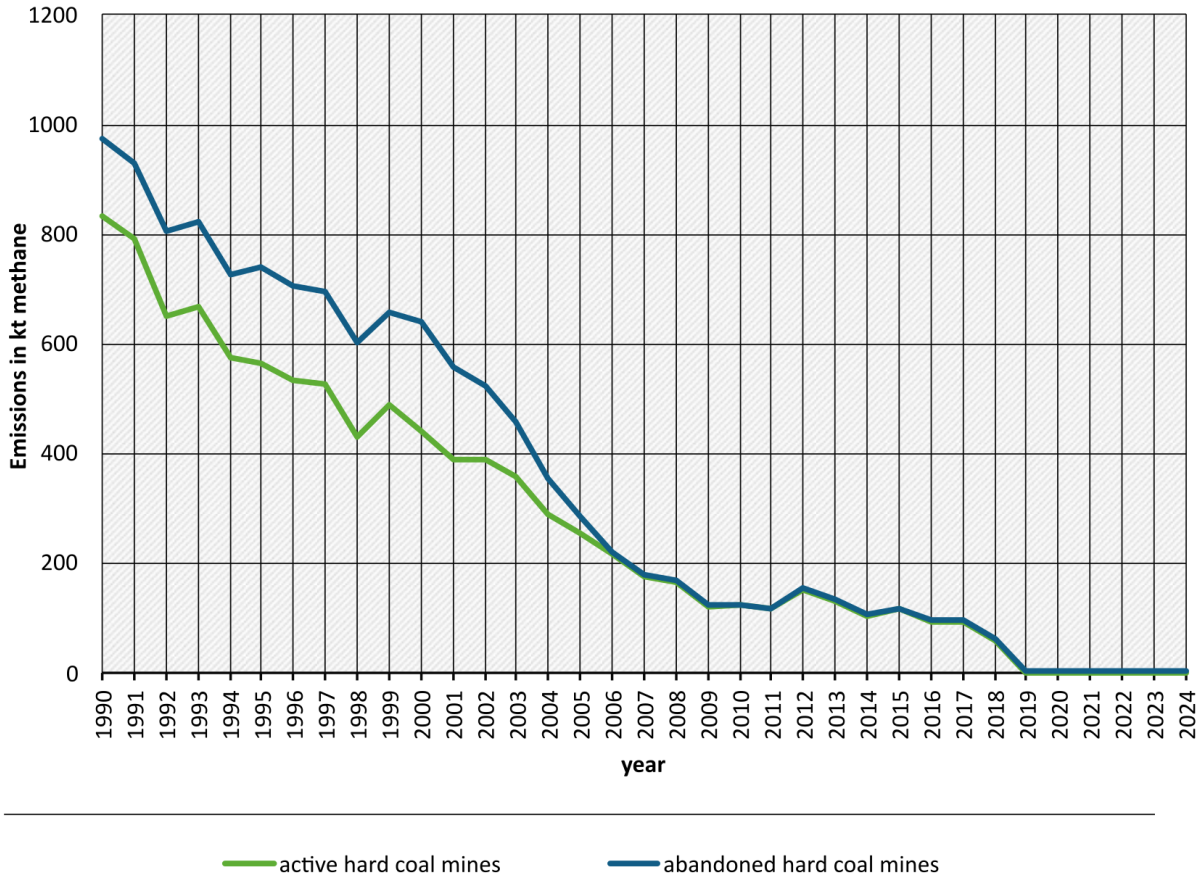
Flaring of mine gas

From 2009 through 2012, a high-temperature flare was operated in the framework of a JI project (cf. NIR 2014, Chapter 3.3.1.3.1.). Otherwise, no flaring takes place in Germany.

Decommissioned hard coal mines

When a hard coal mine is decommissioned, methane can escape from neighbouring rock, and from coal remaining in the mine, into the mine's network of shafts and passageways. Since the mine is no longer artificially ventilated, the methane collects and can then reach the surface through gas pathways in the overlying rock or through the mine's own shafts and passageways.

Figure 40: Development of mine gas emissions in active and decommissioned mining



Source: own illustration, German Environment Agency

Although mine gas is a fossil fuel with finite reserves, it was included in the Renewable Energy Sources Act (RES Act) in 2000 as its use helps lowers climate emissions. The Act requires network operators to accept and provide specified compensation for electricity generated with mine gas and fed into the grid. Figure 40 shows the impacts of the RES Act.

3.3.1.1.2 Methodological issues (1.B.1.a.i)

The emissions are determined in accordance with the DMT model (Meiners, 2018), in an approach comparable to the Tier 3 method pursuant to the IPCC Guidelines. Emissions from hard coal mining through 2018 have been calculated by the Gesamtverband Steinkohle (GVSt) association of the German hard coal mining industry, using the Tier 3 method pursuant to the IPCC Guidelines. This approach meets the requirements for determining mine-specific emissions. For safety reasons, the gas composition and air flow are measured continuously in all

mine shaft systems. The resulting data is used to determine levels of methane emissions. Expert review was carried out by the competent state supervisory authority (the mining authority – Bergamt). In addition, the resulting data were verified in research projects (Meiners, 2014).

3.3.1.1.3 Uncertainties and time series consistency (1.B.1.a.i)

The DMT model (Meiners, 2018)has been used throughout the entire relevant time period. Chapter 6.2 of the research project report (Meiners, 2014) cites a relative total error of +/- 60%.

3.3.1.1.4 Category-specific QA/QC and verification (1.B.1.a.i)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

Hard coal is no longer mined in Germany.

3.3.1.2 Open-pit mining – lignite

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 2	AS	CS

3.3.1.2.1 Category description (open-pit mining – lignite)

In Germany, lignite is mined in three coalfields (DEBRIV, 2024).

Activity data

Table 110: Extraction of lignite, in million t

1990	1995	2000	2005	2010	2015	2020	2023	2024
356.5	192.7	167.7	177.9	169.4	178.1	107.4	102.0	91.9

(Kohlenwirtschaft, 2025)

3.3.1.2.2 Methods (1.B.1.a.ii)

The emissions from open-pit lignite mining are calculated with the Tier 2 method. The EU Methane Regulation has been in force since 4 August 2024, requiring companies to determine emissions on a region-specific basis. These data are used for the first time in the 2026 reporting.

The lignite samples were taken directly from the freshly exposed coal embankment. The sample was sealed gas-tight on site, broken down in a laboratory, and the released sample gas was quantitatively determined using a flame ionisation detector.

Emission factors

Until 2023, an average emission factor of 0.015 m^3 CH4/t (equivalent to 0.011 kg CH_4/t) was assumed for German lignite. This emission factor is based on a 1989 study of RWE Rheinbraun AG (DEBRIV, 2004) and was substantiated by publications of the German Society for Petroleum and Coal Science and Technology (DGMK) (DGMK, 1992). From 2024 onwards, emissions will be determined on a region-specific basis. These vary between 0.00002 and 0.0111 kg/t depending on the region and depth. The average implicit emission factor for Germany is 0.004 kg/t or 0.006 m^3/t.

No lignite storage takes place; usage is “mine-mouth”, i.e. extracted coal is moved directly to processing and to power stations.

3.3.1.2.3 Uncertainties and time series consistency (1.B.1.a.ii)

The uncertainties in the activity data result primarily from inaccuracies in weighing extracted coal. The error was quantified at < 3% by consulting experts (NaSE-Workshop, 2004).

3.3.1.2.4 Category-specific QA/QC and verification (1.B.1.a.ii)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

As part of verification for the current report, various data sources for activity data in coal mining and the relevant EFs used were compared with the corresponding sources and EFs of other countries (cf. Table 111).

Table 111: IEF comparison with countries that use a higher-Tier method for above-ground lignite production

	Emission factor	Source
Germany	0.006 m^3/t	Operator reports pursuant to the EU Methane Regulation (EU, 2024a)
Poland	0.019 m^3/t	Poland's NIR 2011, p. 83 (UNFCCC, 2011a)
Greece	0.014 m^3/t	Greece's NIR 2023, p. 170 (UNFCCC, 2023b)
Hungary	0.00 m^3/t	Hungary's NIR 2023, p. 91 (Kis-Kovács et al., 2023)
Spain	0.10 m^3/t	Spain's NIR 2010, Table 3.10.3 (UNFCCC, 2010b)
Canada	0.09 m^3/t	Canada's NIR 2023, Annex Table A.3.2-1 (Minister of Environment and Climate Change, 2023)
Australia	0.016 m^3/t	Australia's NIR 2023, p. 123 (Commonwealth of Australia, 2023)
IPCC GL 2006	1.2 m^3/t	(IPCC, 2006a)

The country-level comparison of specific emission factors for open-pit mining has a wide range. The values of Spain and Canada are higher than those of Germany, since their open-pit mines have also produced sub-bituminous and bituminous coal (Rio, 2017) (page 5) (Canada's NIR: (Minister of Environment and Climate Change, 2023), Annex Table A.3.2-1).

The IPCC emission factors were derived from figures for American bituminous coal and thus, according to national experts, cannot be applied to German lignite, which did not exceed a temperature of 50°C during the coalification process. However, significant methane releases occur only at temperatures above 80°C (DGMK, 1992).

3.3.1.3 Solid fuel transformation

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 2/Tier 3	AS	CS
CO_2	Tier 2/Tier 3	AS	CS
NMVOC	Tier 2/Tier 3	AS	CS
CO	Tier 2/Tier 3	AS	CS
SO_2	Tier 2/Tier 3	AS	CS

3.3.1.3.1 Source category description (1.B.1.b)

Charcoal production

Charcoal is commercially produced at only one location in Germany. The relevant facility reports pursuant to the 17th Ordinance on the Implementation of the Federal Immission Control Act. The emissions are included in 1.A.1.a. The use of charcoal is summarised under 2.G.4. For this reason, "IE" is reported here.

Vegetable carbon production

In Germany, vegetable carbon is produced only in very small quantities, and it is not used as a fuel. For this reason, "NA" is reported here.

Wood pellet production

For the most part, wood pellets are produced in sawmills and wood processing plants by pressing wood residues. Emissions from production of the heat used for drying in such facilities are included in 1.A.1.a. No data are available on fugitive greenhouse gas emissions directly from wood pellets; for this reason, "NA" is reported here.

Coal hydrogenation

No commercial coal hydrogenation has taken place in Germany since 1987 (Farrenkopf, 2009). For this reason, "NO" is reported here.

Synthesis gas production

Currently synthesis gas production is included completely in 1.A. This also applies to synthesis gas production in primary industry. "IE" is reported in this area, because currently available statistics do not support differentiation in it by products and fuels.

Coke production and refined coal products

Table 112: Activity data for processed products [figures in tonnes]

	Lignite briquettes	Lignite coke	Lignite dust	Hard coal coke
1990	40,045,000	3,355,937	3,791,431	18,545,000
1995	5,010,829	191,883	2,700,110	11,102,000
2000	1,819,263	179,453	2,678,926	9,115,000
2005	1,489,922	173,443	2,923,620	8,397,000
2010	2,024,103	175,932	3,632,333	8,171,000
2015	1,640,000	170,000	4,398,000	8,800,000
2020	1,285,809	145,525	3,419,679	7,942,860
2023	692,000	156,000	3,140,100	8,034,624
2024	495,000	149,000	2,928,600	8,259,996

(Kohlenwirtschaft, 2025); Figures of AGEB

3.3.1.3.2 Methodological issues (1.B.1.b)

The emissions are calculated using the Tier 2 method, while those for lignite processing are calculated using the Tier 3 method.

Emission factors

No methane emissions are to be expected from processing of lignite products, since the EF used for 1.B.1.a.ii corresponds to the gas content of the lignite occurring in Germany. The other identified emissions are based on measurements made by the sole (at present) German producer of lignite coke at the Fortuna-Nord hearth furnace plant.

The methane emission factor used for calculation of CH_4 emissions from hard coal coke production (coking plants) is 0.049 kg methane per tonne of hard coal coke. The CO_2 emission factor is determined on the basis of the conservative assumption that about 1% of the coke is lost, in the form of fugitive emissions, between the time the blast furnace door is opened and the coke is extinguished. The activity data used consists of the total relevant quantities of hard coal and lignite coke.

Table 113: Emission factors for the production of hard coal coke

Product	Gas	Emission factor	Units
Hard coal coke	CH_4	0.049	kg/t
	CO_2	31.56	kg/t
Lignite coke	CH_4	0.0	kg/t
	CO_2	2,945.5	kg/t

The emission factors for the non-greenhouse gases originate from the research project "Emission factors for the iron and steel industry, for emissions reporting" ("Emissionsfaktoren zur Eisen- und Stahlindustrie für die Emissionsberichterstattung") (Hensmann et al., 2011).

3.3.1.3.3 Uncertainties and time series consistency (1.B.1.b)

The uncertainties for the emission factors for processing of coal have been estimated by experts as 10% to 25%.

For the activity data, a consistent source is used throughout the entire time series. The uncertainties result primarily from inaccuracies in weighing coal products. The error was quantified at < 3% by consulting experts (NaSE-Workshop, 2004).

3.3.1.3.4 Category-specific QA/QC and verification (1.B.1.b)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

In consideration of emission factors, the IPCC conversion factor of 0.67 $Gg/10^6m^3$ at 20°C and 1 atmosphere should be applied to the units used in Germany: normal cubic metres at 1.01325 bar and 0°C (DIN 2004, DIN No. 1343). When considering the EFs, information from the IPCC on default EFs and information from other publications should be taken into regarding Germany's use of normal cubic metres. When using EF data published in Germany, it is assumed that the relevant figures use normal cubic metres (substantiated by survey of experts at the NaSE workshop NaSE-Workshop (2004)).

The guideline figures are oriented to 20°C and 1,013 mbar. Based on the isobaric proportionality of methane, the factor 1.07 can be used to convert from Nm^3 to m^3.

Conversion factor, normal cubic metres ⇔ kilogrammes:

Equation 1:

0.717 Nm3/kg (1.01325 bar, 0°C) = **0.67 Gg/10^{6}m^3** (20°C, 1 atmosphere) * **1.07 Nm^3/m^3**

A comparison with other countries is not possible in this category, as the exact quantities and composition of the converted coal products cannot be determined from the CRT tables. The IPCC Refinement 2019 (IPCC, 2019) has adopted Germany's approach for assessing production of hard coal coke, however.

3.3.1.4 Category-specific recalculations (1.B.1 all)

Minor recalculations have been made due to changes in statistics (energy balance).

3.3.1.5 Category-specific planned improvements (1.B.1 all)

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

3.3.2 Oil and natural gas and fugitive emissions from energy production (1.B.2)

This category is subdivided as follows:

Source category			Included emissions
1.B.2. Oil, natural gas and fugitive emissions from energy production			
	a	**Oil**	
		i) Exploration	Total emissions from exploratory drilling for oil and gas
		ii) Production	Fugitive emissions from oil production and from oil processing (separation of water and accompanying gases)
		iii) Transport	Emissions from transport of crude oil via pipelines and inland waterway tankers
		iv) Refining/storage	Emissions from the desulphurisation and refining of oil, the storage of crude oil and mineral oil products and the cleaning of storage tanks
		v) Distribution of oil products	Emissions from the distribution of petroleum products, refuelling processes and drip losses and cleaning tanks of transport vehicles
		vi) Abandoned wells	No data are yet available on emissions from abandoned wells, "NE" is therefore reported for this area.
		vii) Other	No emissions occur in this category, "NO" is therefore reported
	b	**Gas**	
		i) Exploration	The emissions are assigned to category 1.B.2.a.i, since they cannot be separated out, "IE" is therefore reported for this area.
		ii) Production	Fugitive emissions from natural gas production
		iii) Processing	Emissions from desulphurisation and processing of sour gas and from processing of town gas (until 1997)
		iv) Transport	Emissions from long-distance high-pressure pipelines, compressors, shut-off devices and underground gas storage (caverns and porous rock reservoirs)
		Distribution	Emissions from natural gas distribution and above-ground storage facilities
		vi) End users	Fugitive emissions from installations in the residential and commercial (small consumers) sector
		vii) Tanks of natural gas-powered vehicles	Fugitive leakage from tanks of natural gas-powered vehicles

Source category			Included emissions
		viii) Abandoned wells	No data are yet available on emissions from abandoned wells, "NE" is therefore reported for this area.
		ix) Other	No emissions occur in this category, "NO" is therefore reported
	c	**Venting and flaring**	
		i) Venting	
		- Oil	The emissions are included in the categories 1.B.2.a.iii and 1.B.2.a.v, "IE" is therefore reported for this area.
		- Gas	The emissions are included in the categories 1.B.2.b.iv and 1.B.2.b.v, "IE" is therefore reported for this area.
		- Combined	No emissions occur in this category, "IE" is therefore reported
		ii) Flaring	
		- Oil	Flaring emissions from oil production and refining
		- Gas	Flare emissions in natural gas production
		- Combined	No emissions occur in this category, "IE" is therefore reported

3.3.2.1 Oil (1.B.2.a)

KC	Category	Activity	EM of	1990 (kt CO2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
-/-	1 B 2 a, Fugitive Emissions from Oil	0	CO_2	477.63	0.04	387.01	0.06	-18.97
-/-	1 B 2 a, Fugitive Emissions from Oil	0	CH_4	275.47	0.03	23.60	0.01	-91.43
-/-	1 B 2 a, Fugitive Emissions from Oil	0	N_2O	0.28	0.01	0.23	0.01	-20.23

The category 1.B.2.a. "Oil" is not a key category.

3.3.2.1.1 "Oil, Exploration" (1.B.2.a.i)

Gas	Method used	Source for the activity data	Emission factors used
CO_2, CH_4	Tier 1	AS	D
NMVOC	Tier 2	AS	CS

3.3.2.1.2 Category description, "Oil, exploration" (1.B.2.a.i)

This category's emissions consist of emissions from activities of drilling companies and of other participants in the exploration sector. Gas and oil exploration takes place in Germany. The statistics do not distinguish between pure oil and natural gas drilling.

Activity data

Table 114: Number of exploratory wells (total for oil and natural gas)

1990	1995	2000	2005	2010	2015	2020	2022	2023	2024
12	17	15	23	16	18	12	7	12	18

(BVEG, 2024)

Emission factors

Table 115: Emission factors used for category 1.B.2.a.i

Gas	Emission factor	Method
CO_2	0.48 kg/No	Tier 1
CH_4	64 kg/No	Tier 1
NMVOC	576 kg/No	Tier 2

The emission factors were taken from the 2000 IPCC Good Practice Guidance (Penman et al., 2000); the factors given in the IPCC GL 2006 ((IPCC, 2006a): Table 4.2.4) refer to production quantities and not to exploratory wells. Therefore, these factors cannot be used.

3.3.2.1.2.1 Methodological issues of the category "Oil, exploration" (1.B.2.a.i)

According to the BVEG, virtually no fugitive emissions occur in connection with drilling operations, since relevant measurements are regularly carried out at well sites (methane sensors in wellhead protection structures, ultrasound measurements and annulus manometers), and since old/abandoned wells are backfilled and normally covered with concrete caps.

Since measurements are not available for the individual wells, a conservative approach is used whereby well emissions are calculated on the basis of the default factor pursuant to IPCC GPG 2000 (Penman et al., 2000) for carbon dioxide and methane using the Tier 1 method. For a conservative estimate, the total of the emission factors for "drilling", "testing" and "servicing" was used.

3.3.2.1.2.2 Uncertainties and time series consistency, category "Oil, exploration" (1.B.2.a.i)

The uncertainties in the activity data for oil and gas exploration have been quantified as +/- 5%. The emission factors are assigned the default uncertainties from the Good Practice Guidance 2000 +/- 25%.

For the activity data and the emission factors, a consistent source is used throughout the entire time series.

3.3.2.1.2.3 Category-specific QA/QC and verification, category "Oil, exploration" (1.B.2.a.i)

General quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

Due to a lack of country-specific data, an external assessment (Bender & Langer, 2009) was commissioned. In its source category analysis, the assessment concluded that the default factors are applicable to Germany. It was not possible to carry out a comparison with the results for other countries, because the relevant data lack basic comparability – for example, they use a range of units that are not mutually convertible.

3.3.2.1.3 "Oil, production and preprocessing" (1.B.2.a.ii)

Gas	Method used	Source for the activity data	Emission factors used
CO_2, CH_4	Tier 2	AS	CS
NMVOC	Tier 2	AS	CS

3.3.2.1.3.1 Category description, "Oil, production and preprocessing" (1.B.2.a.ii)

This category's emissions are produced in the petroleum industry's extraction (crude oil) and pre-treatment of raw materials (petroleum). Because Germany's oil deposits are old, oil production in Germany is highly energy-intensive (thermal extraction, operation of pumps to inject water into the deposit).

The pre-treatment of extracted petroleum (crude oil) in processing plants is designed to remove gases, water and salts from crude oil. The crude oils extracted directly from the boreholes do not meet the requirements for safe and trouble-free transport in pipelines due to their composition, as they contain impurities, gas and, above all, water. No substances are converted. Impurities – especially gases (petroleum gas), salts and water – are removed to produce crude oil of a suitable quality for transport in pipelines.

Activity data

Table 116: Extracted quantity of petroleum, in kt

1990	1995	2000	2005	2010	2015	2020	2022	2023	2024
3,606	2,959	3,113	3,573	2,516	2,414	1,907	1,705	1,636	1,627

(BVEG, 2024)

Emission factors

Table 117: Emission factors used for production and processing

Gas	Emission factor	Method
CO_2	94 g/m³	Tier 2
CH_4	68 g/m³	Tier 2
NMVOC	47 g/m³	Tier 2

3.3.2.1.3.2 Methodological issues of the category "Oil, production and preprocessing" (1.B.2.a.ii)

Emissions from extraction and processing are measured or calculated by the operators and published in the annual report of the Federal association of the natural gas, oil and geothermal energy industries (BVEG). The emission factors are determined from the reported emissions and the activity data shown in Table 114.

The emissions are calculated in accordance with the Tier 2 method.

3.3.2.1.3.3 Uncertainties and time series consistency in the category "Oil, production and preprocessing" (1.B.2.a.ii)

The uncertainties in this category are estimated at 5 to 10% for the activity rate and are based on estimates by experts from the BVEG and national experts.

The uncertainties for the emission factors in the category amount to 25%.

3.3.2.1.3.4 Category-specific QA/QC and verification for the category "Oil, production and preprocessing" (1.B.2.a.ii)

General quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

The emission factors that have been used are of the same order of magnitude as those provided in the 2006 IPCC Guidelines (IPCC, 2006a).

Table 118: IEF Conciliation Comparison with IPCC default values

Gas	CS emission factor used	IPCC GL 2006 (Table 4.2.4)	
	Units in [g/m³]	Units in [Gg/1000m³]	Units in [g/m³]
CO_2	94 g/m³	1.1*10-07 to 2.6*10-04	0.11 – 260.00
CH_4	68 g/m³	1.5*10-06 to 6.0*10-02	1.50 – 60,000
NMVOC	47 g/m³	1.8*10-06 to 4.5*10-03	1.80 – 4500.0

3.3.2.1.4 "Oil, Transport "(1.B.2.a.iii)

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 2	AS	CS
NMVOC	Tier 2	AS	CS

3.3.2.1.4.1 Category description, "Oil, transport" (1.B.2.a.iii)

Emissions in this category comprise activities carried out by logistics companies and operators of pipelines and pipeline networks. After the pre-treatment, crude oil is transported to refineries.

Almost all transports of crude oil take place via pipelines. Pipelines are stationary and normally run underground. Unlike other types of transports, petroleum transports are not interrupted by handling processes.

Activity data

Table 119: Transport of domestically produced crude oil in kt

1990	1995	2000	2005	2010	2015	2020	2022	2023	2024
3,606	2,959	3,113	3,573	2,516	2,414	1,907	1,705	1,636	1,627

(BVEG, 2024)

Table 120: Transport of imported crude oil in kt

1990	1995	2000	2005	2010	2015	2020	2022	2023	2024
84,043	86,063	89,280	97,474	93,270	91,275	83,049	88,169	77,198	84,026

(BAFA, 2025a)

Table 121: Crude oil transport on inland waterway tankers in kt

1990	1995	2000	2005	2010	2015	2020	2022	2023	2024
88.9	66.6	111.8	176.4	5.6	43.1	46.4	52.7	44.5	4.8

(Statistisches Bundesamt, 2025c)

Emission factors

Table 122: Emission factors used for category 1.B.2.a.iii, in [kg/t]

Source category	Gas	Emission factor
Transport of imported crude oil	NMVOC	0.064
	CH_4	0.0064
Transport of domestically produced crude oil	NMVOC	0.13

Source category	Gas	Emission factor
	CH_4	0.013
Crude oil transport via inland-waterway tankers	NMVOC CH_4	0.34 0.032

3.3.2.1.4.2 Methodological issues of the category "Oil, transport" (1.B.2.a.iii)

The emissions are calculated in accordance with the Tier 2 method.

The emission factors for methane in connection with pipelines were taken from the 2006 IPCC Guidelines 2006 (IPCC, 2006a). The factors for inland waterway tankers were confirmed in the research project "Determination of emission factors and activity data in areas 1.B.2.a.i through vi" ("Ermittlung von Emissionsfaktoren und Aktivitätsraten im Bereich 1.B.2.a.i bis vi" (Theloke et al., 2013). Since long-distance pipelines are constantly monitored and disruptive incidents in these pipelines are very rare (CONCAWE – "Performance of European cross country oil pipelines" (Cech et al., 2017)), emissions occur – in small quantities – only at their transfer points. The emission factor is thus highly conservative.

The emission factor includes handling/pumping at the pumping station and all infrastructure (connections, control units, measuring devices) along the pipelines, as well as handling at the refinery, and was determined using conservative assumptions. For imported quantities, only one transfer point (withdrawal station only) is assumed, since the station for input into the pipeline network is not within the national borders of Germany's.

3.3.2.1.4.3 Uncertainties and time series consistency in the category "Oil, transport" (1.B.2.a.iii)

The uncertainties for the emission factors were quantified as ±20%, while those for the activity data were quantified as ±10%. The emission factors and the activity data are consistent throughout the entire time series.

3.3.2.1.4.4 Category-specific QA/QC and verification for the category "Oil, transport" (1.B.2.a.iii)

General quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

The emission factors that have been used are of the same order of magnitude as those provided in the 2006 IPCC Guidelines.

In the 2016 ESD Review, it was noted that Germany reports no CO_2 emissions in this category, although the 2006 IPCC Guidelines specify a Tier 1 default value. In a telephone conversation between experts of the German Environment Agency and the Association of the German Petroleum Industry (MWV) (Bittkau, 2017), the MWV experts confirmed that no CO_2 emissions from transport pipelines occur.

The 2022 review (E13 Table 5) made repeated references to the IPCC Guidelines. They refer to the study (Harrison et al., 1999): "Methane Emissions from the U.S. Petroleum Industry". The study does not provide any information as to how the CO_2 emission factor originated. As Chapter 5.2.2 notes, however, natural gas industry data are used to estimate emission factors. For this reason, national experts assume that the emission factor given in the IPCC Guidelines is based on the CO_2 fraction present in natural gas.

3.3.2.1.5 "Oil, refining and storage" (1.B.2.a.iv)

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2	AS	CS
CH_4	Tier 2	AS	CS
SO_2	Tier 2	AS	CS
CO	Tier 2	AS	CS
NO_X	Tier 2	AS	CS
NMVOC	Tier 2	AS	CS

3.3.2.1.5.1 Category description, "Oil, refining and storage" (1.B.2.a.iv)

The emission in this category consist of emissions from activities of refineries and of refining companies in the petroleum industry. Crude oil and intermediate petroleum products are processed in Germany. For the most part, the companies receive crude oil for refining and processing. Processing takes place in state-of-the-art plants.

Refinery tank storage systems are used to store both crude oil and intermediate and finished petroleum products. They are therefore different from non-refinery tank storage systems in terms of both the products they store and the quantities they handle. Tank storage facilities outside of refineries are used especially for interim storage of heating oil, gasoline and diesel fuel. The storage capacities of caverns used for storing petroleum products are listed separately. Due to the structures of the caverns, it can be assumed that no emissions of volatile compounds occur. This is taken into account in the emissions calculation.

Tanks are emptied and cleaned for tank inspections and repairs. In tank cleaning, a distinction is made between crude oil tanks and product tanks. Because of the sediment deposits, cleaning crude oil tanks is more labour-intensive than cleaning product tanks. Product tanks contain no sedimentable substances and are thus cleaned only when the products they contain are changed. Emissions are calculated according to an estimate by (Zimmermann et al., 2025)

Activity data

Table 123: Quantity of refined crude oil, in kt

1990	1995	2000	2005	2010	2015	2020	2022	2023	2024
107,058	96,475	107,632	114,589	95,378	93,391	83,990	89,312	79,153	85,274

(BAFA, 2025a; En2x, 2024)

Table 124: Capacity utilisation rate of refineries, in percent

1990	1995	2000	2005	2010	2015	2020	2022	2023	2024
106.2	92.1	95.3	99.5	81.1	91	81.8	84.5	75.7	82.9

(En2x, 2024)

Table 125: Crude oil refining capacity in refineries, in kt

1990	1995	2000	2005	2010	2015	2020	2022	2023	2024
100,765	104,750	112,940	115,630	117,630	103,080	105,655	105,655	104,086	102,943

(En2x, 2024)

Table 126: Storage capacity of tank storage facilities in refineries and pipeline terminals, in millions of m³

1990	1995	2000	2005	2010	2015	2020	2023	2024
27.2	28.4	24.9	24.0	22.5	22.1	20.7	21.1	21.1

(Koj, 2024)

Table 127: Storage capacity of tank storage facilities outside of refineries, in millions of m³

1990	1995	2000	2005	2010	2015	2020	2023	2024
15.4	15.9	18.1	17.0	15.95	15.3	15.3	15.0	15.0

(Koj, 2024)

Table 128: Storage capacity of caverns, in millions of m³

1990	1995	2000	2005	2010	2015	2020	2023	2024
26.6	25.3	27.9	27.2	27.3	25.5	25.5	28.3	28.3

(Koj, 2024)

Emission factors

Table 129: Emission factors used for category 1.B.2.a.vi, "Fugitive emissions at refineries"

Gas	Emission factor	Method
CH_4	0.225 g/t	Tier 2
CO	0.494 g/t	Tier 2
CO_2	537 g/t	Tier 2
SO_2	0.854 g/t	Tier 2
NMVOC	7.24 g/t	Tier 2
NO_X	6.02 g/t	Tier 2

Table 130: Emission factor used for category 1.B.2.a.vi, "Anode production at refineries"

Gas	Emission factor	Method
CO_2	159.8 kg/t	Tier 2

Several research projects have shown that emissions from cleaning transport vehicles and storing products have been overestimated. The origin of the factors was outlined in the accompanying report "Aktualisierung der VOC-Emissionen für die Bereitstellung von Mineralölprodukten" ("Update of VOC emissions for the supply of petroleum products" (Böttcher, 2025)).

3.3.2.1.5.2 Methodological issues of the category "Oil, refining and storage" (1.B.2.a.iv)

The emissions for all sub-areas are calculated in accordance with the Tier 2 method.

Further processing

The emission factors used for NMVOC, CH_4, CO_2, CO, NO_x and SO_2 were determined by evaluating the emissions declarations of the period 2004 to 2016 in a research project (Bender & von Müller, 2019a).

Anode production

The activity data are calculated from the quantity of petroleum coke, minus own consumption (coke burn-off in catalyst regeneration – cf. 1.A.1.b). The data were obtained from the Official Mineral Oil Statistics. This "green coke" is processed via calcining. The emission factor is calculated from the activity data and the emissions data of the EU Emissions Trading System (ETS).

Tank storage facilities in refineries

In accordance with the results of the research project "Processing of data of emissions declarations pursuant to the 11th Ordinance on the Implementation of the Federal Immission Control Act – the area of storage facilities" ("Aufbereitung von Daten der Emissionserklärungen gemäß 11. BImSchV - Bereich Lageranlagen") (Bender, 2009), the crude oil distillation capacity is used as the activity data for estimation of emissions from storage in refineries. The fugitive VOC emissions value specified in VDI Guideline 2440 (VDI, 2000, p. 82), 0.16 kg/t, can be used as the emission factor. The EF for methane was derived from it (5-10% of 0.16 kg) and then deducted accordingly (Theloke et al., 2013).

Tank storage facilities outside of refineries

According to Müller-BBM (Bender, 2009), it is not possible to derive emission factors that are representative of individual storage facilities based on the evaluation of emission declarations for storage facilities, as the emission behaviour of the individual facilities varies greatly. However, aggregate emission factors were calculated by relating the total emissions for each data set to the total capacities. For tank storage facilities outside of refineries, distinctions can be made between the storage of liquid and gaseous petroleum products, as the available data is differentiated accordingly. Studies by (Zimmermann et al., 2025) have estimated the cleaning emissions. This is illustrated by an example from a report covering one year (Böttcher, 2025). While fuels are reported under 1.B.2, chemical products are reported under 2.B.10.

Claus plants

The emission factors used for NMVOC, CO, NO_x and SO_2 were determined by evaluating the emissions declarations of the period 2004 through 2016 in a research project (Bender & von Müller, 2019a). Since no data were available for earlier years, the data so obtained were used for all years as of 1990.

3.3.2.1.5.3 Uncertainties and time series consistency in the category "Oil, refining and storage" (1.B.2.a.iv)

Uncertainties of +/- 20% are assumed for the emission factors for refining of crude oil. The uncertainties for the activity data are assumed to be +/- 10%. The total uncertainties of the emission factors for storage and cleaning are estimated at 177% and 65% for the activity rates. These figures are based on estimates of national experts, as well as on the research report of Müller BBM, (Bender, 2009), (Theloke et al., 2013) and (Böttcher, 2025).

The emission factors and the activity data are consistent throughout the entire time series.

3.3.2.1.5.4 Category-specific QA/QC and verification for the category "Oil, refining and storage" (1.B.2.a.iv)

General quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

Due to the complexity of the category, the data cannot be cross-checked against those of other countries. This was also confirmed at the 2014 EU Workshop (Harthan et al., 2017).

3.3.2.1.6 "Oil, distribution of oil products" (1.B.2.a.v)

Gas	Method used	Source for the activity data	Emission factors used
NMVOC	Tier 2	AS	CS

3.3.2.1.6.1 Category description, "Oil, distribution of oil products" (1.B.2.a.v)

The category comprises transports and handling of petroleum products, via inland´ waterway tankers, pipelines, railway tank cars, road tankers and canisters, as well as cleaning of transport vehicles.

Activity data

Table 131: Filling stations in Germany (number)

1990	1995	2000	2005	2010	2015	2020	2022	2023	2024
19,317	17,957	16,324	15,187	14,744	14,531	14,459	14,452	14,442	14,376

(BTF; En2x, 2024)

Table 132: Distributed quantities of petroleum products, in kt

	1990	1995	2000	2005	2010	2015	2020	2022	2023	2024
Diesel fuel	21,817	26,208	28,922	28,531	32,128	36,756	35,163	34,761	33,279	32,455
Jet fuel	4,584	5,455	6,939	8,049	8,465	8,550	4,725	8,952	9,479	9,016
Light heating oil	31,803	34,785	27,875	25,380	21,005	16,127	15,558	12,128	11,493	10,736
Gasoline	31,257	30,333	28,833	23,431	19,634	18,226	16,218	16,996	17,394	17,650

(BAFA, 2025a)

Emission factors

The emission factors listed below were verified in the studies (Theloke et al., 2013) and (Zimmermann et al., 2025). The model used to calculate gasoline emissions is described in Chapter (Zimmermann et al., 2025).

Petroleum products are transported by inland waterway tanker ships, product pipelines, railway tank cars and road tankers, and transferred from tanks to other tanks. Experts consider the emissions from refuelling of aircraft to be non-existent, since the equipment used for refuelling is fitted with dry couplings. The emissions from filling private heating oil tanks are also very low thanks to high safety standards.

In this category, petroleum products are handled and distributed that have undergone fractional distillation in refineries, i.e. processes in which gaseous products are separated out – no significant methane emissions are expected as a result. Only small amounts of methane can escape during storage of some mineral oil products. To avoid underestimation, methane content of 5% was assumed in all categories. This is explained in the accompanying report (Böttcher, 2025).

Table 133: NMVOC emission factors 1.B.2.a.v "Gasoline distribution"

Process responsible for emissions	EF in [kg/TJ]	Method
Drip losses when refuelling at filling stations	0.117 kg/t	Tier 2
Transfers from road tankers to filling stations (20th Ordinance on the Implementation of the Federal Immission Control Act – vapour displacement)	1.4[32] kg/t	M (Tier 2)
Ventilation during transport by inland waterway tankers	0.025 kg/t	Tier 2
Transfers from filling station tanks to vehicle tanks (21st Ordinance on the Implementation of the Federal Immission Control Act – vapour recovery)	1.4 kg/t	M (Tier 2)

Table 134: NMVOC emission factors for 1.B.2.a.v "Diesel distribution"

Process responsible for emissions	EF in [kg/TJ]	Method
Drip losses in refuelling at filling stations	0.1 kg/t	Tier 2
Transport from refineries to transport vehicles	0.008 kg/t	Tier 2
Transfer from filling station tanks to vehicle tanks	0.003 kg/t	Tier 2

Table 135: NMVOC emission factors for 1.B.2.a.v "Light heating oil distribution"

Process responsible for emissions	EF in [kg/TJ]	Method
Drip losses in refuelling at transfer stations	0.0011 kg/t	Tier 2
Transport from refineries to transport vehicles	0.0053 kg/t	Tier 2
Transfer from filling station tanks to vehicle tanks	0.0063 kg/t	Tier 2

Table 136: NMVOC emission factors for 1.B.2.a.v "Kerosene distribution"

Process responsible for emissions	EF in [kg/TJ]	Method
Drip losses in refuelling at transfer stations	0 kg/t	Tier 2
Transport from refineries to transport vehicles	0.055 kg/t	Tier 2
Distribution from filling station tank to vehicle tank	0.02 kg/t	Tier 2

Table 137: NMVOC emission factors for 1.B.2.a.v "Cleaning"

Process responsible for emissions	EF in [g/t][33]	Method
Cleaning of road tankers	1.1 g/t	Tier 2
Cleaning of rail tank cars	0.47 g/t	Tier 2
Cleaning of inland waterway tankers	18.8 g/t	Tier 2

3.3.2.1.6.2 Methodological issues of the category "Oil, distribution of oil products" (1.B.2.a.v)

Transport

After gasoline has been transported by inland waterway tankers, considerable quantities of gasoline vapours remain in their tanks after the gasoline is unloaded. When the ships change loads or spend time in port, their tanks have to be ventilated (Bauer et al., 2010).

[32] The factor does not include reduction measures – cf. Table 138

[33] The reference figure is the total quantity of gasoline transported in Germany with the type of vehicle.

The gasoline fuels transported and handled in Germany on railway tank cars produce annual emissions of about 1,400 t VOC (Joas et al., 2004). The logistics chain comprises filling tank cars, transport and emptying and cleaning tank cars. It can be assumed that the emissions from transporting and emptying tank cars are negligible.

Half of the filling stations are supplied directly from refineries by road tankers, while the other half are supplied through temporary storage facilities, although one in three of these temporary storage facilities is supplied by pipelines (von Winkler, 2004).

As a means of transport, pipelines produce no significant emissions (von Winkler, 2004). Pursuant to the German Society for Petroleum and Coal Science and Technology (DGMK), the fugitive emissions that occur at pipeline pumps or flanges are negligible (Theloke et al., 2013).

Filling stations

Significant quantities of fugitive VOC emissions are released into the environment during transfers from tanker vehicles to storage facilities and during refuelling of vehicles. A standardised emission factor of 1.4 kg/t is used to determine the emissions. This refers to the saturation concentration for hydrocarbon vapours – and thus corresponds to the maximum possible emissions level in the absence of reduction measures.

The immission control regulations issued in 1992 and 1993 (BMJ & BfJ, 2017a, 2017b) that required filling stations to limit these emissions promoted a range of reduction measures. These measures affect both the transfer and storage of gasoline (BMJ & BfJ, 2017a) and the fuelling of vehicles with gasoline at filling stations (BMJ & BfJ, 2017b).

The use of prescribed mitigation technologies such as vapour balancing (20th Ordinance on the Implementation of the Federal Immission Control Act, (BMJ & BfJ, 1998b)) and vapour recovery (21st Ordinance on the Implementation of the Federal Immission Control Act, (BMJ, 1992)) systems, along with use of automatic monitoring systems (with the amendment of the 21st Ordinance on the Implementation of the Federal Immission Control Act on 6 May 2002), led to a steady decline in VOC emissions, which is reflected in the degree of use (Table 138).

The degree of use and efficiency stipulated in the two ordinances are taken into account when calculating emissions for filling stations. The following assumptions are made based on the technical options currently available:

Table 138: Requirements for use and efficiency for filling stations of the 20th and 21st Ordinances on the Implementation of the Federal Immission Control Act (BImSchV)

Ordinance		Factor	
20st BImSchV	Vapour balancing	Degree of use	98%
		Degree of efficiency	98%
21st BImSchV	Vapour recovery	Degree of use	98%
		Degree of efficiency	85%

The emissions are calculated with the following formula:

Equation 2:

Emissions = activity data * unreduced emission factor (from Table 133) * (level of use * (1 - efficiency) + (1 - level of use))

In addition, permeation of hydrocarbons occurs in tank hoses. The DIN EN 1360 standard sets a limit of 12 ml/hose meter per day for this permeation. Based on evaluations of measurements, experts at the German Environment Agency have assumed a conservative factor of 10 ml/m per day. This factor is used to determine the NMVOC emissions. The calculation is carried out in accordance with the formula of the University of Stuttgart's Institute for Machine Components (Haas, 2015):

Equation 3:

Number of service stations * number of fuel pumps per service station * number of hoses per fuel pump * hose length * emission factor

Refuelling from canisters

Refuelling of recreational motorboats by pouring fuel from canisters into fuel tanks releases small quantities of fugitive VOC emissions into the environment. As with filling stations, a standard emission factor of 1.4 kg/t is used to determine emissions, calculated from the saturation concentration of hydrocarbon vapours and thus the maximum possible emission quantity. The following assumptions are also made: the average canister volume is 15 l; the drip loss is 1 kg/t (estimation): 0.24% of the country's population owns a motorboat in Germany (Mell, 2008); a total of 1.9 million refuelling operations take place per year. The calculations exclude all instances of refuelling at filling stations for boats – emissions from such refuelling are already included in the "filling stations" category.

Cleaning of transport vehicles

The interior of the tank is cleaned before repair work, before safety inspections, when changing products or when leasing agreements are changed. A detailed description of the individual cleaning processes and the breakdown by fuel and chemical products can be found in the accompanying report (Böttcher, 2025).

3.3.2.1.6.3 Uncertainties and time series consistency in the category "Oil, distribution of oil products" (1.B.2.a.v)

The uncertainties in the category are specified for the emission factors with 177% log normal distribution and quantified for the activity rates at 65% (Theloke et al., 2013).

3.3.2.1.6.4 Category-specific QA/QC and verification for the category "Oil, distribution of oil products" (1.B.2.a.v)

General quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

The data cannot be compared with those of other countries, since the CRT tables do not indicate what factors influenced the reported emissions.

3.3.2.2 Natural gas (1.B.2.b)

KC	Category	Activity	EM of	1990 (kt CO2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
-/-	1 B 2 b, Fugitive Emissions from Natural Gas	0	CO_2	986.72	0.08	398.54	0.06	-59.61
L/T	1 B 2 b, Fugitive Emissions from Natural Gas	0	CH_4	9892.63	0.77	1732.86	0.25	-82.48

The category 1.B.2.b "Natural gas" is a key category of CH_4 emissions in terms of emissions level and trend.

3.3.2.2.1 "Natural gas, exploration" (1.B.2.b.i)

Gas	Method used	Source for the activity data	Emission factors used
CH_4	IE	IE	IE
NMVOC	IE	IE	IE

3.3.2.2.1.1 Category description, "Natural gas, exploration" (1.B.2.b.i)

Category 1.B.2.b.i is considered together with category 1.B.2.a.i (Oil, exploration). Consequently, the aggregated, non-subdivided data of 1.B.2.b.i are included in category 1.B.2.a.i.

3.3.2.2.1.2 Methodological issues of the category "Natural gas, exploration" (1.B.2.b.i)

The possibility of breaking exploration down into oil exploration and natural gas exploration was reviewed (Herold et al., 2014), but then abandoned due to a lack of statistics and very small emissions quantities. The emissions are thus listed completely, for both oil exploration and gas exploration, under 1.B.2.a.i.

3.3.2.2.1.3 Uncertainties and time series consistency of the category "Natural gas, exploration" (1.B.2.b.i)

See 1.B.2.a.i. for explanations of uncertainties and time series consistency.

3.3.2.2.1.4 Category-specific QA/QC and verification, category "Natural gas, exploration" (1.B.2.b.i)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

3.3.2.2.2 "Natural gas, production" (1.B.2.b.ii)

Gas	Method used	Source for the activity data	Emission factors used
CO_2, CH_4	Tier 2	AS	CS
NMVOC	Tier 2	AS	CS

3.3.2.2.2.1 Category description, "Natural gas, production" (1.B.2.b.ii)

The emissions of this category consist of emissions related to production. The 2021 annual report of the Federal association of the natural gas, oil and geothermal energy industries (BVEG) notes that reserves are declining due to depleted deposits and low exploration activity (BVEG, 2022).

Activity data

Table 139: Extracted quantity of natural gas, in billions of m^3

1990	1995	2000	2005	2010	2015	2020	2022	2023	2024
15.3	19.1	20.1	18.8	12.7	8.6	5.2	4.8	4.3	4.2

(BVEG, 2024)

Emission factors

Table 140: Emission factors used for production

Gas	Emission factor	Method
CO_2	0.13 g/m³	Tier 2
CH_4	0.02 g/m³	Tier 2
NMVOC	0.002 g/m³	Tier 2

3.3.2.2.2.2 Methodological issues of the category "Natural gas, production" (1.B.2.b.ii)

The BVEG has been determining and publishing production emissions annually since 1998. For the period prior to 1998, the emissions were determined using default factors from the 2006 IPCC Guidelines. The emissions are calculated in accordance with the Tier 2 method.

3.3.2.2.2.3 Uncertainties and time series consistency of the category "Natural gas, production" (1.B.2.b.ii)

In this category, the uncertainty for the activity data is given as 5%. The figures are based on estimates of BVEG experts and national experts.

The uncertainties for the emission factors in the category amount to 25%.

3.3.2.2.2.4 Category-specific QA/QC and verification, category "Natural gas, production" (1.B.2.b.ii)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

Natural gas producers report their methane emissions to comply with the EU Methane Regulation (EU, 2024a). However, at the time this report was written, this data had not yet been evaluated.

The emission factors that have been used are of the same order of magnitude as those provided in the 2006 IPCC Guidelines.

Table 141: IEF Conciliation Comparison with IPCC default values

Gas	CS emission factor used	IPCC GL 2006 (Table 4.2.5)	
	Units in [g/m³]	Units in [Gg/10 6 m³]	Units in [g/m³]
CO_2	0.13 g/m³	$1.4*10^{-05}$ to $1.8*10^{-04}$	0.014 – 0.18
CH_4	0.02 g/m³	$3.8*10^{-04}$ to $2.4*10^{-02}$	0.380 – 24.0
NMVOC	0.002 g/m³	$9.1*10^{-05}$ to $1.2*10^{-03}$	0.091 – 1.20

3.3.2.2.3 Natural gas, processing (1.B.2.b.iii)

Gas	Method used	Source for the activity data	Emission factors used
CO_2, CH_4	Tier 3	AS	CS
CO	Tier 2	AS	CS
SO_2, NMVOC	Tier 2, Tier 3	AS	CS

3.3.2.2.3.1 Category description (1.B.2.b.iii)

Emissions in this category consist of activities related to pre-treatment and processing.

Natural gas extracted from deep underground is first treated in above-ground drying and processing plants. This pre-treatment of natural gas usually takes place in facilities at the production station. This separates out any associated reservoir water, liquid hydrocarbons and solids. Glycol is then used to remove the water vapour remaining in the gas ((WEG, 2008))[34]: p. 25). Natural gas dehydration systems are self-contained systems in which all overpressure protection devices are integrated into a flare system for safety reasons. When these protection devices are triggered, the surplus gas is guided to a flarehead, where it can be safely burned. After drying, the natural gas is ready for sale and can be delivered to customers directly by pipeline (EXXON, 2014). The relevant quantities of flared gas are reported under 1.B.2.c.

The natural gas taken from Germany's Zechstein geological formation contains hydrogen sulphide. In this original state, the gas – known as "sour gas" – has to be subjected to special treatment. This gas is transported via separate, specially protected pipelines (due to the hazardousness of hydrogen sulphide) to German processing plants that wash out its hydrogen sulphide via chemical and physical processes. About 40% of the natural gas extracted in Germany is sour gas (WEG, 2008).

The natural gas that leaves processing plants is ready for use. The hydrogen sulphide is converted into elementary sulphur and is used primarily by the chemical industry as a basic raw material.

The quantities of natural gas being produced and the country's natural gas deposits have been declining for decades now. The reasons for this include depletion of deposits and a lack of new exploration; cf. (BVEG, 2022).

Biogas/Biomethane

Production of biogas is reported under CRF 3.B. This biogas is used directly on site for electricity generation (emissions are reported under CRF 1.A); in addition, it is fed into the gas network as biomethane. Prior to being fed into the gas network, it has to be processed to meet natural gas standards (emissions are reported under CRF 3.B). Pursuant to the 2006 IPCC Guidelines, fossil and biogenic fractions of methane are not differentiated. For this reason, no fossil-biogenic differentiation is provided in CRF 1.B.2.

Activity data

Table 142: Sulphur production from natural gas production in Germany, in kt

1990	1995	2000	2005	2010	2015	2020	2022	2023	2024
915	1,053	1,100	1,050	832	628	353	371	277	280

(BVEG, 2024)

Figures for natural gas production are listed in Table 139 in Chapter 3.3.2.2.2.1.

Emission factors

Table 143: Emission factors used for 1.B.2.b.iii "Processing"

Gas	Emission factor	Method
NMVOC	0.003 g/m³	Tier 3
CH_4	0.05 g/m³	

[34] WEG 2008a: Erdgas-Erdöl, Entstehung-Suche-Förderung, Hannover, 34 pp.

Gas	Emission factor	Method
CO_2	341 g/m³	

3.3.2.2.3.2 Methodological issues (1.B.2.b.iii)

The emissions were calculated in keeping with the Tier 3 method.

For processing of sour gas, data of the BVEG (the former WEG) for the period since 2000 are used. These data are the result of the association members' own measurements and calculations. For the period prior to 2000, the average CO_2 emission factor reported by Austria, 0.23 t/1,000 m^3, is used since, according to the BVEG, the German desulphurisation plant is comparable to the Austrian plant.

A split factor of 0.4 based on the activity rate is used to calculate emissions from sour gas treatment. This split factor, which is based on the WEG report on sour gas processing(WEG, 2008), was confirmed again in 2023 after consultation with BVEG (Böttcher & Lillie, 2023).

3.3.2.2.3.3 Uncertainties and time series consistency (1.B.2.b.iii)

For the emissions data, the category uncertainties are given as 10 to 30%. These figures are based on estimates of national experts and are within the range listed for relevant default emission factors ((IPCC, 2003), Chapter 2.7.1.6.).

3.3.2.2.3.4 Category-specific QA/QC and verification (1.B.2.b.iii)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

Table 144: Comparison of national IEFs with IPCC default values

Source	CS emission factor used	IPCC GL 2006 (Table 4.2.4)[35]	
	in [g/m³]	in [Gg/10⁶m³]	in [g/m³]
CO_2	341	$7.9*10^{-06}+ 3.6*10^{-3}+ 6.3*10^{-2}$	66.608
CH_4	0.05	$9.7*10^{-05} + 2.4*10^{-6}$	0.099
NMVOC	0.003	$6.8*10^{-05} + 1.9*10^{-6}$	0.068

A comparison with the IPCC default factors (IPCC, 2006a) shows that the national emission factors for methane are within the range given for the default factors. However, the figure for carbon dioxide exceeds this value significantly, although Germany's is of the same order of magnitude as Austria's (Table 145). The discrepancies with the IPCC default values result in that the German emission factors include the relevant sulphur production. Pursuant to the BVEG, one sixth of the emissions may be ascribed to sulphur production.

Table 145: Comparison of emission factors for carbon dioxide (2022) in [g/m³]

Source	CS emission factor
Austria	269
Germany	340

[35] Addition of fugitive emissions, flare emissions and raw-CO_2 venting

A comparison with other countries could not be carried out because the CRT tables do not show what proportion of processed natural gas can be attributed to sour gas.

3.3.2.2.4 Gas, transmission (1.B.2.b.iv)

Gas	Method used	Source for the activity data	Emission factors used
NMVOC; CO_2; CH_4	Tier 3	AS	CS

3.3.2.2.4.1 Category description (1.B.2.b.iv)

The emissions in this source category comprise emissions from the activities of gas suppliers. In Germany, natural gas is transported from production and processing companies/plants to gas suppliers and other processors. In addition, natural gas is imported and transported via long-distance pipelines.

Only steel pipelines are used to transport natural gas (Zöllner, 2014).

Activity data

Table 146: Length of long-distance high-pressure pipelines, in [km]

1990	1995	2000	2005	2010	2015	2020	2023	2024
22,696	29,866	32,214	34,086	35,503	34,270	33,809	34,035	34,035

Own enquiry submitted to FNB Gas, the association of supra-regional gas transmission companies in Germany

Part of the natural gas is temporarily stored in underground storage facilities to ensure security of supply.

Table 147: Underground gas storage volume, in [billions of m³]

	1990	1995	2000	2005	2010	2015	2020	2023	2024
Cavern reservoirs	2.8	4.8	6.1	6.8	9.2	14.3	15.1	14.3	14.0
Porous rock reservoirs	5.2	8.5	12.5	12.4	12.1	9.8	8.6	8.6	8.6

(BVEG, 2024)

Compressors, which are used approximately every 100 kilometres to maintain pressure in the pipelines, are a significant source of emissions (GASUNIE, 2014). The pipelines are also fitted with shut-off devices (sliding sleeves) located along the high-pressure pipelines and gas pressure regulating (measuring) systems.

Tools known as pipeline inspection gauges ("pigs") are used to inspect and clean the pipelines. In a pipeline system, a pig moves, driven by the gas flow, from a launching station to a receiving station (pig trap). Systems for launching and catching pigs can be either fixed or portable. Small amounts of methane are emitted during both filling and emptying. In addition, pig traps may have leaks, but these are checked regularly and repaired if necessary. Not all types of pipelines can be pigged; diameter reductions, isolation valves, bends, etc. in pipelines can block passage. These emissions have been estimated as part of a study carried out by DBI Gas- und Umwelttechnik GmbH (Grosse, 2021).

LNG terminals

The first Floating Storage and Regasification Unit (FSRU) terminal went into operation on 17 December 2022. Two more went into operation in 2023 and 2024.

Emission factors

In Germany, natural gas extracted from production fields and local production stations (onshore and offshore) as well as imported natural gas is mainly transported via pipelines.

FSRU and LNG operators report their methane emissions to comply with the EU Methane Regulation (EU, 2024a). At the time the report was written, not all operator data was available, so the reported data was used to make an estimate. The emission factor calculated using this method is 30,124 kg CH_4 per station.

According to Deutsche Re-Gas, there are no flaring systems at German LNG terminals. All CO_2 emissions are reported in the ETS and are therefore already covered by 1.A.1.c. As a safety device, the boil-off gas is not blown out, but is captured and used for vessel propulsion.

The emission factors for the underground gas storage facilities were determined by (Bender & Langer, 2012) and extrapolated to 2023 using a reduction factor (Böttcher, 2022) (Chapter 5.3). Underground storage facility operators (EU, 2024a) report their methane emissions to comply with the EU Methane Regulation (see Table 148). The emission factor for 2024 is 0.05 kg CH_4 per 1000 m^3 of storage.

Table 148: Emissions of the underground storage facility operators pursuant to the EU Methane Regulation

Asset	OGMP category	Emissions
Compressor Stations (Injection/Withdrawal)	2.1	941.1 t
Treatment & Wells & Dehydrators	2.2	178.6 t

Long-distance gas network operators report their methane emissions to comply with the EU Methane Regulation (EU, 2024a). The following data were submitted:

Table 149: Emissions of the long-distance gas network operators pursuant to the EU Methane Regulation

Asset	OGMP category	Emissions
Long-distance lines	1.1	1,020 t
Compressors	1.2	2,755 t
Control systems	1.3	2,771 t

The NMVOC and CO_2 emission factors were determined using split factors from the gas composition described by (Lubenau & Schuetz, 2014) and (Böttcher, 2022) (Chapter 6).

3.3.2.2.4.2 Methodological issues (1.B.2.b.iv)

The requirements of the EU Methane Regulation (EU, 2024a) correspond to the Tier 3 approach under the UNFCCC.

3.3.2.2.4.3 Uncertainties and time series consistency (1.B.2.b.iv)

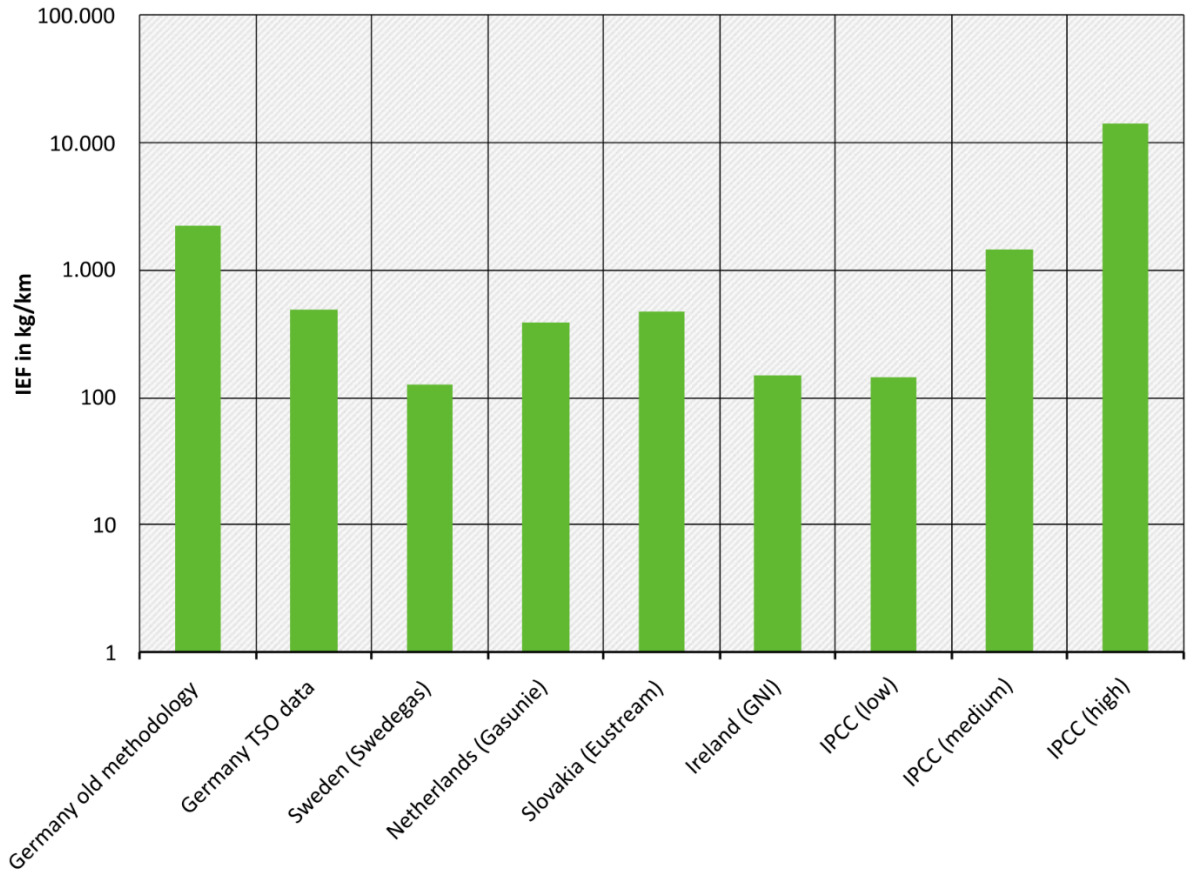
For the emissions data, the category uncertainties are given as 10 to 50%.

3.3.2.2.4.4 Category-specific QA/QC and verification (1.B.2.b.iv)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

A comparison of the category with the relevant IPCC default factors (Table 4.2.8) indicates that the emission factors for methane lie within the specified range. In comparison with neighbouring countries that have carried out similar measurement programmes, Germany ranks in the upper mid-range (cf.).

Figure 41: Comparison with international IEFs for methane from 1.B.2.b iv Logarithmic representation; reference to the year 2020



Data of the IPCC (Volume 2, Chapter 4 – Table 4.2.8) converted from m³/a into kg/a, with a density of 0.717 kg/m³
Source: Background paper (Böttcher, 2022), German Environment Agency

3.3.2.2.5 Natural gas, distribution (1.B.2.b.v)

Gas	Method used	Source for the activity data	Emission factors used
NMVOC; CO_2; CH_4	Tier 3	AS	CS

3.3.2.2.5.1 Category description (1.B.2.b.v)

Emissions caused by gas distribution have fallen significantly despite a considerable increase in gas throughput and a distribution network that is significantly larger than in 1990. One important reason for this improvement is that the gas distribution network has been modernised. In particular, the share of grey cast iron lines in the low-pressure network was reduced and replaced by low-emissions plastic pipelines. Another reason for the reduction is that fugitive losses in distribution were reduced through technical improvements (tightly sealing fittings such as flanges, valves, pumps, compressors) following implementation of emission control requirements from regulations ((TA Luft, 1986) and (TA Luft, 2002)).

Activity data

Table 150: Gas distribution network, figures in km

Parameter	1990	1995	2000	2005	2010	2015	2019	2020	2023	2024
Total length of pipeline network[36]	282,612	366,987	362,388	402,391	471,886	474,570	489,100	503,543	527,000	557,000

(BNetzA & BKartA, 2025)

3.3.2.2.5.2 Methodological issues (1.B.2.b.v)

Pipeline network

The calculation was carried out using the Tier 3 method on the basis of the pipeline length data available in the monitoring report (BNetzA & BKartA, 2025) and the breakdown by supply and grid connection lines given in the GaWaS online application (Grosse, 2023). In the early 1990s, emissions from distribution of town gas were also taken into account in calculations. In 1990, the town gas distribution network accounted for a total of 16% of the entire gas network. Of that share, 15% consisted of grey cast iron lines and 85% consisted of steel and ductile cast iron lines.

The emission factors originate from a study conducted by the DVGW (German Technical and Scientific Association for Gas and Water) (Große et al., 2022).

Distribution network operators report their methane emissions to comply with the EU Methane Regulation (EU, 2024a). At the time of writing, not all operator data was available. Due to the large number of companies and the highly heterogeneous reports, it was not possible to extrapolate data. The data were not used as a result.

Storage facilities

Man-made, above-ground storage facilities are suitable for the storage of medium-sized quantities of natural gas, and meeting and balancing rapid fluctuations in demand. In Germany, spherical and pipe storage tanks and other types of low-pressure containers are used for this purpose. Results from a research project (Bender & Langer, 2012) have made it possible to derive new country-specific emission factors for this area. The emissions were calculated in accordance with the Tier 2 method.

3.3.2.2.5.3 Uncertainties and time series consistency (1.B.2.b.v)

The uncertainties for emissions in this category range from 44% to 112%(Große et al., 2022) (Chapter 5.2.4).

The uncertainties for the activity data are influenced primarily by pipeline length. There are several statistics in Germany, some of which differ considerably (cf. comparison Table 151).

Table 151: Comparison of the pipeline length of various statistics for the year 2020

	Pipeline length	Source
BDEW	492,500 km	Website[37]
BNetzA	522,000 km	Monitoring report [38]

[36] The data provided include building connection lines

[37] https://www.bdew.de/service/daten-und-grafiken/gasnetzentwicklung-deutschland/

[38] https://www.bundeskartellamt.de/SharedDocs/Publikation/DE/Berichte/Energie-Monitoring-2020.html

	Pipeline length	Source
DVGW	412,992 km	Data query [39]
UBA	503,543 km	BDEW data for 2018 have been extrapolated, with average rates of capacity addition

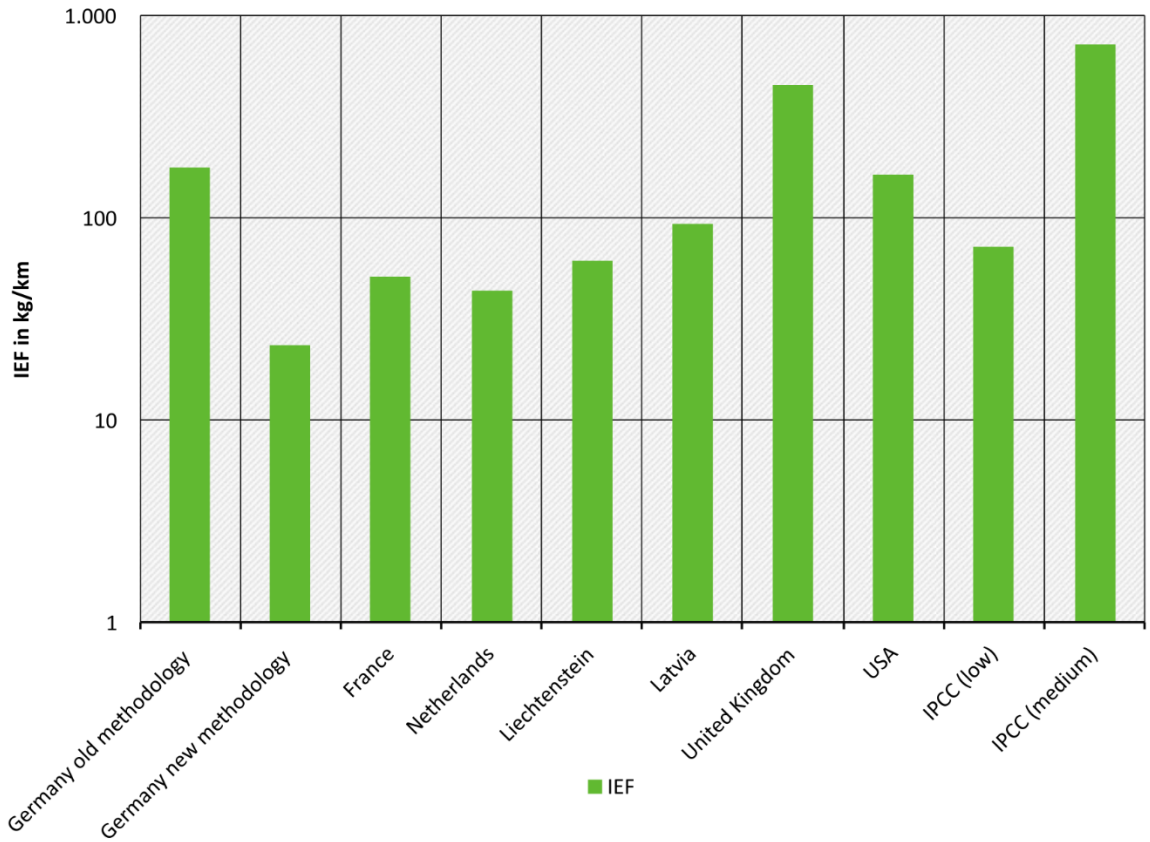
To make a conservative estimate, the data from the monitoring report is used, but with an uncertainty of 25%.

3.3.2.2.5.4 Category-specific QA/QC and verification (1.B.2.b.v)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

Böttcher (2022) (Chapter 4.3) compared the results of this category with other countries. The comparison found that the implied emission factor is quite low overall (Figure 42). However, it must be noted that Germany lists "post-meter" emissions separately, under 1.B.2.b.vi. When these emissions are taken into account, Germany's IEF lies within the range for neighbouring countries.

Figure 42: Comparison with international IEFs for methane from 1.B.2.b v



Logarithmic presentation; reference to the year 2020; Data of the IPCC (Volume 2, Chapter 4 – Table 4.2.8) converted from m³/a into kg/a, with a density of 0.717 kg/m³

Source: Own description, German Environment Agency

[39] Total of NAL and VL from Grosse, C. (2022). *Qualitätsprüfung der Texte für die nationalen Inventarberichte 2023 und 2024 und Datenerhebung in der Quellgruppe 1.B.2.b - Zwischenbericht 2022.*

3.3.2.2.6 Gas – fugitive emissions at end users' facilities (1.B.2.b.vi)

Gas	Method used	Source for the activity data	Emission factors used
NMVOC; CO_2; CH_4	Tier 2	AS	CS

3.3.2.2.6.1 Category description (1.B.2.b.vi)

This category describes emissions from the point of handover from the gas supplier to the end user. They include emissions from installations in place (gas meters, lines within buildings), as well as leaks resulting from start-stop processes of natural gas appliances. In addition, they include emissions from natural gas-powered vehicles.

Activity data

Table 152: Number of natural gas-powered vehicles in Germany

	1990	1995	2000	2005	2010	2015	2020	2023	2024
Number	0	0	7,500	28,500	90,000	97,804	100,807	100,000	100,000

Source: (ADAC, 2025)

Table 153: Activity data used for category 1.B.2.b.vi, "Fugitive emissions at sites of natural gas use"

	1990	1995	2000	2005	2010	2015	2020	2023	2024
Number of gas meters in the residential and institutional/commercial sectors [millions]	10.3	12.7	12.8	13.3	12.9	13.0	13.1	13.2	13.3

Own survey

Emission factors

Table 154: Emission factors used for category 1.B.2.b.vi, "Fugitive emissions at end users' facilities"

Activity	Emission factor
Residential, institutional and commercial (small consumers)	4 m^3/No
Commerce, trade, services	0.5 m^3/No
Industry	IE (in 1.A.1)

3.3.2.2.6.2 Methodological issues (1.B.2.b.vi)

Residential, institutional and commercial (small consumers)

Emissions from natural gas appliances were analysed in a study conducted by the GWI (a research and service institute for the German gas sector) commissioned by the German Technical and Scientific Association for Gas and Water (DVGW) (Brandes, 2022). In the process, emissions from residential, commercial and industrial gas use in Germany were determined.

In one result, the study found that solar heating systems influence emissions behaviour when – as is often the case – the systems are operated in "convenience" modes linked with gas-fired water heaters. Since GWI experts concluded in a discussion that most households with solar heating systems operate these systems in "convenience" modes, scenario 4 from the study is used (Table 6-10 in the study).

The emissions in source category 1.A.4.b.i "Stationary" also include methane emissions of residential, institutional and commercial sectors (small consumers). According to (Struschka et al., 2008), start-stop emissions are at least partly included. However, the emissions determined there are two orders of magnitude lower than those determined by GWI. To prevent any underestimation, the GWI's emissions data are reported in this category.

Pursuant to Arbeitsblatt [Worksheet] G 600 (Schuhmann, 2018) of the German Technical and Scientific Association for Gas and Water (DVGW), a leakage rate of 0-1 l/h has no effect on building installations. When a leak test shows that an installation is leaking at a rate higher than that figure, the installation has to be promptly repaired. The maximum emissions thus convert to between 0 und 8.76 $m^3_{natural\ gas}$/year or 6.3 $kg_{natural\ gas}$/year. In a conservative approach, that value is applied for the year 1990. To that end, the 8.76 $m^3_{natural\ gas}$/year are multiplied by 0.9 to take account of the methane fraction. The figure determined this was is 7.9 m^3CH_4/year. As of 2021, the emission factor in the GWI study (residential plus installations plus meter exchanges), amounting to a total of 4 m^3/No (gas meter) is being used. Intermediate values have been interpolated.

Commerce, trade, services

The GWI study (Brandes, 2022) found that the emissions of the Commercial and Institutional sector amount to more than four kilotonnes of methane per year. The factors used in 1.A.4 yield emissions that are two orders of magnitude lower, however. Since the reason for this discrepancy has not been conclusively determined, the Commercial and Institutional sector's emissions from start-stop losses are included in this category. To form a time series, these emissions are divided by the relevant number of gas meters. This yields a factor of 0.5 m^3/No. This factor is used throughout the entire time series, since the study (Chapter 1) has shown that it can safely be assumed that the relevant numbers of equipment and appliances have hardly changed in recent decades.

Industry

Evaluation by Böttcher (2022) (Chapter 5.6) and consultations with experts on stationary combustion systems indicate that the methane emissions are already included in 1.A.1. For this reason, they are reported in this category as "IE."

Natural gas-powered vehicles, and CNG fuelling stations

In Germany, these vehicles are refuelled at CNG fuelling stations connected to the public gas network using compressors from high-pressure storage tanks. Some 666 CNG fuelling stations are now in operation nationwide (erdgas-mobil, 2025). Due to the high safety requirements for refuelling and for the tanks themselves, emissions are very low – about 30 t per year and are mainly caused by pressure testing and emptying tanks. The emissions were calculated in accordance with the Tier 2 method. For statistical reasons, methane emissions from compressors (slip) are included in 1.B.2.b.v "distribution."

3.3.2.2.6.3 Uncertainties and time series consistency (1.B.2.b.vi)

For the emissions data, the category uncertainties are given as 20%. These figures are based on estimates of experts, and they lie within the range listed for relevant default emission factors (Penman et al. (2000), Chapter 2.7.1.6.).

3.3.2.2.6.4 Category-specific QA/QC and verification (1.B.2.b.vi)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

Böttcher (2022) (Chapter 5.6) compared the results of this category with other countries. It was found that while the UK has carried out similar studies, their emissions are an order of magnitude smaller than the German emissions. Betzenbichler et al. (2016) also came to a similar conclusion.

In addition, in its NIR, Latvia (Skrebele et al., 2023) (Tables 3.56 and 3.57) estimates that about 85% of fugitive emissions in the natural gas chain (category 1.B.2.b.vi divided by category 1.B.2.b-all) occur at end users' sites. If the German figures are compared, the ratio is 64%.

While the 2006 IPCC Guidelines provide no method description for this category, their Table 4.2.8 presents a range for the expected emission factors. Here, it must be noted that the Guidelines refer to the number of end user appliances involved, and not to the number of gas meters in question. Pursuant to data of the national chimney-sweep association (Bundesverband des Schornsteinfegerhandwerks), as of 2021 15.1 million gas appliances were in operation (ZIV, 2024) (Chapter 3) – based on the 13.3 million gas meters, this is equivalent to a factor of 1.1 appliances per gas meter. This factor must be multiplied by the 4.5 m^3/gas meter to arrive at approx. 5 m^3/gas appliance (see Table 155).

Table 155: Comparison with IPCC default values

System or mechanism	CS emission factor	2006 IPCC GL – Table 4.2.8
Losses at the point of use (Residential + Commercial and Institutional sector)	5 m^3/gas appliance	2 to 20 m^3/gas appliance

3.3.2.3 Venting and flaring (1.B.2.c)

KC	Category	Activity	EM of	1990 (kt CO2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
-/-/2	1 B 2 c, Venting and Flaring (oil, gas, combined oil and gas)	0	CO_2	543.52	0.05	319.64	0.05	-41.19
-/-	1 B 2 c, Venting and Flaring (oil, gas, combined oil and gas)	0	CH_4	1.85	0.01	0.63	0.01	-65.94
-/-	1 B 2 c, Venting and Flaring (oil, gas, combined oil and gas)	0	N_2O	1.74	0.01	0.62	0.01	-64.51

The categories in the overarching group of fugitive emissions from 1.B.2.c "Venting and flaring" cover greenhouse gas and air pollutant emissions either vented or flared directly into the atmosphere. The emissions from venting processes are included in the category 1.B.2.a.iv for oil, and in categories 1.B.2.b.iii and 1.B.2.b.iv for natural gas.

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2	AS	CS
CH_4	Tier 2	AS	CS
N_2O	Tier 2	AS	CS
NMVOC	Tier 2	AS	CS

Category 1.B.2.c, "Venting and flaring," is a key category for CO_2 pursuant to the Approach 2 analysis.

3.3.2.3.1.1 Category description, "Venting and flaring" (1.B.2.c)

Pursuant to general requirements of the (TA Luft, 2002), gases, steam, hydrogen and hydrogen sulphide released from pressure valves and venting equipment must be collected in a gas collection system. Wherever possible, gases so collected are burned in process combustion. Where such use is not possible, the gases are piped to a flare. Flares used for flaring of such gases must fulfil at least the requirements for flares for combustion of gases from operational disruptions and from safety valves. For refineries and other types of plants in categories 1.B.2, flares are indispensable safety components. In crude oil refining, excessive pressures can build up in process systems, for various reasons. Such excessive pressures have to be reduced via safety valves to prevent tanks and pipelines from bursting. Safety valves release relevant products into pipelines that lead to flares. Flares carry out controlled burning of gases released via excessive pressures. In the process, more than 99% of the hydrocarbons in the gases are converted to CO_2 and H 2. When in place, flare gas recovery systems liquify most of these gases and return them to refining processes or to refinery combustion systems. As a result, it is rare to see more than a small pilot flame at the flarehead.

Activity data

Since 2018, the Federal association of the natural gas, oil and geothermal energy industry (BVEG) has published annual data on quantities of gas flared, broken down into the two areas a) sites for gas production sites and b) sites for oil production. Previously, only the data for natural gas production were listed separately. The activity data for natural gas production increased sharply between 2018 and 2019. This cannot be directly attributed to a significantly higher amount of flare gas, but rather to the amount of pilot gas now reported by the industry association BVEG. Pilot gas is used to ensure that flares are operating properly and that gases sent to flares are safely and reliably ignited. In years prior to 2019, pilot gas emissions were already into account. The emission factors have been adjusted accordingly for the period as of 2019.

Table 156: Flared gas quantities in millions of m³

Flared gas quantities	1990	1995	2000	2005	2010	2015	2018	2020	2022	2023	2024
Natural gas production	36	33	36	19	12	10	11	14	10	11	10
Oil production	NA	NA	NA	NA	NA	NA	10	8	8	8	5

(BVEG, 2024)

Emission factors

Flaring takes place at extraction and pumping systems and in refineries. In refineries, these are differentiated by normal operation and operation during disruptions and startup/shutdown. At gas/oil production sites, these operations are grouped into the areas "routine," "non-routine" and "safety-relevant."

The data are determined for each specific operator and transmitted to the German Environment Agency. They are then used as a basis for deriving implied emission factors.

Table 157: Implied emission factors for category 1.B.2.c, "Flaring emissions in natural gas extraction"

Gas	Value	Method
CO_2	1.8 kg/m³	Tier 3

Table 158: Implied emission factors for category 1.B.2.c, "Flaring emissions in petroleum extraction"

Gas	Value	Method
CO_2	2.8 kg/m³	Tier 3

Pursuant to the Federal association of the natural gas, oil and geothermal energy industries (BVEG), the nitrous oxide emissions are extremely insignificant. One study reached the same conclusion (Theloke et al., 2013). To maintain a conservative approach, the IPCC default value was used in the calculation.

The SO_2 emissions are determined based on the activity data for the flared natural gas (Table 156) and an emission factor of 0.140 kg/1,000 m^3, a factor which takes account of an average H_2S content of 5% by volume.

The emission factors for refinery flaring have been derived from the 2004 and 2008 emissions declarations (Theloke et al., 2013) and updated for 2019 for CH_4, N_2O, CO, NMVOC, NO_x and SO_2 on the basis of (Bender & von Müller, 2019b).

Table 159: Emission factors used for category 1.B.2.c, "Flaring emissions in refineries": normal flaring operations"

Gas	Value	Method
CH_4	0.222 g/t	Tier 2
CO_2	2.60 kg/t	Tier 2
N_2O	0.03 g/t	Tier 2
CO	0.76 g/t	Tier 2
NMVOC	4.14 g/t	Tier 2
SO_2	3.28 g/t	Tier 2
NO_X (as NO_2)	0.49 g/t	Tier 2

Table 160: Emission factors used for category 1.B.2.c, "Flaring emissions in refineries: disruptions of flaring operations"

Gas	Value	Method
CH_4	0.095 g/t	Tier 2
CO_2	1.47 kg/t	Tier 2
N_2O	0.3 mg/t	Tier 2
CO	0.71 g/t	Tier 2
NMVOC	0.73 g/t	Tier 2
SO_2	7.48 g/t	Tier 2
NO_X (as NO_2)	4.18 g/t	Tier 2

3.3.2.3.1.2 Methodological issues of the category "Venting and flaring" (1.B.2.c)

Venting emissions are taken into account in category 1.B.2.b.iii.

The emissions listed in the BVEG annual report also include combustion-related emissions from engines. Pursuant to the study (Fritsche et al., 2006) and to our own surveys, only about 0.1% of

the carbon dioxide emissions listed in that source must be considered fugitive emissions and less than 5% should be seen as flare emissions. For this reason, the emissions data listed in the BVEG annual report cannot be used directly for reporting purposes.

The carbon dioxide emissions from flaring at oil production sites were determined by multiplying the reported quantities of flared gas by a factor of 2.8 kg/m^3 (https://www.worldbank.org/en/programs/zero-routine-flaring-by-2030/qna#17).

The emission factors are determined on the basis of emissions reports, crude oil refining capacity and total capacity utilisation at German refineries. The evaluation assessment of (Theloke et al., 2013) serves as a basis.

For years prior to 2018, oil production emissions are calculated from the figures given in the study (Fritsche et al., 2006) (Table 5). These emissions are calculated in accordance with the Tier 2 method.

For years prior to 2004, emissions from refinery flares are calculated from the figures provided in the study (Theloke et al., 2013) (Table 5). These emissions are calculated in accordance with the Tier 2 method.

In the 2022 Review, Germany was asked to explain why its CRT tables list the activity data as "IE." This was done to prevent generation of an incorrect IEF in the CRT tables, in keeping with the fact that CO_2 is calculated with respect to flared gas quantities (Tier 2 approach), while N_2O is calculated with respect to production quantities (Tier 1 approach).

3.3.2.3.1.3 Uncertainties and time series consistency for the category "Venting and flaring" (1.B.2.c)

The quantitative uncertainties for the emission factors for carbon dioxide and methane from flaring processes during normal operations are assumed to be +/-10% (95% confidence interval, normal distribution). The uncertainties for the activity data are assumed to be +/- 5% (95% confidence interval, normal distribution).

The uncertainties for the emission factors for disruption-related flaring processes (operations during disruptions; startup/shutdown operations) are much higher since the emissions quantities can vary widely from year to year. They are estimated to be -90%/+300% (95% confidence interval, log normal distribution). The uncertainties for the activity data are assumed to be +/-10% (95% confidence interval, normal distribution) (Theloke et al., 2013).

3.3.2.3.1.4 Category-specific QA/QC and verification, category "Venting and flaring" (1.B.2.c)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

Quality control at BVEG is carried out using a standardised procedure for determining emissions. Member companies, self-published, last revised in December 2016 (BVEG, 2016).

A comparison of the category with the IPCC Guidelines reveals considerable differences in individual factors. At the EU Workshop held in Dessau (cf. (Harthan et al., 2017)), the participating experts agreed that the default values are considerably higher than the emission factors currently used in Europe.

Table 161: Comparison of national IEFs with IPCC default values

Gas and system	CS emission factor used[40]	IPCC GL 2006 (Table 4.2.4)	
	in [g/m³]	in [Gg/1000m³]	in [g/m³]
CO_2 in refinery flares	3,503	$3.4*10^{-02}$	34,000
CH_4 in refinery flares	0.27	$2.1*10^{-05}$	21
NMVOC in refinery flares	4.86	$1.7*10^{-05}$	17

3.3.2.4 Geothermal energy (1.B.2.d)

3.3.2.4.1 Category description (1.B.2.d)

The category 1.B.2.d "Geothermal energy" is not a key category.

Geothermal energy is a renewable form of energy. Geothermal energy systems that tap geothermal heat to a depth of 400 metres are classified as "near-surface" geothermal energy systems. Near-surface geothermal systems generate heating and cooling energy (usually by means of heat pumps) and are also used for heating service water. Geothermal energy systems that tap geothermal heat at depths greater than 400 metres are classified as "deep" geothermal energy systems. Geothermal heating stations normally use the heat in their thermal water flows directly and provide heating and cooling to end consumers via district heating/district cooling networks. Geothermal power stations use technology to convert the heat from thermal water flows into electricity and generally generate both electricity and heat in a combined process.

Operation of geothermal power stations and heat stations in Germany produces no emissions of climate-relevant gases. The thermal water circuits of these installations are closed and airtight, both above and below ground level. As a result, no emissions occur during operation. Even a release of the gases dissolved in the heat-carrying fluid – primarily H_2, CH_4, CO_2 and H_2S – would not lead to concentrations worth reporting (cf. (Kaltschmitt, 2007): Chapter A.2.3.5). For this reason, the emissions are reported as "NE". In the report year, all geothermal energy systems met their own power requirements (primarily power for operating pumps) by drawing electricity from the grid. They are listed in the report in the relevant source categories.

3.3.2.4.2 Methodological issues (1.B.2.d)

The IPCC Reference Manual does not describe any methods for category 1.B.2.d "Other" ((Houghton et al., 1997): Vol. 3, p. 1,132f)

No emission factors for greenhouse gases and pollutants that could escape during drilling for tapping of geothermal energy (both near-surface and deep energy) are known for Germany at present. In drilling operations, even those not oriented to hydrocarbon exploration, releases of gases trapped underground – including climate-relevant gases – must always be expected (cf. (Kaltschmitt, 2007): Chapter A.2.1.5). In drilling operations for near-surface geothermal energy, as in drilling of wells for drinking water, only low emissions levels are normally encountered, due to the low gas concentrations found near the surface. In order to prevent gas leaks, the same safety regulations apply to deep geothermal drilling as to hydrocarbon exploration, including the obligation to use blowout prevention devices and blowout preventers to prevent accidents. (Theloke et al., 2013) estimates that the fugitive emissions related to deep geothermal wells are in the order of kilograms. The emissions in this category are therefore reported as NE because their contribution to the total emissions is less than 0.05% of the overall inventory or 500 kt CO_2 equivalents (pursuant to FCCC/SBSTA/2013/L.29/Add.1), and since it cannot be assured that

[40] For refineries, determined as a mean value between normal operation and operation during disruptions

annual inventories of such emissions (pursuant to FCCC/SBSTA/2013/L.29/Add.1, para 37) will be carried out. In Chapter 5, the emissions contribution to the overall inventory is presented (on a one-time basis). A compilation of all sources for which the entry "not estimated" is retained is presented in Chapter 1.7.2.

3.3.2.4.3 Uncertainties and time series consistency (1.B.2.d)

No explanations of uncertainties and time series consistency are required.

3.3.2.4.4 Category-specific QA/QC and verification (1.B.2.d)

No explanations on category-specific QA/QC and verification are required.

3.3.2.5 Category-specific recalculations (1.B.2 all)

The figures for the past two years have been recalculated, because some of the statistics they were based on were provisional. Furthermore, changes occurred in the storage and cleaning of mineral oil products.

Table 162: Recalculations in category 1.B.2 – NMVOC emissions, in kt

	1990	1995	2000	2005	2010	2015	2020	2023
2026 submission	176.5	118.2	77.6	47.3	37.6	32.2	28.3	27.5
2025 submission	168.0	112.5	74.2	46.4	38.4	33.0	28.9	28.0
Difference	-8.5	-5.7	-3.3	-1.0	0.8	0.8	0.6	0.5

Table 163: Recalculations in category 1.B.2 - CO_2 emissions in kt

	1990	1995	2000	2005	2010	2015	2020	2023
2026 submission	2,008	2,127	2,214	2,213	1,898	1,672	1,190	1,006
2025 submission	2,008	2,127	2,214	2,213	1,898	1,672	1,190	1,003
Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-3.4

Table 164: Recalculations in category 1.B.2 - CH_4 emissions in kt

	1990	1995	2000	2005	2010	2015	2020	2023
2026 submission	363.0	382.1	288.1	243.3	198.3	136.1	77.0	63.3
2025 submission	363.2	382.3	288.3	243.4	198.4	136.2	77.2	64.1
Difference	0.2	0.2	0.2	0.1	0.1	0.1	0.3	0.8

3.3.2.6 Category-specific planned improvements (1.B.2 all)

The emission data determined under the EU Methane Regulation (EU, 2024a) will be used for UNFCCC reporting in future. This year, however, many of the reports could not be evaluated before the editorial deadline.

In the area of end user emissions (1.B.2.b.vi), some overlapping with emissions from 1.A.1., 1.A.2 and 1.A.4 occurs. It is therefore being examined whether this results in double counting. Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

3.4 Carbon capture, transport and storage (CCS) CRF 1.C)

3.4.1 Category (1.C)

3.4.1.1 Category description (1.C)

According to the operator of the only pilot installation in Germany, about 67 kt has been sequestered to date for testing purposes (GFZ, 2018). Since then, measurements taken to monitor the system have not detected any leaks. However, to remain conservative in our reporting, the quantities stored in the German inventory were not deducted. For this reason, any possible leakage was already taken into account.

3.4.1.2 Methodological issues (1.C)

Following recommendations in the 2016 In-Country Review, the notation key *NO* is currently being used.

3.4.1.3 Description of the applied flexibilities (1.C)

No descriptions of flexibilities are required.

3.4.1.4 Uncertainties and time series consistency (1.C)

No explanations of uncertainties and time series consistency are required.

3.4.1.5 Category-specific QA/QC and verification (1.C)

No explanations on category-specific QA/QC and verification are required.

3.4.1.6 Category-specific recalculations (1.C)

No descriptions of recalculations are required.

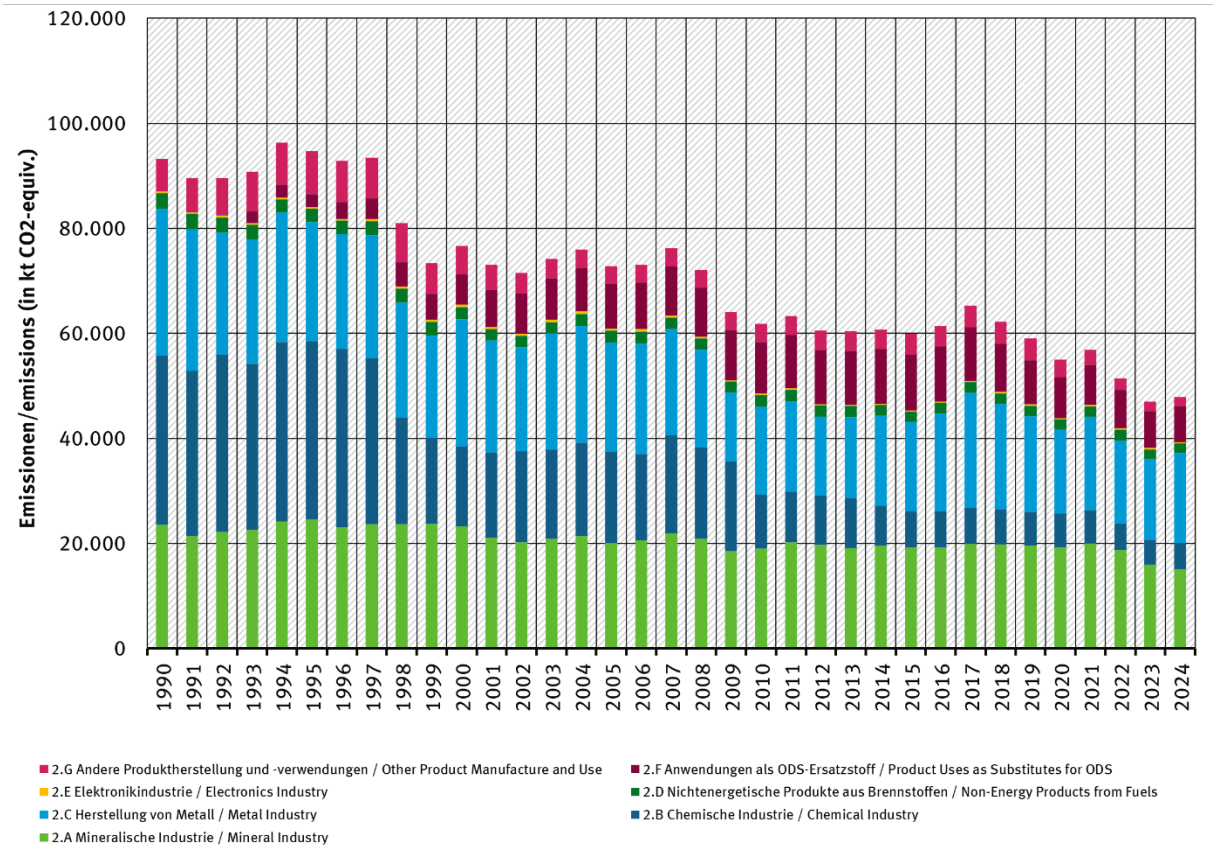
3.4.1.7 Category-specific planned improvements (1.C)

No improvements are planned.

4 Industrial processes (CRF Sector 2)

4.1 Overview (CRF Sector 2)

Figure 43: Overview of greenhouse gas emissions in CRF Sector 2



Source: own illustration, German Environment Agency

4.2 Mineral industry (2.A)

The CRF category 2.A Mineral industry is divided into subcategories 2.A.1 to 2.A.4. These include:

- cement clinker production (2.A.1, Chapter 4.2.1),
- lime burning (2.A.2, Chapter 4.2.2),
- glass production (2.A.3, Chapter 4.2.3)
- ceramics production (2.A.4.a, Chapter 4.2.4.1),
- other soda ash use (2.A.4.b, Chapter 4.2.4.2),
- production of non-metallurgic magnesium products (2.A.4.c, Chapter 4.2.4.3)
- other limestone and dolomite use (2.A.4.d, Chapter 4.2.4.4).

4.2.1 Mineral industry: Cement production (2.A.1)

4.2.1.1 Category description (2.A.1)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
L/T	2 A 1, Cement Production	0	CO_2	15,297.27	1.19	9,830.97	1.39	-35.73

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2	AS	CS
NO_X, SO_2	Tier 1	AS	CS

The category "Cement" is a key category for CO_2 emissions in terms of emissions level and trend. The descriptions below refer only to production of cement clinkers because clinker grinding is not relevant as a source of dust in this context. In Table 165, cement production is included solely for reference purposes without any relevance to emissions in this context.

The clinker-burning process emits climate-relevant gases. CO_2 accounts for the vast majority of these emissions. The CO_2 emissions from raw materials are tied directly to the quantities of cement clinkers that are produced. Pursuant to the German Emissions Trading Authority (DEHSt, 2025b), clinker production in 2024 in Germany amounted to 18,185 kt· CO_2 emissions related to raw materials are calculated from plant-specific data, including discharged bypass dust with a country-specific emission factor of 0.53 t CO_2/t cement clinker as determined by the German Cement Works Association (VDZ). On this basis, clinker production resulted in CO_2emissions from raw materials of 9,831 kt CO_2 in 2024.

Table 165: Production and raw material-related CO_2 emissions in the German cement industry, in [kt/a]

	Clinker production + discharged bypass dust[41]	Raw material-related CO_2 emissions	Cement production
1990	28,863	15,297	37,772
1995	29,363	15,562	35,862
2000	28,779	15,253	35,414
2005	24,622	13,050	31,009
2010	23,456	12,431	29,915
2015	23,822	12,626	31,160
2020	25,203	13,357	35,485
2021	25,736	13,640	35,622
2022	23,657	12,538	32,901
2023	20,312	10,765	28,185
2024	18,549	9,831	26,830

Source: Own calculations derived from BDZ (2005) to 1994, VDZ (2016) from 1995 and, from 2015, from DEhSt (2016), (DEhSt, 2021), (DEhSt, 2022), (DEhSt, 2023), (DEhSt, 2024), (DEhSt, 2025a)

[41] The bypass dust quantity is estimated by experts based on actual clinker production, assuming the following: 1% for the years 1990-2008; 2% as of 2009.

4.2.1.2 Methodological issues (2.A.1)

Activity data

The collection of activity data is based on the total of individual company data, up to 1994 on the basis of data from the BDZ German cement industry association. As of 1995, following optimisation of data collection within the association, activity data were compiled by the VDZ and its cement industry research institute in Düsseldorf by surveying German cement works and using BDZ figures. The data largely consist of data published as part of CO_2 monitoring, supplemented by data for plants that are not BDZ members (in part, also VDZ estimates). This corresponds to the Tier 2 method of the IPCC Guidelines ((IPCC, 2006a): Volume 3, Chapter 2.2.1.1).

For internal reasons, the VDZ association was unable to provide the data for the years as of 2015. As a result, the cement clinker figures are based on aggregated, plant-specific data of the DEHSt. A comparison for the previous years 2005-2014 showed that the DEHSt's emissions trading figures and the VDZ's data on cement clinker production constantly differed by around 1%, meaning that a high level of agreement between the two data sets can be assumed. In general, completeness is assured if one of the two data sets is used.

According to the VDZ, the fraction of bypass dust from clinker production in the years 2009 to 2016 ranged between 1 and 2%. This figure cannot be provided annually by the VDZ in a form that is sufficiently quality-assured, and this does not appear to be possible in the future either. For this reason, a conservative estimate of 2% bypass dust has been used since 2009, which is in line with the guidelines (IPCC, 2006a). No detailed information on the fraction of bypass dust is available for the years prior to 2009. In a conservative approach, it is assumed to have been a constant 1% in the years 1990 to 2008.

Emission factors

The emission factor used for emissions calculation, 0.53 t CO_2/t cement clinkers, is based on mass-weighted figures for individual plants, i.e. the VDZ determined the emission factor by aggregating plant-specific data on fractions of CaO and other metal oxides (MgO; in raw materials and containing carbonate) in clinkers. The emission factor was determined in two research projects, (Ruppert et al., 2009), (Schäfer et al., 2022), and confirmed by the VDZ for the other years. This corresponds to the Tier 2 method of the IPCC Guidelines (IPCC (2006a): Volume 3, Chapter 2.2.1.2).

In the German cement industry, dust separated from furnace exhaust gas is returned to the burning process. As a result, carbonate release from clinker raw materials can be determined directly from the metal oxide in the clinker without any need to take account of significant losses via the exhaust gas pathway. In addition, the dust discharged via the bypass pathway throughout the entire time series is taken into account to determine CO_2 emissions related to raw materials.

The emission factor of 0.53 t CO_2/t cement clinkers was applied to the entire time series. Applying the conservative assumption that the bypass dust in question is completely deacidified, the same emission factor is used for this substance flow.

The CO_2 emissions are calculated in accordance with the *IPCC Guidelines* ((IPCC, 2006a): Volume 3, Equation 2.2, in conjunction with Equation 2.5) using the following equation:

Equation 4:

$$EM_{CO2} = EF_{Klinker} \times Klinkerproduktion + EF_{Klinker} \times \%_{Bypassstaub} \times Klinkerproduktion$$

4.2.1.3 Uncertainties and time series consistency (2.A.1)

For the activity data, time series consistency is assured by the association's long history of data collection. For the years as of 2015, the high degree of consistency in previous years means that emissions trading data have proven to be a suitable alternative. For the emission factor, time series consistency is assured in that a consistent approach has been used for all years.

The uncertainties specified were calculated based on expert estimates.

Most companies are required to report clinker production data as part of CO_2 emissions trading. The EU monitoring guidelines for emissions trading specify a maximum accuracy of 2.5%. The uncertainties for the activity data used were thus estimated at ±2.5%.

The uncertainty for the emission factor used was estimated at ±1%. This was confirmed by surveys conducted as part of a research project.

4.2.1.4 Category-specific QA/QC and verification (2.A.1)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

For purposes of quality assurance, all of the data used were checked for plausibility. Said data are from the BDZ, VDZ and emissions trading, along with comparative data from the literature. During the inventory review (ICR 2016), VDZ materials were used to demonstrate that procedures were being carried out in line with QSE requirements. These materials were accepted by the review team as proof. The emission factor for raw material-related CO_2 was compared with the emission factors of other countries. The small deviation (about 1%) from the IPCC Tier 1 default factor, 0.52 t CO_2/t clinkers ((IPCC, 2006a): Volume 3, Equation 2.4), results from the higher lime content found in some German clinkers.

The emission factor used differs only slightly from the average emission factors used in connection with the ETS in Germany, i.e. emission factors that are checked by authorities and reviewed in light of companies' obligations to provide records. No calculations are available for the emission factor prior to 2000; the standard approach for all years is based on expert estimates.

The comparison with the emissions trading figures for process-related emissions showed very good agreement.

4.2.1.5 Category-specific recalculations (2.A.1)

No recalculations are required.

4.2.1.6 Category-specific planned improvements (2.A.1)

No improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

4.2.2 Mineral industry: Lime production (2.A.2)

4.2.2.1 Category description (2.A.2)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
L/T	2 A 2, Lime Production		CO_2	5,986.62	0.47	3,979.72	0.57	-33.52

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2	AS	D
NO_X, SO_2	Tier 1	AS	CS

The category "Lime" is a key category for CO_2 emissions in terms of emissions level and trend.

The statements made below regarding category 2.A.2 refer solely to the amounts of burnt lime and dolomite lime produced in German lime works. In addition to the lime kilns covered in this chapter, lime kilns were also identified in the iron and steel industry and the sugar industry. They are not covered in this chapter, but in the sections for the respective categories, 2.C.1 (Chapter 4.4.1) and 2.H.2 (Chapter 4.9.2). Information on other sectors that use limestone is provided in Chapter 4.2.4.4 (CRF 2.A.4d).

Table 166: Production and CO_2 emissions in the German lime industry, in [millions of t]

	Lime		Dolomite lime	
	Production	CO_2 emissions	Production	CO_2 emissions
1990	7.324	5.463	0.603	0.523
1995	7.611	5.678	0.556	0.482
2000	6.994	5.217	0.536	0.465
2005	6.535	4.875	0.474	0.411
2010	6.124	4.569	0.342	0.296
2015	6.247	4.660	0.248	0.215
2020	5.367	4.004	0.204	0.177
2021	5.943	4.434	0.221	0.192
2022	5.682	4.239	0.229	0.198
2023	4.871	3.634	0.227	0.197
2024	5.057	3.772	0.239	0.207

Source: Production: Basic data from (BV Kalk, 2025); supplemented by UBA

4.2.2.2 Methodological issues (2.A.2)

CO_2 is released when burning limestone and dolomite, and it reaches the atmosphere as part of the exhaust gas from that process. The emissions level is obtained by multiplying the amount of product in question (lime or dolomite lime) by the relevant emission factor. Use of the emission factors explained below, together with lime production figures for each country, is a Tier 2 method as defined in the *2006 IPCC Guidelines* (IPCC (2006a)): Volume 3, Chapter 2.3.1.1).

Emission factors

The CO_2 emissions are calculated with the following factors:

EF_{lime}	0.746 t CO_2/t lime (stoichiometric 0.785 * oxide fraction 0.95)
$EF_{dolomite\ lime}$	0.867 t CO_2/t dolomite lime (stoichiometric 0.913 * oxide fraction 0.95)

The emission factors used are based on the stoichiometric factors as well as the assumption that 95% of the burnt lime consists of CaO, 95% of the dolomite lime consists of **CaO • MgO**, and 5% of the total mass consists of impurities that are not relevant in terms of CO_2 emissions. This approach is in accordance with the *2006 IPCC Guidelines* (IPCC (2006a): Volume 3, Chapter 2.3.1.2).

Activity data

The German Lime Association (BVK) collects the production data for the entire time series at each plant and makes them available for reporting purposes. The quantities produced by plants that are not included in the German Lime Association's statistics are estimated using existing information (such as operator figures and data published as part of emissions trading) and then added to the German Lime Association's figures. This ensures that all of German lime production is taken into account. Since the methodology was changed to conform with the *2006 IPCC Guidelines*, it is also assumed that, in all years of the reporting period from 1990 onwards, 2% of the burnt lime is separated as dust using appropriate exhaust gas cleaning equipment and is not returned to the burning process. This is taken into account using an imputed 2% increase in the activity data. The 2% increase has no longer been applied since 2015, however, because since that year the activity data provided by the German Lime Association have included the quantities of dust that are filtered out.

The activity data provided by BV Kalk (German lime-industry association) are currently supplemented annually by the German Environment Agency with data from a smaller plant not covered by the association. The estimates provided by this plant were usually based on allocation quantity figures in the operator holding account in the German Emissions Trading Authority (DEHSt) framework. Since 2013, the actual CO_2 emissions listed in the operator holding account covered by that work have been published and are below the allocated quantity. It is now possible to access the operator holding account's data on actual CO_2 emissions at the time the data are collected.

The manner in which the activity data are determined conforms with the Tier 2 model of the *2006 IPCC Guidelines* (IPCC (2006a): Volume 3, Chapter 2.3.1.3).

4.2.2.3 Uncertainties and time series consistency (2.A.2)

The EU monitoring guidelines for emissions trading call for activity data to have an accuracy of 2.5%. Since a) the German Lime Association's lime production data are based on operator figures as provided as part of CO_2 emissions trading, b) these data have been obtained through two separate, parallel channels and are therefore quality assured, and c) the plants not included in the association's statistics (and thus assessed retrospectively) represent only a small share of the total number of plants concerned, the uncertainties for the activity data used are estimated to be ±2.5%. These figures apply to both burnt lime and dolomite lime.

The uncertainties for the emission factors used for burnt lime were estimated at -11% and +5%. The uncertainties for the emission factors used for dolomite lime were estimated at -30% and +2%.

4.2.2.4 Category-specific QA/QC and verification (2.A.2)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

The BV Kalk German lime industry association determines the production quantities by carrying out two surveys within the association. These surveys, of which one has a technical focus and one has a commercial focus, query the individual plants within the association, and they are cross-checked against each other. Any plant-specific discrepancies between the two surveys are clarified before the activity data are forwarded to the German Environment Agency (UBA). The activity data provided to UBA thus undergo adequate quality assurance (Tier 2).

The comparison with the available information from the ETS yielded discrepancies that can be explained as the result of differences in methods: On the one hand, as differences between the specifications in the ETS and on the part of the IPCC, and, on the other hand, as the result of methodological changes made between ETS trading periods. During the inventory review (ICR 2016), graphic comparisons were used to show that the methodological discrepancies provide no grounds to doubt the quality of the inventories' data.

The IPCC default factors used are suitable for the country-specific method.

The comparison with the emissions trading figures for process-related emissions showed very good agreement.

4.2.2.5 Category-specific recalculations (2.A.2)

No recalculations are required.

4.2.2.6 Category-specific planned improvements (2.A.2)

No improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

4.2.3 Mineral industry: Glass production (2.A.3)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
-/-	2 A 3, Glass Production		CO_2	780.48	0.07	763.49	0.11	-2.18

Gas	Method used	Source for the activity data	Emission factors used
CO2	Tier 2	AS	CS
NOX, NMVOC, SO2	Tier 2	AS	CS

The category "Mineral products: glass production" is not a key category.

4.2.3.1 Category description (2.A.3 Glass production)

Germany's glass industry produces a wide range of different glass types with different chemical compositions. Germany's glass sector comprises the following subsectors: container glass, flat glass, domestic glass, special glass and mineral fibres (glass and stone wool). The subsectors with the highest production shares are container glass (accounting for about half of total glass production) and flat glass (about one-fourth of total glass production)(Bundesverband

Glasindustrie e.V., 2025) The inventory calculations do not include the category "water-glass production". All relevant soda ash quantities for water-glass production are taken into account in 2.A.4.b (Chapter 4.3.7).

In production, homogeneous glass mixtures combining primary and secondary raw materials are melted down at temperatures between 1,450°C and 1,650°C. The process-related CO_2 emissions under consideration here are released from the raw-material carbonates during the melting process in the furnace. Low levels of CO_2 emissions also occur when using limestone or other carbonates to neutralise HF, HCl and SO_2 in exhaust gases. Since the levels involved are so small, these emissions are not considered here.

The following table shows the trends, since 1990, in activity data, process-related CO_2 emissions and the implied emission factors resulting for all glass types in five-year steps from 1990.

It is clear that emissions tend to follow the trend in activity data. At the same time, the implied emission factors indicate that the correlation is not rigid; some discrepancies do occur. The discrepancies are due to annual fluctuations in production quantities of various individual glass types, and in cullet inputs. They are thus logical and correct from a calculational standpoint. The IEF has been increasing intermittently for all types of glass. This is due to absolute and relative increases of products causing higher emissions – especially mineral fibres.

The emissions from precursor substances, which also occur during glass production, are not discussed here. But due to limitations in the UNFCCC software, they cannot be reported in this category either, but instead are reported in Chapter 4.2.4.4.

4.2.3.2 Methodological issues (2.A.3 Glass production)

The CO_2 emissions (the main pollutant) are calculated by a Tier 2 method since the detailed activity data are tied to specific emission factors (according to carbonate concentration). The following carbonates are taken into account as the main sources of CO_2 formation during the melting process: calcium carbonate ($CaCO_3$), soda ash/sodium carbonate (Na_2CO_3), magnesium carbonate ($MgCO_3$) and barium carbonate ($BaCO_3$). In this context, the CO_2 emissions from all carbonates are reported as a sum; inputs of raw materials – soda ash – are considered under 2.A.4.b (cf. 4.2.4.2). Here, it should be noted that the calculated soda ash input quantities cannot be published because data on soda ash production are subject to statistical confidentiality and must not be derivable from balance calculations.

The production figures (activity data) are taken from the regularly appearing annual reports of the Federal Association of the German Glass Industry (Bundesverband Glasindustrie). "Production" refers to the amount of glass produced, which is considered equivalent to the amount of glass melted down. It must be kept in mind that a fraction of the molten glass, corresponding to the quantity of internal cullet, is not included in production statistics (see also the remarks below regarding cullet inputs). As a result, the figures provided in the statistics correspond not to the actual quantities of molten glass, but to the molten glass quantities consisting of primary raw materials and external cullet. Further processing and treatment of glass and glass objects are not considered.

The following activity data were determined for 2024:

Table 167: Glass: Activity data for the various industry sectors (types of glass), in [t]

Industry sector	Activity data, 2024
Container glass	3,788,200 t
Flat glass	1,794,100 t

Industry sector	Activity data, 2024
Glass fibre and wool	287,800 t
Special glass	292,500 t
Stone wool	498,200 t
Domestic glass	25,300 t

Source: (Bundesverband Glasindustrie e.V., 2025)

The following sector-specific cullet percentages are assumed:

Table 168: Cullet percentages for the various types of glass, in [%]

Industry sector	Cullet percentage with respect to total raw material input
Container glass	55-75 (annually varying)
Flat glass	10 (entire time series)
Domestic glass	5 (entire time series)
Special glass	5 (entire time series)
Glass fibre and wool	40 (entire time series)
Stone wool	40 (entire time series)

Source: (Gitzhofer, 2021) and surveys by the Federal Association of the German Glass Industry (Bundesverband Glasindustrie e.V., 2025)

The cullet percentage for container glass is known only for the western German federal states as of 1990. For Germany as a whole, it is known for the period since 1995. No data are available for the new German federal states for the period 1990-1994. For that reason, an average cullet percentage input was estimated on the basis of the various glass sectors' average percentages of total glass production. In 2007, cartel law required a company called Gesellschaft für Glasrecycling und Abfallvermeidung mbH (GGA) to cease operations. As a result, no reliable cullet-input data have been available from that source since 2007. Since 2012, the Federal Association of the German Glass Industry has provided data from association surveys on cullet inputs in the container glass industry for the period as of 2007 (BV Glas, 2025). The association also uses member data to verify the other cullet fractions that enter into reporting. The various sectors' cullet fractions contain only external cullet as internal cullet is not included in the production statistics on which the activity data are based. An industrial operation's total cullet fractions in its vats can be considerably higher, depending on how much internal cullet is produced (for example, when changing colour). The cullet percentage for container glass in 2024 uses the 2023 value as the association was yet to complete its data collection.

Since the exhaust gases occurring during the melting process are drawn off together with combustion-related exhaust gases, i.e. as a collective exhaust gas stream, measurements cannot be used to determine the CO_2 quantities produced by the German glass industry. For this reason, a calculation procedure is used that is based on the weight shares for the aforementioned carbonates and on cullet input in the container glass and flat glass industry. Figures on the chemical composition of the various types of glass produced in Germany have been taken from VDI-Richtlinie (guideline) 2578 (VDI, 2017) and from the ATV-DVWK Merkblatt (standards sheet of the German Association for Water, Wastewater and Waste) 374 (ATV-DVWK, 2004).

The approach used to determine emission factors for the various glass oxides and the emissions is described in detail in the NIR (UBA, 2007) (Chapter 4.1.7.2, pp. 251 ff.).

The emission factors below were calculated for the various industry sectors and vary annually consistent with variations in cullet inputs (ranges are specified for container glass).

Table 169: CO_2 emission factors for various glass types (calculated in comparison with figures from the 2006 IPCC Guidelines)

Glass type	Calculated EF [kg CO_2/ t $_{molten\ glass}$] – stoichiometric / incl. cullet input –	Default EF [kg CO_2/ t $_{molten\ glass}$] - pursuant to 2006 IPCC Guidelines (IPCC (2006a): Vol. 3, Tab. 2.6)-
Container glass	193 / 49-86*	210
Flat glass	208 / 187	210
Domestic glass	120 / 114	100
Special glass	113 / 107	30 - 200
Glass fibres	198 / 119	190 - 250
Stone wool	299 / 179	-
Unspecified	174 / 139	-

* Most recently, 71 kg CO_2 per t of molten glass

The stoichiometrically calculated emission factors are very similar to the default factors. The emission factors, including cullet inputs, are considerably lower than the default values since cullet inputs tend to be very high in Germany. In the sole exception, this EF relationship does not apply to household and table glassware – possibly as a result of the high quality requirements involved, which entail low cullet inputs.

4.2.3.3 Uncertainties and time series consistency (2.A.3 Glass production)

The production data have been taken from the internal statistics of the Federal Association of the German Glass Industry. Since that association represents nearly all of Germany's container-glass and flat-glass manufacturers, the sectoral data it provides are highly accurate. An uncertainty of 5% was thus assumed. The association does not fully cover all other glass sectors and therefore cannot guarantee completeness. For this reason, an uncertainty of 10% was assumed for these areas. Until about 2002, the Federal Association of the German Glass Industry also cross-checked the data against those of the Federal Statistical Office.

The uncertainty in the cullet figures for container glass lies within the customary range for statistical determinations. For the new German federal states, an uncertainty of 20% has been assumed because no statistical survey has been carried out, i.e. only an estimate is available. Use of data from the association's own internal surveys on cullet use as of 2007 increases the uncertainties. For example, surveys take account only of production sites' internal cullet and external container-glass cullet, and do not cover any quantities of flat glass that may be used in container-glass production.

The figures on cullet use for all other glass types are considerably less precise, however, since only estimates are available for these areas. An uncertainty of 20% was thus assumed.

For the CO_2 emission factors, an uncertainty of 14% is used in the case of container glass, and a figure of 22% is used for all other types of glass.

4.2.3.4 Category-specific QA/QC and verification (2.A.3 Glass production)

General quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

The calculated emission factors were compared with several different sources, including the IPCC Guidelines (IPCC, 2006a) and the "Baden-Württemberg 2004 emissions declaration" (Emissionserklärung 2004 Baden-Württemberg (UMEG, 2004)), an emission factor manual. According to that comparison, the calculated emission factors may be considered accurate. In addition, the IEF was compared with those of the following countries, which also report on soda ash use only as an integrated part of glass production, i.e. do not report on it separately: Spain (0.10), Italy (0.10) and Portugal (0.09). These values are comparable to the German IEF for the glass industry (which fluctuates around 0.1).

The calculated emissions were also cross-checked against the ETS data for Germany. This showed that the calculated emissions were about 11% higher than the emissions pursuant to ETS. This can be attributed to differences in allocation of materials to process- and energy-related emissions.

The information on chemical composition of the various glass types is still deemed correct in this context. However, the rate of cullet input has a significant influence, and the available data still needs to be improved. (cf. Chapter 4.2.3.3).

4.2.3.5 Category-specific recalculations (2.A.3 Glass production)

Recalculations were carried out in 2023 to account for corrections of individual production figures.

4.2.3.6 Planned improvements, category-specific (2.A.3 Glass production)

No improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

4.2.4 Mineral industry: Other process uses of carbonates (2.A.4)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
-/-	2 A 4, Other Process Uses of Carbonates		CO_2	1,458.01	0.12	505.61	0.08	-65.32

The overarching category 2.A.4 – Mineral products: Other process uses of carbonates is not a key category. This category is largely determined by the ceramics industry, both in terms of the level of emissions and the level of detail of the methodology.

Emissions of the precursor substances SO_2, NO_X, CO and NMVOC are reported in this category whenever the UNFCCC's 'CRT Software' does not permit them to be entered in subcategories. The specifics are described in 4.2.4.4.1.

4.2.4.1 Mineral industry: Ceramics (2.A.4.a)

4.2.4.1.1 Category description (2.A.4.a Ceramics)

Gas	Method used	Source for the activity data	Emission factors used
CO2	Tier 2	NS	CS
NOX, NMVOC, SO2	Tier 1	NS	CS

Germany's ceramics industry, like its glass industry, is highly diverse. It produces many different products with many different chemical compositions for a variety of different applications. Along with clay (the main raw material involved), sand and other natural raw-material mixtures, the industry also uses synthetically produced substances, such as aluminium oxide and silicon dioxide. The following application areas can be differentiated within Germany's ceramics sector: structural ceramics (bricks, tiles, drain pipes), sanitary ceramics (toilet bowls, washbasins), ceramic tableware (dinnerware, household porcelain), technical ceramics (insulators, structural components), fireproof ceramics (furnace walls, refractory concrete), ceramic bonded abrasives and expanded clay (VDI Guideline 2585) (VDI, 2006). The largest production quantities in percentage terms are in the bricks sector (about 80% of total ceramics production), followed by fireproof products (about 10%) and tiles (about 6%).

In ceramics production, homogeneous mixtures consisting largely of primary raw materials and only small quantities of secondary raw materials are fired primarily in tunnel kilns and hearth furnaces at temperatures between 800 and 1,300°C. The firing durations, which normally amount to several hours (European Commission (EC), 2007a), can vary depending on the products involved. Significantly higher firing temperatures are used in connection with refractory products and technical ceramics. The process-related CO_2 emissions under consideration here are released during firing processes in kilns. Emissions are produced from both carbonate and fossil components of raw materials. In some cases, process-related CO_2 emissions are also produced by pore-forming agents (such as sawdust, papermaking sludges and polystyrene), which are used especially in brick production (clay blocks). In determination of CO_2 emission factors, only non-biogenic fractions are taken into account.

The "ceramics products" time series (cf. Table 170) comprise the activity data and process-related CO_2 emissions of the entire ceramics industry in Germany for the period since 1990[42]. The non-CO_2 emissions (NO_X, NMVOC, SO_2, etc.) for the entire ceramics industry are calculated using these activity data.

Table 170: Activity data and process-related CO_2 emissions in the ceramics industry (CRF 2.A.4.a) since 1990, in [kt]

	Activity data		Process-related CO_2[43]
	Total production	CO_2-relevant production[44]	
1990	17,691	15,628	1,122
1995	25,167	23,254	1,742
2000	20,649	18,914	1,314

[42] Expanded clay is not included here since there are no data available (production quantities/activity data)

[43] Clay blocks, facing bricks, bricks for floor and road surfaces, roof tiles and accessories, tiles, stoneware, vitrified clay pipes and other structural formed products, household and sanitary ceramics: porcelain, household and sanitary ceramics: stoneware, earthenware

	Activity data		Process-related CO_2[43]
2005	14,199	12,547	772
2010	11,921	10,254	607
2015	11,645	10,084	552
2020	11,611	10,371	552
2021	12,245	10,828	581
2022	12,130	10,724	572
2023	7,960	6,740	334
2024	6,788	5,642	275

Source: Own calculations (UBA)

4.2.4.1.2 Methodological issues (2.A.4.a Ceramics)

The 2006 IPCC Guidelines for National Greenhouse Gas Inventories contain information on calculating process-related CO_2 emissions for the ceramics industry (IPCC (2006a): Volume 3, Chapter 2.5.1 “Ceramics”). In general, the following product groups are normally allocated to this industrial production sector: roof tiles and masonry bricks, stoneware pipes, refractory products, expanded clay, wall and floor tiles, household ceramics, sanitary ceramics, technical ceramics, inorganic bonded abrasives. With regard to produced quantities, the product groups roof tiles and masonry bricks, refractory products and wall and floor tiles are especially relevant. Depending on the data available, nearly all of the products are taken into account for emissions calculations.

With regard to assessment of methods, the 2006 IPCC Guidelines only provide basic information on carbonate inputs. Since this method takes account of additional CO_2 sources, it is seen as a country-specific Tier 2 method.

Activity data

In terms of production data (activity data), data from the Federal Statistical Office are used (Statistisches Bundesamt, 2025c). In the interest of completing the database for all product categories of the ceramics industry, also with regard to calculating process-related CO_2 emissions, the annual production quantities were determined for each product category as part of an expert opinion prepared in cooperation with the Federal Statistical Office (Gottwald et al., 2017). The project covered the period 1990-2015 and its scope has been expanded since then. As a result, 52 to 67 product categories from official statistics have to be considered. The last adjustment was carried out in 2019, meaning that a total of 57 product reporting numbers are now used. The data provided by the Federal Statistical Office vary with regard to the units used (tonnes, square metres, unit counts, value). To enable the data to be processed in a consistent manner, all units have been converted to tonnes [t]. Where produced quantities are not available in tonnes [t], conversion factors have to be applied. These conversion factors are provided in the project report.

As of data year 2019, quantities of tiles – which are reported in square metres – are converted in accordance with an adjusted method. The ten statistical reporting numbers previously used for various tile products have been published in three new reporting groups with a new classification system from the 2019 data year onwards. This in turn rendered the previously used conversion factors unsuitable. In August 2020, discussions were held with Bundesverband Keramische Fliesen e.V. (the Federal association of the German ceramic tile industry) regarding the average weights per unit area that are needed for conversion into tonnes, and the resulting weights assigned to the tile types (BKF, 2020).

In a departure from reliance on the aforementioned expert opinion, the conversion factors for facing bricks, clay blocks and roof tiles were revised at the suggestion of the German brick and tile industry association (Bundesverband der Deutschen Ziegelindustrie e. V.) on the basis of technical discussions with representatives of environmental and industrial associations. In the revision, average raw density values for clay blocks were used. The values were determined for the years 1994 and 2016. The raw densities involved decrease continuously over time since the share of porous products and the products' degree of porosity have both been growing. The values for the years between 1994 and 2016 have been linearly interpolated.

Emission factors

The process-related CO_2 emissions originate in the raw materials used to manufacture ceramic products. Normally, these consist of locally available loams and clays containing varying fractions of non-biogenic carbon (such as carbonates) and organic carbon. In addition, small quantities of process-related CO_2 emissions are produced by pore-forming agents which are added to raw materials used to produce clay blocks. Most of the porosity agents used are renewable resources (such as sludges from the paper industry, including some with fossil components, and paper fibres). Small quantities of non-renewable substances (especially polystyrene) are also used, however. (Organic) binders, which are also used in small quantities in refractory and abrasive products, also contribute to process-related CO_2 emissions, albeit in insignificant quantities.

The emission factors suitable for Germany have been developed in two stages: first, by appropriate labelling of the statistical figures for CO_2-relevant product groups (Gottwald et al., 2017); second, by way of specific emission factors (Rothe, 2017) calculated by the German Emissions Trading Authority (DEHSt). In the process, verified installation data (emissions reports, product allocations, production quantities, ash contents of raw-material samples) available to the DEHSt for the years 2012 to 2015 were used[45]. Data on product groups considered relevant in terms of CO_2 emissions, but for which the DEHSt was unable to determine emission factors directly, have been supplemented (estimate by experts) by assumption and comparison to other product groups (raw material composition)[46]. As a result of this step-by-step assessment, refractory products, ornamental articles, technical ceramics and abrasives were excluded from the CO_2 calculations. Table 171 contains the CO_2 emission factors determined for the various product groups.

Table 171: CO_2 emission factors for various ceramics product groups

Product group	CO_2 emission factor [t_{CO2} /$t_{product}$]	Notes
Tiles, stoneware	0.018	DEHSt
Backing bricks	0.1047	DEHSt
Facing bricks	0.0189	DEHSt
Bricks for floor and road surfaces	0.016	DEHSt/UBA*
Roof tiles, accessories	0.0112	DEHSt

Product group	CO_2 emission factor [t_{CO2} /$t_{product}$]	Notes
Ceramic pipes and other structural formed products	0.0112	DEHSt/UBA*
Household and sanitary ceramics: porcelain	0.009	DEHSt/UBA*
Household and sanitary ceramics: stoneware, earthenware	0.018	DEHSt/UBA*

* Emission factors determined as an estimate by experts (see the above description)

The implied emission factor (IEF) for the German ceramics industry is obtained from the process-related CO_2 emissions and the activity data for CO_2-relevant ceramics production for the respective year (cf. Table 170). With this approach, an IEF of 0.049 $CO_2/t_{product}$ was calculated for 2024[47].

4.2.4.1.3 Uncertainties and time series consistency (2.A.4.a Ceramics)

As the volume and area data need to be converted to produced masses (tonnes [t]), and since there are uncertainties when generating production statistics, the uncertainties for the activity data are estimated as +6% / -7%.

The uncertainties for CO_2 emission factors used for the product groups listed in Table 171 vary considerably at times. For example, the uncertainties for the clay blocks product group are -18% / +18%, while those for tiles are -53% / +53%. Most of the determined uncertainties are tied to the empirical data of the DEHSt. For emission factors that were not determined directly (such as those for ceramic pipes), uncertainties shares for analogies used have been added (for household and sanitary ceramics, for example, the result is -57% / +57%).

Time series consistency related to activity data is assured for the majority of the product groups listed in Table 171 and for the associated CO_2 emission factors.

Time series breaks for individual product groups (changes in the availability of statistical data, product group changes in the past) have been recorded and described in Gottwald et al. (2017). These time series breaks are either irrelevant or negligible CO_2 emissions.

As of report year 2023, there is a clear drop in the activity data, particularly in the product categories demanded by the construction sector (clay blocks, roof tiles, tiles, etc.). This decline is in line with the development in the construction industry in the report year, and is thus plausible.

4.2.4.1.4 Category-specific QA/QC and verification (2.A.4.a Ceramics)

General quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

The calculated CO_2 emissions are transparent and in the same order of magnitude as the emissions recorded in the ETS.

It is not feasible to compare the emission factors with the IPCC default emission factors because the Guidelines' emission factors are based solely on raw materials, while the country-specific emission factors are based on products.

[47] This value differs from the CO_2 IEF specified in the CRF tables because that IEF (i.e. in the tables) includes the total activity data for all ceramic products. It also subsumes products that, due to their raw material composition and intended quality levels, include no carbonates or CO_2-relevant additives.

The CO_2 IEF for the German ceramics industry, like the IEFs of most other countries, is in the lower to middle band of the range. The IEF values of some countries are higher by a factor 5 to 10, however, which renders them unsuitable for comparison.

4.2.4.1.5 Category-specific recalculations (2.A.4.a Ceramics)

No recalculations were required for this report.

4.2.4.1.6 Planned improvements, category-specific (2.A.4.a Ceramics)

Currently, no improvements are planned other than the review referred to in Chapter 4.2.4.1.4.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

4.2.4.2 Non-metallic minerals industry: other soda ash use (2.A.4.b)

4.2.4.2.1 Category description (2.A.4.b)

Gas	Method used	Source for the activity data	Emission factors used
CO2	Tier 1	NS	D

The overarching category 2.A.4 - Mineral products: Other process uses of carbonates is not a key category.

Soda ash is used in a wide range of industrial applications. The most important areas of use include the glass industry, production of detergents and cleansers and the chemical industry. It is assumed that the carbon contained in soda ash is released into the air as CO_2 sooner or later, regardless of the use involved.

Emissions resulting solely from use of soda ash have a fixed correlation with the calculated quantities used - in this context, outside of the glass industry (cf. the methodological issues in the following chapter):

Table 172: Activity data and use-related CO_2 emissions outside of the glass industry

	Activity data in [t]	CO_2 emissions in [kt]
1990	809,885	336.1
1995	340,793	141.4
2000	411,281	170.7
2005	517,159	214.6
2010	475,836	197.5
2015	717,723	297.9
2020	613,470	254.6
2024	556,400	230.9

Source: Calculations of the German Environment Agency (UBA); for derivation, cf. the following chapter

4.2.4.2.2 Methodological issues (2.A.4.b)

Activity data

Since the 2010 inventory review, the quantities of soda used that are not included in other categories for emission calculations have been determined. The calculations are based on the highest possible emissions from the use of soda ash. The total quantity of soda ash used in

Germany is determined by balancing (quantity produced plus imports and less exports) (a). The import and export quantities are taken from the foreign trade statistics of the Federal Statistical Office (Statistisches Bundesamt, o.J.). Category-specific emissions from soda ash use in the glass industry are already taken into account under category 2.A.3 (b). The soda ash quantities used in that category are deducted from the soda ash use of relevance in this section. The activity data in the above table (c) is calculated using the following formula:

Equation 5:

$$c = a - b$$

When calculating the Energy Balance for the years 2017 to 2021, an average foreign trade balance figure for the previous five years was carried forward as the Federal Statistical Office provided a very high export figure. From 2022 onwards, the Federal Statistical Office's balance framework is once again plausible and is used in its original form.

Emission factor

Stoichiometrically, the emission factor for soda ash use is 415 kg CO_2 per tonne of soda ash, assuming that release is complete (a conservative approach).

4.2.4.2.3 Uncertainties and time series consistency (2.A.4.b)

Activity data

The calculations of the relevant quantities of soda ash used are subject to high levels of uncertainties (maximum of ±18%) because, in addition to the statistical fluctuations in soda production and foreign trade in soda, calculation assumptions based on the above derivation are also taken into account.

Emission factor

The emission factor for soda ash use is subject to small, justified uncertainties in terms of product purity and completeness of the chemical conversions involved (-5% / +0%).

4.2.4.2.4 Category-specific QA/QC and verification (2.A.4.b)

General quality control and quality assurance, have been carried out in conformance with the requirements of the QSE-manual and its associated applicable documents, by the Single National Entity.

At present, it is not possible to verify quantitatively the input quantities of soda ash that cannot be allocated to the glass industry. However, as conservative estimates they do not underestimate the quantities in the inventory. Qualitatively, the calculation results do not contradict the randomly sampled sales figures provided by soda ash producers.

The stoichiometric emission factor corresponds to the default figures provided in the IPCC Guidelines (IPCC (2006a): Volume 3, Chapter 2, Table 2.1)

4.2.4.2.5 Category-specific recalculations (2.A.4.b)

Recalculations were necessary because data for use in the glass industry have changed:

Table 173: Category-specific recalculations (2.A.4.b), in [kt CO_2]

	2026 submission	2025 submission	Change
2022	264.2	264.1	+0.1
2023	250.3	261.5	-11.2

Source: Calculations by UBA

4.2.4.2.6 Category-specific planned improvements (2.A.4.b)

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter. No additional improvements are planned at present.

4.2.4.3 Production of non-metallurgical magnesium products (2.A.4.c)

4.2.4.3.1 Category description (2.A.4.c)

The greenhouse gas emissions from this category account for less than 0.05% of the total inventory (without LULUCF) and are less than 500 kt CO_2-equivalents; moreover, it is not possible to guarantee that they are recorded annually (UNFCCC, 2013). These emissions are therefore not reported. This chapter provides a one-off quantitative estimate of the emissions not included in the inventory. In addition, a compilation of all sources listed as "not estimated" is provided in Chapter 1.7.2 of this report.

4.2.4.3.2 Methodological issues (2.A.4.c)

It was not possible to identify any suitable activity data for this category segment in the official statistics. Some product types, such as refractory bricks, are already included in the activity data for the ceramics industry (CRF 2.A.4.a, Chapter 4.2.4). The additionally identified category "production of other carbonates" is a collective in which magnesium carbonates are a non-quantifiable sub-quantity. The resulting time series shows only production quantities less than 300,000 t. The lowest threshold for inclusion would be about one million tonnes of a product with large fractions of CaO and MgO. No product type, not even those already included in other categories, achieves this level.

Since the statistics contain collective categories, the potential CO_2 emissions cannot be precisely calculated. They are estimated to be considerably less than 100,000 t of carbon dioxide.

4.2.4.3.3 Uncertainties and time series consistency (2.A.4.c)

No conclusions can be drawn in terms of uncertainties and time series consistency.

4.2.4.3.4 Category-specific QA/QC and verification (2.A.4.c)

Due to limited resources and the area's minimal relevance, no QC/QA has been carried out for reporting in this area.

An initial estimate was made as part of a research project and then reviewed by the specialised contact person at the German Environment Agency (UBA) and confirmed as described above.

4.2.4.3.5 Category-specific recalculations (2.A.4.c)

Recalculations are not included as the emissions are not reported.

4.2.4.3.6 Category-specific planned improvements (2.A.4.c)

No improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

4.2.4.4 Non-metallic minerals industry: other limestone and dolomite use (2.A.4.d)

4.2.4.4.1 Category description (2.A.4.d)

This category's carbon dioxide emissions are not reported separately; instead, they are reported in the sections for the categories that use limestone and dolomite (they are thus included elsewhere - IE). The respective categories are also taken into account in the key category analysis.

In this category, until the 2014 submission, in addition to the 1996 IPCC Guidelines, the entire production and use of limestone and dolomite was taken into account in the balance and comparisons were made with the categories in the inventory. This "limestone balance" (Röhling & Kludt, 2010) appeared most recently in the 2014 NIR.

No findings are available regarding use of limestone in emissions-relevant sectors other than the categories listed below.

Emissions of the precursor substances SO2, NO_x, CO and NMVOC are entered in this category in the UNFCCC's CRF software because, with the exception of SO_2 from 2.A.1, no entry is possible in subcategories of 2.A. Specifically, these are:

- NO_X and NMVOC from 2.A.1, 2.A.2, 2.A.3 and 2.A.4.a,
- SO_2 from 2.A.2, 2.A.3 and 2.A.4.a, including a statistical figure for the new German federal states in 1990.
- CO from 2.A.2 and 2.A.3,
- this allocation also means that no entry of activities in this category is possible, only in the categories causing emissions.

4.2.4.4.2 Methodological issues (2.A.4.d)

The following section provides an overview of national limestone inputs (category references). Emissions calculations are carried out for the categories in which CO_2 emissions are produced from limestone use:

- 1.A.1.a Flue-gas desulphurisation in power stations (limestone inputs)
- 2.A.1 Cement clinker production (limestone fraction in the raw materials)
- 2.A.2 Limestone production (limestone inputs)
- 2.A.3 Glass production (limestone fraction in the raw materials)
- 2.A.4.a Ceramics production (carbonate fraction in the raw materials)
- 2.B.7 Soda ash production (limestone inputs)
- 2.C.1 Iron and steel production (limestone inputs and lime kilns)
- 2.H.2 Sugar production (lime furnaces)
- 3.G-I Soil liming in agriculture and forestry (limestone and dolomite)

The data are updated in the relevant categories (cf. the above list). In addition, the methodological issues are explained in the relevant category chapters.

4.2.4.4.3 Uncertainties and time series consistency (2.A.4.d)

Information regarding uncertainties for activity data and emission factors for the relevant limestone uses is provided in the respective category chapters.

4.2.4.4.4 Category-specific QA/QC and verification (2.A.4.d)

The activity data and the emission factors for the relevant limestone uses are verified and updated in the respective categories.

4.2.4.4.5 Category-specific recalculations (2.A.4.d)

Recalculations have been carried out in the respective categories.

4.2.4.4.6 Category-specific planned improvements (2.A.4.d)

No improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

4.3 Chemical industry (2.B)

Category 2.B is divided into the subcategories 2.B.1 to 2.B.10. These include ammonia production (2.B.1), nitric acid production (2.B.2), adipic acid production (2.B.3), caprolactam, glyoxal and glyoxylic acid production, (2.B.4), carbide production (2.B.5), titanium dioxide production (2.B.6), soda ash production (2.B.7), petrochemical and carbon black production (2.B.8) and production of fluorinated chemicals (2.B.9).

In the category *Other* (2.B.10), only precursor substances from production of fertilisers and sulphuric acid are reported. Production of 1,12 dodecanedioic acid is described in 2.B.10, while process-related N_2O emissions are reported under 2.B.3 for confidentiality reasons.

4.3.1 Chemical industry: Ammonia production (2.B.1)

4.3.1.1 Category description (2.B.1)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
L/-	2 B 1, Ammonia Production		CO_2	6,025.00	0.47	3,267.00	0.47	-45.78

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 3	PS	PS
NO_X			D

The category “Chemical industry: ammonia production” is a key category for CO_2 emissions in terms of emissions level.

Ammonia is produced with hydrogen and nitrogen using the Haber-Bosch process, which also forms CO_2. Hydrogen is produced from synthetic gas (usually) based on natural gas using a highly integrated process called *steam reforming*, while nitrogen is produced by air dissociation.

The various plant types for the production of ammonia cannot be divided into individual units and compared as independent process parts due to the highly integrated character of the procedure. *Steam reforming* involves one of the three following processes:

- ACP - advanced conventional process with a fired primary reformer and secondary reforming with excess air (stoichiometric H/N ratio)
- RPR - reduced primary reformer process carried out under mild conditions in a fired primary reformer and with secondary splitting with excess air (sub-stoichiometric H/N ratio)
- HPR - heat exchange primary reformer process -autothermic splitting with heat exchange using a steam reformer heated with process gas (heat exchange reformer) and a separate secondary reformer or a combined autothermic reformer using excess air or enriched air (sub-stoichiometric or stoichiometric H/N ratio).

The following procedure is also used:

- Partial oxidation - gasification of natural gas, fractions of heavy mineral oil or vacuum residues in production of synthetic gas.

As of mid-2014, ammonia is only produced at four locations in Germany. The production operations use both the steam-reforming and partial-oxidation processes.

The production decrease of more than 15% (equating to nearly 300 kt) in the first year after German reunification was the result of a market shake-up, over 2/3 of which was borne by the new German federal states. The production level then remained largely constant in subsequent years until 1994. It has not been possible to determine the reason for the renewed growth as of 1995, which returned production to the level seen in 1990. However, the growth could be due to resumption of production processes in the new German federal states following extensive modernisations. Since 1995, production levels have fluctuated only slightly. The nearly 8% production decrease that occurred in 2009 was due to the global economic crisis. Until 2013, the IEF was higher than that of other countries since in Germany, heavy fuel oil is used for partial oxidation alongside natural gas. Heavy fuel oil produces significantly higher CO_2 emissions than natural gas does. Since mid-2013, partial oxidation has been carried out primarily with natural gas. In addition, sizable quantities of CO_2 are captured and processed into urea for use in AdBlue, as well as for use as fertiliser. As a result, the IEF no longer differs significantly from that of other countries.

4.3.1.2 Methodological issues (2.B.1)

In line with this category's classification as a key category for CO_2 emissions, emission data from this category has been collected and reported according to Tier 3 since the 2010 reporting period, with the exception of one plant which was collected according to the Tier 2 method until 2012, as the default carbon content was used. As of 2013, all plant data have been obtained pursuant to the Tier 3 method. This is being carried out on the basis of a cooperation agreement with the plant operators for delivery of plant-specific data. Use of the Tier 2 and Tier 3 methods mean that the collected data meet for the requirements for key categories throughout the entire time series.

The operators transmit their plant-specific data to the Industrieverband Agrar (IVA) agrochemical industry association. That association anonymises the data for confidentiality reasons, then sends it to the German Environment Agency (UBA) for each specific plant. The German Environment Agency carries out quality assurance and then aggregates the data.

The plant operators report:

- the ammonia quantities produced (activity data),
- the quantities of raw materials used in the process (natural gas, heavy mineral oil), less the fuel quantities used for energy purposes reported in the Energy Balance (TFR_i),
- its C factor (CCF_i) and carbon oxidation factor (COF_i),
- the quantity of CO_2 that undergoes further processing (R_{CO2}) and the purpose for which it is used.

CO_2 emissions

The CO_2 emissions are calculated in accordance with Equation 3.3 in the 2006 IPCC Guidelines ((IPCC, 2006a)):

Equation 6:

$$EF_{CO2} = \sum(TFR_i * CCF_i * COF_i * \frac{44}{12} - R_{CO2})$$

The recovered quantity of CO_2, which is used in other production processes such as urea production and is also reported there, is not included in the reported emissions.

Since 2013, all ammonia plants have been subject to emissions trading, which means that all plants for determining carbon content also meet the requirements for emissions trading.

One producer uses a standard factor that has been obtained by ongoing operational analysis (C content = 86.1% by weight). Until 2013, the second producer used the IPCC default value for natural gas. For the residual gases, the carbon content was determined by analysis, and the carbon content of the gas mixture used was calculated on a quantity-weighted basis from the carbon content of the individual input materials. In two cases, producers use the data provided by the natural gas suppliers.

Emission factor for NO_x

The emission factor that has been used for NO_X is the default emission factor provided in the *CORINAIR Guidebook*, 1 kg/t HNO_3 (EMEP (2009): EMEP EEA Emission Inventory Guidebook, TFEIP-endorsed draft, May 2009).

4.3.1.3 Uncertainties and time series consistency (2.B.1)

The uncertainties reported by the operators are aggregated by UBA in accordance with Equation 3.2 (IPCC (2006a): Vol. 1, Chapter 3) and entered into the tables.

The uncertainty for the activity data is ±0.6%. The uncertainty for the emissions is ±1%.

4.3.1.4 Category-specific QA/QC and verification (2.B.1)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

4.3.1.5 Category-specific recalculations (2.B.1)

No recalculations have been carried out.

4.3.1.6 Category-specific planned improvements (2.B.1)

No further improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

4.3.2 Chemical industry: Nitric acid production (2.B.2)

4.3.2.1 Category description (2.B.2)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
-/T	2 B 2, Nitric Acid Production		N_2O	2,896.77	0.23	114.29	0.02	-96.05

Gas	Method used	Source for the activity data	Emission factors used
N_2O	Tier 3	PS	PS

The category "Chemical industry: Nitric acid production" is a key category for N_2O emissions in terms of trend.

In production of nitric acid, nitrous oxide occurs in a secondary reaction. In Germany, there are currently nine nitric acid production plants.

HNO_3 production occurs in two stages:

- Oxidation of NH_3 to NO and
- Conversion of NO to NO_2 and absorption in H_2O.

Details of the process are outlined below:

Catalytic oxidation of ammonia

A mixture of ammonia and air at a ratio of 1:9 is oxidised in the presence of a platinum catalyst alloyed with rhodium and/or palladium at a temperature of between 800 and 950°C.

The relevant reaction based on the Ostwald process is as follows:

$$4\ NH_3 + 5\ O_2 \rightarrow 4\ NO + 6\ H_2O$$

Simultaneously, nitrogen, nitrous oxide and water are formed as undesirable secondary reactions:

$$4\ NH_3 + 3\ O_2 \rightarrow 2\ N_2 + 6\ H_2O$$

$$\mathbf{4\ NH_3 + 4\ O_2 \rightarrow 2\ N_2O + 6\ H_2O}$$

All three oxidation reactions are exothermic. Heat may be recovered to produce steam for the process and for export to other plants and/or to preheat the residual gas. The reaction water is condensed in a cooling condenser during cooling of the reaction gases and then conveyed into the absorption column.

4.3.2.2 Methodological issues (2.B.2)

As set forth in the 2006 IPCC Guidelines (IPCC, 2006a), nitric acid production is now reported for each plant in accordance with the Tier 3 method. This is being carried out on the basis of a cooperation agreement with the plant operators for delivery of plant-specific data. Up to the 2014 reporting round, six operators sent data to the Industrieverband Agrar (IVA) industrial association. After carrying out quality assurance, the IVA aggregated the data to protect confidentiality and then sent the aggregated data (AD and EF) to the German Environment Agency. Two companies sent their data (AD, EF, N_2O emissions and information about any reduction equipment used) directly to the German Environment Agency. After carrying out quality assurance, the German Environment Agency then aggregated these companies' data with the data provided by the IVA and entered the aggregated data into the CSE emissions database.

The cooperation agreement was adapted for the new commitment period and in accordance with the new 2006 IPCC Guidelines. Since then, the German Environment Agency (UBA) has been receiving plant-specific data via the IVA for six companies with seven plants in anonymised form. Two other operators send their data directly to the German Environment Agency.

The plant operators report:

- the quantities of nitric acid produced (activity data);
- the EF;
- the N_2O emissions measured in the raw gas;
- where emissions reduction equipment is used, the N_2O emissions measured in the emissions reduced exhaust gas;
- the uncertainties for the activity data, the emission factor and emissions reductions.

The reduction technologies used are selective catalytic reduction (SCR) and EnviNOx technology, the latter of which reduces N_2O emissions by over 99%. Catalytic decomposition reduces both N_2O and NH_3 emissions. One plant has been retrofitted with a second waste gas treatment system (SCR).

Until 2006, production quantities correlated with the N_2O emissions. Subsequently, a considerable decoupling of production quantities and N_2O emissions has become apparent that is due to use of emissions reduction equipment. In 2017, one plant's catalytic converter was replaced. The effects of this replacement are seen in 2018 in the form of a reduced EF.

For the year 2021, one producer, who is responsible for minor emissions quantities, was unable to carry out emissions measurements completely. For this reason, the emission factor for this plant was interpolated from the available data for the period between 2020 and 2022.

The total emissions, which have been lower since 2023, can be explained by the replacement of catalysts and the implementation of additional De-N_2O measures.

NO_X emission factor:

The emission factor that has been used for NO_X are the T2 default emission factors provided in the *CORINAIR Guidebook* (EMEP (2009): EMEP EEA Emission Inventory Guidebook, TFEIP-endorsed draft, May 2009). In line with developments over time and technology, the corresponding emission factors with and without exhaust gas treatment were taken into account. Further details are available in the Informative Inventory Report (IIR).

4.3.2.3 Uncertainties and time series consistency (2.B.2)

Activity data

The activity rate uncertainty was determined by the German Environment Agency as per Equation 3.2 (IPCC (2006a), Vol. 1, Ch. 3) using the figures provided by the operators. The uncertainty is ±1%.

Emission factor

For the N_2O emission factor, the operators provide an uncertainty of ±5%.

4.3.2.4 Category-specific QA/QC and verification (2.B.2)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

4.3.2.5 Category-specific recalculations (2.B.2)

No recalculations were required.

4.3.2.6 Category-specific planned improvements (2.B.2)

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

4.3.3 Chemical industry: Adipic acid production (2.B.3)

4.3.3.1 Category description (2.B.3)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
L/T	2 B 3, Adipic Acid Production		N_2O	16,074.90	1.25	32.92	0.01	-99.80

Gas	Method used	Source for the activity data	Emission factors used
N_2O	Tier 3	PS	PS
NO_X, CO	Tier 3	PS	PS

The category "Chemical industry: adipic acid production" is a key category for N_2O emissions in terms of emissions level and trend.

On an industrial scale, adipic acid is produced through oxidation of a mixture of cyclohexanol and cyclohexanone with nitric acid. In that reaction, considerable amounts of nitrous oxide (N_2O) are formed.

Until the end of 1993, the two sole German producers emitted all of their nitrous oxide directly into the atmosphere. One producer has since introduced a system for thermal decomposition of nitrous oxide into nitrogen and oxygen. Decomposition takes place nearly completely. In 2009, a second, additional (i.e. redundant) thermal N_2O decomposition facility was added. N_2O decomposition rates of over 99% are now being achieved.

At the end of 1997, the other producer put a catalytic N_2O decomposition system into operation that, in constant operation, achieves an N_2O decomposition rate of 97-98%. At the end of 2009, a second, redundant decomposition reactor was added.

Since 2010, N_2O emissions have continued to decrease significantly since the two producers have each installed a redundant waste gas treatment facility.

In March 2002, a third producer, with one plant, began production. That plant also uses the thermal N_2O decomposition process. Since 2013, that producer also has had the option of using a redundant emissions reduction system if his primary system should fail. N_2O decomposition rates of over 99% are now being achieved.

The overall fluctuations in the decomposition rates - and, thus, in the residual emissions - are the result of functional impairments in the emissions control equipment, of planned interruptions in their operation and of variances in production volumes.

Driven by demand, output had roughly doubled compared to 1990, but saw sharp fallbacks in 2022 and 2023 in particular.

N_2O emissions from production of 1,12-dodecanedioic acid (DDDA) are also reported here, but the production process for dodecanedioic acid is described in Chapter 4.3.10.

4.3.3.2 Methodological issues (2.B.3)

Since 1990, N_2O emissions from adipic acid production have been calculated on the basis of plant-specific data.

In the years in which no systems for reducing nitrous oxide emissions were in operation, the two producers only provided production quantity data. The nitrous oxide emissions for that period - until 1994 for one facility, and until 1997 for the other - were calculated with the IPCC default emission factor. The calculation of N_2O emissions for these years corresponds to the Tier 2 approach. For the subsequent period, the two producers continuously measured their nitrous oxide emissions and, in addition to providing data on production and on N_2O emissions, also provided the confidential background information needed to gauge the accuracy of the reported data. The third producer has been measuring emissions continuously since 2013. In the period prior to that year, that producer used the quantities of produced adipic acid and a suitable emission factor to calculate the quantities of nitrous oxide that were emitted in two possible plant states (unreduced and reduced operation). These calculations also took into account a) the periods of time for which each plant state was maintained, and b) the plant load levels. An emission factor, taking account of the quantities of adipic acid produced and the results of nitrous oxide concentration measurements, was determined for each of the two operational states.

Determination of N_2O emissions on the basis of continuous nitrous oxide measurement corresponds to the Tier 3 method set forth in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC (2006a): Vol. 3, Ch. 3.4.2.1).

4.3.3.3 Uncertainties and time series consistency (2.B.3)

For installations with thermal decomposition, the 2006 IPCC GL IPCC (2006a): Vol. 3, Tab. 3.4) give uncertainties for the N_2 decomposition rate of ±0.5%; for installations with catalytic decomposition, they give uncertainties of ±2.5%.

According to the producers, uncertainties for the emissions are about ±1 to 6%, regardless of the reduction process used. The uncertainties for production quantities are estimated to be between <0.1 and approximately 1%. The uncertainty for the EF is thus set at 6%, while that for the production quantities is set at 2%.

The third producer's emissions have not been recalculated retroactively to the year 2002 as per the changes in the survey method for this area because of the non-comparable emissions values resulting from the simultaneous commissioning of the redundant reduction system.

4.3.3.4 Category-specific QA/QC and verification (2.B.3)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

Information provided by producers enjoys a high degree of confidentiality protection. For this reason, only emissions figures can be listed in the CRT tables. The reported emissions and activity data have been reviewed by a German Environment Agency expert and cross-checked against other data sources.

Comparisons of the IEF with that of other countries is possible only to a limited degree as only Italy and the U.S. consistently report an emission factor for N_2O. The lower of the two IEFs is comparable to the German national emission factor. Comparisons with PRTR data are not feasible for this category.

Two of the three producers have each carried out a JI project. The projects are available for review in the JI project database[48] under the project IDs DE-1000017 and DE-1000018. The inventory data have been compared with the projects' corresponding figures for the period 2008 to 2012 and confirmed by that comparison.

The emissions data for the period 2013 to 2019 have been cross-checked against the ETS data. The check shows that the data sets are in good agreement.

No expert verification is known for the calculation method prior to the change of method in the 1990s.

4.3.3.5 Category-specific recalculations (2.B.3)

No recalculations have been carried out.

4.3.3.6 Category-specific planned improvements (2.B.3)

No further improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.3.4 Chemical industry: Caprolactam, glyoxal and glyoxylic acid (2.B.4)

4.3.4.1 Category description (2.B.4)

The category "Chemical industry: caprolactam, glyoxal and glyoxylic acid" is not a key category.

Industrially, ε-caprolactam is the most important lactam. It is used primarily for production of PA 6. There are two producers in Germany.

Glyoxal is used in the production of a wide range of products. It serves to improve product properties. There is one producer. The process used by that producer for glyoxal production (oxidation of ethylene glycol during the gas phase) is not a source of process-related nitrous oxide emissions.

[48] cf.: https://ji.unfccc.int/JI_Parties/DB/1JUS6UM3SH2O9VJ0RWUQDB99J8DWTJ/viewDFP

The producer reports that no glyoxal delivered to customers in Germany is processed into glyoxylic acid. We are not aware of any glyoxylic acid production in Germany from other raw materials.

4.3.4.2 Methodological issues (2.B.4)

Caprolactam

Both producers use a synthesis pathway via hydroxylammonium sulphate (HAS) where ammonia is oxidised. Ammonia oxidation is the factor primarily responsible for the N_2O emissions in the production process.

Both producers also employ a thermal waste gas treatment system to destroy nitrous oxide. Both producers' systems have a redundant design. The temperatures involved are much higher than the decomposition temperature of nitrous oxide. As a result, only very small quantities of emissions occur.

For one of the two producers, the N_2O emissions are assigned to nitric acid production (2.B.2) in the interest of consistency with emissions trading data. A Tier 3 reporting method is used. For that system, therefore, "IE" is entered under 2.B.4a in the CRT Table.

With regard to the other producer's installation, the Single National Entity has access to detailed information that indicates that the post-combustion system can be assumed to completely eliminate the nitrous oxide quantities involved. But since the operator of that system is not subject to measurement obligations, and in order to prevent any underestimation of nitrous oxide emissions from other emission sources, the N_2O emissions have been quantitatively estimated, on a one-time basis, using a Tier 2 method. For the estimate, a production capacity is derived from press reports[49], and the N_2O standard emission factor for the production of caprolactam (9 kg N_2O/t caprolactam, pursuant to IPCC (2006a): Vol. 3, Chapter 3.5, Table 3.5) from the 2006 IPCC GL is used alongside standard factors for thermal waste gas treatment in adipic acid production (98.5% reduction rate and 99.91% capacity utilisation pursuant to IPCC (2006a): Vol. 3, Chapter 3.4, Table 3.4). The capacity utilisation factor for the redundantly designed waste gas treatment system is obtained from the 97% capacity utilisation factor for the main installation, and the 97% factor for the second installation that is used for the 3% during which the main system cannot be used. By using standard factors from the IPCC-GL, Germany follows the recommendations provided by the *Expert Review Team for the 2016 In-country Review*. For the year 2015, the estimate is 9.5 kt CO_2-eq. (AR5) for this installation. On the basis of the installation's emissions level, the permissibility of reduced emissions reporting pursuant to FCCC/SBSTA/2013/L.29/Add.1, para 37(b) has been reviewed. To that end, the other installation's N_2O emissions were calculated on the basis of standard emission factors and the production capacity. A total of 15.9 kt CO_2-eq. (AR5) resulted for both installations taken together. Since the calculated N_2O emissions from the category account for less than 0.05% of the total inventory (without LULUCF) because they do not exceed 500 kt CO_2 equivalents, and since annual recording cannot be carried out (as per FCCC/SBSTA/2013/L.29/Add.1, para 37), we opt not to report on this area IPCC (2006a): Vol. 3, Chapter 3.5). In addition, a compilation of all sources listed as *not estimated* is provided in Chapter 1.7.2 of this report. The two installations are shown under 2.B.4.a in the CRT table with the notation "IE" and "NE". This notation is consistent with the information and recommendations provided in the In-country Review.

[49] Last accessed on 25 October 2017

4.3.4.3 Uncertainties and time series consistency (2.B.4)

For the activity data, an uncertainty of ±30% is assumed. For the standard factors, the corresponding uncertainties provided in the 2006 IPCC-GL (IPCC, 2006a) apply.

4.3.4.4 Category-specific QA/QC and verification (2.B.4)

Due to limited resources and the area's minimal relevance, no QC/QA has been carried out for reporting in this area.

Only a few sources are available that can serve as a basis for verification of the producer information in press reports. For the years 1995 to 2008, quantity data for ε-caprolactam production are available (Statistisches Bundesamt (jährlich - FS 4, R. 3.1) (manufacturing industry, production in the manufacturing industry)). Since changes were made to international classifications in 2009, it has no longer been possible to conduct statistical surveys of and separately list produced quantities of ε-caprolactam. ε-caprolactam does continue to be listed separately in foreign-trade statistics. Data on import quantities since 1996 and on export quantities since 2009 are available. The import and export quantities have remained relatively stable.

4.3.4.5 Category-specific recalculations (2.B.4)

No recalculations are required.

4.3.4.6 Category-specific planned improvements (2.B.4)

No further improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.3.5 Chemical industry: Carbide production (2.B.5)

4.3.5.1 Category description (2.B.5)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
-/-	2 B 5, Carbide Production	0	CO_2	443.16	0.04	4.39	0.01	-99.01

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 3	PS	PS (CaC_2) NO (SiC)

The category "Chemical industry: Carbide production" is not a key category.

During the reunification period, calcium carbide was largely produced in the new German federal states. A short time later, production there was discontinued, while only one producer remained in the old German federal states. According to the responsible specialised association in the VCI, no silicon carbide has been produced in Germany since 1993. Emissions from this sector thus no longer occur.

4.3.5.2 Methodological issues (2.B.5)

Activity data

Since Germany has only one producer, this data must be kept confidential. The producer communicates the data directly to the German Environment Agency on an annual basis. The data as of 1997 were obtained from the operator's life cycle assessment and from his annual environmental declarations pursuant to the EMAS (the facility has been certified since 1997). Only production volumes in the former GDR were published by the former Central Statistical Office until 1989. These figures were used in combination with existing estimates for 1991 and 1992 to interpolate production in the new German federal states in 1990.

Emission factor

The stoichiometric emission factor for CO_2 is 688 kg per tonne of calcium carbide (44 g mol^{-1} / 64 g mol^{-1}). Until 1992, this emission factor was used for production in the new German federal states.

Using covered furnaces, producers collect all of the carbon monoxide produced in the process and use it for energy generation. The resulting carbon dioxide serves as auxiliary material in production of calcium cyanamide and derived products. Reactions in these processes yield carbon dioxide in mineral form, as black chalk. In this form, it is used in agriculture. In 2012, carbide furnace operations were refined to considerably reduce the amount of surplus furnace gas that had to be flared off. The new operational mode has also enabled the furnaces to run more "calmly", meaning that they produce fewer pressure surges that have to be buffered by raw-gas flares. The emission factor also includes the CO_2 emissions from flare use.

As a result, the emission factor for carbon dioxide from calcium carbide production is now substantially lower than it has been in previous years.

Upon request, the producer provides the German Environment Agency with data on total emissions and on quantities produced. The emission factor is obtained by dividing the emissions quantity by the activity data.

4.3.5.3 Uncertainties and time series consistency (2.B.5)

The uncertainties related to the data provided by the producer are considered slight overall.

4.3.5.4 Category-specific QA/QC and verification (2.B.5)

General quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

Information provided by producers is subject to strict confidentiality. For this reason, only emissions figures can be listed in the CRF tables. No calculations for verification could be carried out. It may be noted, however, that some of the figures have also been provided to licensing authorities and thus are considered trustworthy.

4.3.5.5 Category-specific recalculations (2.B.5)

No category-specific recalculations were carried out.

4.3.5.6 Category-specific planned improvements (2.B.5)

No further improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.3.6 Chemical industry: Titanium dioxide production (2.B.6)

There are several producers of titanium dioxide in Germany. One of the plants involved produces titanium dioxide using the chloride process. The others produce using the sulphate process and emit no process-related CO_2. The CO_2 emissions estimate was provided by experts on the basis of the production capacity and an emission factor that is itself based on an expert estimate. This estimate was made with confidential data that, by virtue of their confidentiality, cannot be presented here.

Since the greenhouse gas emissions from the category titanium dioxide production account for less than 0.05% of the total inventory (without LULUCF), and since they would not exceed 500 kt CO_2 equivalents (significance thresholds pursuant to FCCC/SBSTA/2013/L.29/Add.1), and as annual recording cannot be guaranteed (in accordance with FCCC/SBSTA/2013/L.29/Add.1, para 37), we have decided not to report on this area IPCC (2006a): Vol. 3, Chapter 3.7). In addition, a compilation of all sources listed as *not estimated* is provided in Chapter 1.7.2 of this report.

4.3.7 Chemical industry: Soda-ash production (2.B.7)

4.3.7.1 Category description (2.B.7)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
-/-	2 B 7, Soda Ash Production	0	CO_2	615.50	0.05	404.45	0.06	-34.29

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1/2	NS/PS	CS

The category “Soda ash production” is not a key category.

In Germany, soda ash is produced only chemically. The country has 3 production facilities that use[50] the Solvay process[51]. In principle, the CO_2 contained within the calcium carbonate used in the process is bound in the product, soda ash (Na_2CO_3), and released - if at all - only when that product is used (cf. category 2.A.4.b in Chapter 4.2.4.2). But since production using the Solvay process yields a CO_2 surplus, this results in process-related CO_2 emission.

In the calcination part of the process, coke/anthracite is also used, in turn producing additional (energy-related) carbon dioxide emissions.

4.3.7.2 Methodological issues (2.B.7)

Activity data

The total amounts of soda ash produced in Germany are determined thanks to two data suppliers.

[50] Other processes that are less important in terms of the production quantities involved are not considered here as they use carbon dioxide from sources other than limestone.

[51] Ammonia-soda process pursuant to Ernest Solvay

The Federal Statistical Office has long time series available for this area. The time period 1990 to 1994 is a combination of data from the "old" German federal states and from the transfer of data for the new German federal states to the joint records for Germany as a whole. From 1995 to 2008, the categories light soda and heavy soda were listed separately. As of 2009, there is only a single listing (reporting number (Meldenummer) 2013 43 100). Of that quantity, only the portion "intended for sale" ("zum Absatz bestimmt") is taken into account. This prevents double-counting, since heavy soda is produced from light soda.

Due to the presence of an almost inexplicable trend in the data of the Federal Statistical Office for the period since 2015, the producers were contacted and, in 2021, cooperation agreements were signed with both producers (for all three production sites; cf. also Chapter 1.2.1.4). The German Environment Agency (UBA), which consolidates this data, has decided that as of 2013 the time series is to be filled with the producers' data (this overlaps with a comparison carried out for the period 2013-2021).

Since Germany has only two producers, the production quantity data from the two sources must be kept confidential.

Emission factor

The emission factor is calculated from the carbon dioxide emissions as determined in accordance with the ETS CO_2 balance, and from the production quantities involved. Since the production quantity data is confidential, the EF can also not be provided here.

The coke quantity used in burning the relevant lime has been included in the Energy Balance as a non-energy-related use (i.e. without inclusion of CO_2 emissions).

4.3.7.3 Uncertainties and time series consistency (2.B.7)

Activity data

Uncertainties exist with regard to the production quantities provided by the Federal Statistical Office, especially for the period since the quantities were listed separately and for the period as of 2015.

The uncertainty of the production quantity was revised on the basis of manufacturer data and expert interviews and is 1.5%.

Emission factor

The uncertainty of the emission factor, with regard to production of soda ash, is calculated from the uncertainties for the ETS emission balance and the uncertainties for the production data.

4.3.7.4 Category-specific QA/QC and verification (2.B.7)

General quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

The CO_2 balance for determination of the emissions is produced using data from emissions trading. These data have been fully checked and verified in the framework of the EU Emissions Trading System (ETS).

The production data undergo quality control by the producers with whom cooperation agreements are in place.

4.3.7.5 Category-specific recalculations (2.B.7)

No recalculations were required.

4.3.7.6 Category-specific planned improvements (2.B.7)

No improvements are planned.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.3.8 Chemical industry: Petrochemical and carbon black production (2.B.8)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
-/-	2 B 8, Petrochemical and Carbon Black Production		CO_2	973.97	0.08	756.98	0.11	-22.28
-/-	2 B 8, Petrochemical and Carbon Black Production		CH_4	373.73	0.03	423.06	0.06	13.20

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2 (carbon black) CS (petrochemical industry)	NS	D (carbon black) CS (petrochemical industry)
CH_4	Tier 1	NS	D
CO, SO_2	Tier 1 (carbon black)	NS	D (carbon black)
NMVOC	Tier 1 (petrochemical industry)	NS	C & CS (petrochemical industry)

The category “Chemical industry: petrochemical and carbon black production” is not a key category. Carbon-black production predominates in this category, accounting for about 75% of its emissions.

4.3.8.1 Chemical industry: Petrochemicals (2.B.8 Petrochemicals)

4.3.8.1.1 Category description (2.B.8 Petrochemicals)

The petrochemicals sector produces basic organic chemicals, from natural gas and from petroleum fractions, that are processed into a great many different intermediate and end products (primarily polymers). In the 2006 IPCC Guidelines (IPCC, 2006a), section 2.B.8 highlights the production of the basic chemicals (a) methanol, (b) ethylene, (c) ethylene chloride and vinyl chloride, (d) ethylene oxide and (e) acrylonitrile due to their potential carbon dioxide and methane emissions.

Production of petrochemicals and derivatives, along with production of pharmaceuticals, production of fine and specialty chemicals and production of polymers, is one of the most important sectors of the chemical-pharmaceutical industry in terms of production value[52].

4.3.8.1.2 Methodological issues (2.B.8 Petrochemicals)

Activity data

No installation-related data are available for the production of the above products; only nationally aggregated production quantities are available. These have been made available to

[52] Chemiewirtschaft in Zahlen 2023, Verband der Chemischen Industrie e.V. (2024): https://www.vci.de/services/publikationen/broschueren-faltblaetter/chemiewirtschaft-in-zahlen.jsp

the German Environment Agency by the Federal Statistical Office on the basis of its "Fachserie 4, Reihe 3.1, Produzierendes Gewerbe, Produktion im Produzierenden Gewerbe" (Manufacturing industries, production in manufacturing industries) (Statistisches Bundesamt, FS 4, R 3.1), including confidential data.

In official production statistics, petrochemicals and derivatives are listed as "other basic organic substances and chemicals" (sonstige organische Grundstoffe und Chemikalien) under WZ-Nummer (number in the German Classification of Economic Activities) 20.14.

The data on acrylonitrile production quantity is confidential, as is that of methanol and ethylene dichloride in certain years. For these reasons, all production quantities for the products in groups a) to e) are aggregated and then reported together with the accompanying CO_2 and CH_4 emissions under 2.B.8.g.

To determine NMVOC emissions, production of products that have to be reported under the CLRTAP is also taken into account in addition to the production of the products in groups a) to e). Detailed reporting on products that have to be reported under the CLRTAP is provided in the Informative Inventory Reports (IIR) pursuant to the CLRTAP.

CO_2 emission factors

Since 2013, pursuant to Annex 1 Part 2 Activity No. 27 German Greenhouse Gas Emission Allowance Trading Act (TEHG), all of the installations located in Germany for production of the aforementioned organic basic chemicals have been subject to the EU Emissions Trading System (ETS) as their production outputs are greater than 100 t/d (36,500 t/a).

A comparison of a) the total CO_2 emissions of the ETS installations pursuant to a) to e) that have been reported for purposes of the greenhouse gas emissions trading system with b) the CO_2 emissions for the year 2013 as calculated with the new IPCC standard emission factors shows that the standard emission factors lead to higher emissions. And this in the case even though the total installation-related emissions from emissions trading include both emissions from combustion processes and other process-related emissions. In the German greenhouse gas inventory, most combustion-related emissions are already accounted for in the energy statistics for the energy sector. The standard emission factors thus cannot be used as this would be double-counting.

Along with combustion processes in boilers and cracking furnaces, the CO_2 emission sources to be considered include combustion processes in flares, decoking processes and other process-related emissions.

It would not be justified to quantify the other process-related emissions since the installation-related CO_2 emissions of steam cracker units, which are by far the largest group of emitters considered in this context, occur almost exclusively from combustion in cracking furnaces, auxiliary boilers or flares. With the exception of flares in the petrochemical industry, these combustion-related emissions are included in the energy sector section in 1.A.2.c.

The CO_2 emissions from flaring losses are quantified, however, in order to fulfil the inventory aim of recording emissions as completely as possible. In future, decoking processes will also be included. Only that fraction of flare gases is considered that can be allocated to the aforementioned products in groups a) to e).

Since pre-2013 ETS data are not available for all of the aforementioned products, the CO_2 emissions are calculated on the basis of a CO_2 emission factor derived for 2013 and the quantities of the relevant products produced annually.

Because residual gases and flare gases are often transported between installations (with different installations producing different products), it seems useful to use an emission factor that is aggregated over all of the products considered in this category. As a result of this aggregation, uncertainties in allocation of emissions of the aforementioned production processes to the products listed under a) to e) are taken into account, especially because CO_2 emissions from flares of the aforementioned are not necessarily tied to just one of the products in categories a) to e). At chemical industry sites where gases from various different production processes need to be flared, this takes place by way of a central flare that, in terms of its licensing, is allocated only to one production installation. As a result, in these cases, the emissions quantity allocated to a product can be greater than the emissions quantity actually caused by the production process. On the other hand, gases from processes a) to e) that need to be flared may be transported to a flare in an installation that is not considered in this context, meaning that the emissions quantity considered is lower than the actual product-related emission quantity involved.

The flare emissions (ETS data) allocated to the various chemical industry installations for the year 2013 have been added up and then divided by the total production quantity for all products in a) to e) that were produced in 2013; this yields the emission factor for flaring losses (EFflaring). The flare emissions of the steam cracker units at refinery sites have been calculated on the basis of the units' known capacities. The resulting EFflaring for the aforementioned petrochemicals is 28 kg/t product. That emission factor has been used to retroactively calculate annual emissions, using a Tier 1 method, back to 1990.

CH_4 emission factors

The *IPCC Guidelines* list all of the aforementioned installations as potential emission sources.

Pursuant to Point 5.2.5 of the TA Luft (Technical Instructions on Air Quality Control), German plants subject to the TA Luft must meet a standard of 50 mg/m^3 (total carbon) for total mass concentration of organic substances (NMVOC and CH_4, but not including organic substances in dust form). The current state of the art provides for thermal post-combustion of volatile organic substances from plants for production of primary organic chemicals.

A major German producer reported that the methane emissions from ethylene, methanol, ethylene dichloride and styrene are negligible, thanks to the use of thermal post-combustion since the 1980s.

No data from emissions trading can be used for reporting on methane emissions from chemical industry installations since the currently valid German Greenhouse Gas Emission Allowance Trading Act (TEHG) of July 2011 does not mandate reporting on CH_4. Furthermore, since no information from other installation operators is available that could be used for quantification of CH_4 emissions, the methane emissions for all petrochemical industry installations as a whole are calculated using a Tier 1 method, with the 2006 IPCC standard emission factors IPCC (2006a): Vol. 3, Chapter 3.9.2.2).

NMVOC emission factors

The EF data for NMVOC were either taken from the relevant BAT reference document or originate from confidential information provided by German manufacturers. Until 1994, the default factors in the *EMEP/CORINAIR Emission Inventory Guidebook* were used. Relevant detailed reporting is provided in the *Informative Inventory Report* pursuant to the CLRTAP.

4.3.8.1.3 Uncertainties and time series consistency (2.B.8 Petrochemical industry)

CO_2

High uncertainties result from projecting the aforementioned production-related emission factor for flaring losses from the 2013 emissions reports back to the year 1990. On the one hand, in many cases the flare emissions reported in the ETS for report year 2013 were determined and reported on the basis of estimates. On the other hand, it must be assumed that CO_2 emissions from the flares allocated to the relevant installations, under licensing law, cannot be completely assigned to production of the products in groups a) to e). For example, gases (including waste gases) from other production processes are burned in the flares under consideration here. Over time, internal changes to the exhaust gas routing from various processes may also occur, further increasing the uncertainty of the "backward-calculated" product-specific emissions. In addition, the ratios of production quantities to flare gases for the installations under consideration may differ considerably in various years from the corresponding ratios in 2013.

Due to limited data availability, it cannot be completely ruled out that some energy-sector items are being double-counted. Extrapolation of flare emissions of steam cracker units also contributes to the uncertainty of the emission factor. Consequently, an uncertainty of ±50% is assumed.

Consistency of the time series is assured because a consistent method was used to calculate the emissions back to 1990, and because there are no gaps in the activity data or jumps (discontinuities) in the emission factor.

CH_4

In the 1980s, thermal post-combustion was introduced on a large scale. As a result, point-source emissions of organic substances from German plants are likely to be low. Use of standard emission factors is probably leads to an overestimation of the emissions. Since the resulting uncertainties cannot be estimated, the Tier 1 method uncertainties specified in Table 3.27 of the 2006 IPCC Guidelines (IPCC (2006a): Vol. 3) are used.

Consistency of the time series is assured because a consistent method was used to calculate the emissions back to 1990 and because there are no gaps in the activity data or jumps (discontinuities) in the emission factors.

Activity data

The activity data originate from official statistics for which inaccuracies of ±20% in statistical data collection are assumed.

4.3.8.1.4 Category-specific QA/QC and verification (2.B.8 Petrochemical industry)

General quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

The quantity of ethylene produced in 2013, as reported by the Federal Statistical Office, was compared with capacity data provided by the *Association of Petrochemical Producers in Europe* (APPE; Petrochemicals Europe[53]). The resulting national standard capacity utilisation factor of 0.858 is comparable to the standard capacity utilisation factor pursuant to Article 18 (2) of Commission Decision 2011/278/EU (European Commission (EC), 2011).

[53] Website: http://www.petrochemistry.eu

It is not possible to compare the national emission factor for CO_2 with the default values provided in the 2006 IPCC Guidelines and the emission factors of the other countries since the emission factors do not include any CO_2 emissions from flares.

No further sources are available for data verification.

4.3.8.1.5 Category-specific recalculations (2.B.8 Petrochemical industry)

No recalculations are required.

4.3.8.1.6 Category-specific planned improvements (2.B.8 Petrochemical industry)

No further improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.3.8.2 Chemical industry: Carbon black production (2.B.8 Carbon black)

4.3.8.2.1 Category description (2.B.8 Carbon black)

Carbon black is produced as a result of incomplete combustion of gaseous or liquid hydrocarbons. Defined specifications for carbon black are achieved by carefully controlling and monitoring production processes. In Germany, carbon black is produced from hard coal tar oils (anthracene oils) and from oils produced by petroleum refineries (pyrolysis/cracking oils).

A total of 90% of the carbon black produced in Germany results from the furnace black process. The remaining 10% is produced from the flame pressure and gas black processes.

4.3.8.2.2 Methodological issues (2.B.8 Carbon black)

CO_2 emissions

A comparison of the CO_2 emissions figures reported to date based on production data of the Federal Statistical Office with the figures reported to the German Emissions Trading Authority (DEHSt) showed that the figures reported to the DEHSt are considerably lower. Another installation not subject to emissions trading requirements also failed to explain this difference. Consultations with the existing data supplier suggested that the production statistics sometimes reported sales figures instead of production figures. The activity data used to date were thus much too high. From 2005 to 2021, the emissions quantities of the DEHSt were therefore used, with the activity data back-calculated using the default emission factor in the *2006 IPCC Guidelines* (IPCC (2006a): Vol. 3, Table 3.23, *Furnace Black Process (default process), primary feedstock*). The emissions of one installation not subject to emissions trading requirements were reported by the operator directly to the German Environment Agency. One installation (subject to emissions trading requirements) was decommissioned in 2016. Five installations, operated by a total of two operators, are still in operation in Germany. Since 2022, the German Environment Agency has obtained the emissions data directly from the two operators.

CH_4 emission factors

International guidelines only briefly mention this category. The *IPCC Guidelines* list carbon black production as a potential emission source.

Pursuant to Point 5.2.5 of the TA Luft (Technical Instructions on Air Quality Control), German plants subject to the TA Luft must meet a standard of 50 mg/m^3 (total carbon) for total mass concentration of organic substances (NMVOC and CH_4, but not including organic substances in dust form). Based on these facts, German manufacturers of industrial carbon black report an

emission factor of 0.027 kg methane per tonne of industrial carbon black. Since this technology has been in use since the 1970s, this EF is rounded off to 0.03 kg/t and applied to the entire time series.

Emission factors for NMVOC, CO and SO_2

For pollutants other than the methane considered above, the emission factors listed in the following table were used for Germany.

Table 174: Emission factors used in Germany for other pollutants, in [kg/t]

	CO	SO_2[54]
1990	4.8/5	19.5/ ([55])
1991	4.6/5	19/20
1992	4.4/5	18.5/20
1993	4.2	18
1994	4	17.5
1995	3.75	17
1996	3.5	16
1997	3.25	15
1998	3	14
1999	2.9	13.4
2000	2.8	12.8
2001	2.7	12.54
2002	2.65	12.28
2003	2.6	12.0
2004	2.55	11.7
2005	2.5	11.5
2006	2.5	11.2
2007	2.5	10.9
2008	2.5	10.6
2009	2.5	10.3
As of 2010	2.5	10.0

The EF figures for CO and SO_2 in terms of carbon black production are based on the BREF Large Volume Inorganic Chemicals - LVIC - S (European Commission (EC), 2007b) and are identical with the default values presented in the 2008 CORINAIR manual (first order draft).

Activity data

The production statistics of the Federal Statistical Office include the following products (cf. the following table).

[54] Where two EFs are listed, the second figure refers to the new German federal states.

[55] No EF is listed for the new German federal states as these SO_2 emissions can only be accounted for as a lump sum.

Table 175: Reporting numbers (Meldenummern) from production statistics

Line	Carbon black
Until 1994	4113 70
1995-2005	2413 11 300

The figure for carbon black production in the new German federal states in 1990 was taken from the Statistical Yearbook (Statistisches Jahrbuch) for the Federal Republic of Germany Statistisches Bundesamt (1992): p. 234); the figures for 1991 and 1992 were estimated due to confidentiality requirements. The other data for carbon black production as of 1990 were taken from the Federal Statistical Office (Statistisches Bundesamt (FS 4, R 3.1): Manufacturing industries, production in manufacturing industries (Produzierendes Gewerbe, Produktion im Produzierenden Gewerbe)). For the period as of 2005, the activity data are back-calculated from the CO_2 emissions using the default CO_2 emission factor.

4.3.8.2.3 Uncertainties and time series consistency (2.B.8 Carbon black)

While the activity data fluctuate somewhat over time, these fluctuations are largely consistent with global economic fluctuations.

4.3.8.2.4 Category-specific QA/QC and verification (2.B.8 Carbon black)

General quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

4.3.8.2.5 Category-specific recalculations (2.B.8 Carbon black)

No recalculations are required.

4.3.8.2.6 Category-specific planned improvements (2.B.8 Carbon black)

No further improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.3.9 Chemical industry: Production of halocarbons and SF_6 (2.B.9)

KC	Category	Activity	EM of	1995 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1995-2024
L/T	2 B 9 a, By-product Emissions		HFC-23	C	C	C	C	C
-/-	2 B 9 b, Fugitive Emissions		SF_6	164.50	0.02	8.88	0.01	-94.60
-/-	2 B 9 b, Fugitive Emissions		HFC-134a	C	C	C	C	C
-/-	2 B 9 b, Fugitive Emissions		HFC-227ea	C	C	C	C	C
-/-	2 B 9 b, Fugitive Emissions		CF_4	C	C	C	C	C

Gas	Method used	Source for the activity data	Emission factors used
HFC	Tier 3b	PS	PS
SF_6	Tier 3b	PS	PS

The category "Production of halocarbons" is a key category for HFC-23 emissions from by-products in terms of emissions level and trend. It is subdivided into 2.B.9.a By-product emissions and 2.B.9.b Fugitive emissions.

4.3.9.1 By-product emissions (2.B.9.a)

4.3.9.1.1 Category description (2.B.9.a)

For process-related reasons, production of HCFC-22 produces up to 3% HFC-23 as a by-product. For technical reasons, even when the HFC-23 is subjected to further processing (for example, to produce refrigerants) or is collected and then broken down into other substances, some HFC-23 is always released into the atmosphere.

Germany formerly had two production plants for HCFC-22, both operated by a single company, one in Frankfurt and one in Bad Wimpfen. In 1995, a CFC cracking plant went into operation in Frankfurt that cracked, at high temperature, excess HFC-23 produced during production of HCFC-22 and recovered hydrofluoric acid; i.e. no significant emissions were produced. HFC-23 produced at the second German production facility was captured in large amounts at the production system itself; the substance was then sold as a refrigerant or - following further distillative purification - as an etching gas for the semiconductor industry. Beginning in 1999, the excess amount that could not be sold was delivered to the cracking facility in Frankfurt. That measure substantially reduced emissions. In mid-2010, HCFC-22 production was terminated at one site. At the other site it was significantly reduced, and all remaining production serves teflon production. The production quantities have remained at a constant low level since then. As the installation is directly connected to a CFC-cracking plant, only very slight emissions occur.

4.3.9.1.2 Methodological issues (2.B.9.a)

On the basis of producer information from 1996, the HFC-23 emissions are assumed to have remained constant in the years 1990 to 1994. For calculation of HFC-23 production quantities, an unavoidable-formation level of 3% has been assumed.

Beginning in 1995, the producer calculated emissions using a mass balance procedure based on HCFC-22 production, HFC-23 concentrations in exhaust gas (as measured annually), sales of HFC-23 and quantities of HFC-23 delivered to the cracking plant. For report year 1995, emissions reduction measures (the cracking plant) for the first production plant were assumed to have been in place since mid-year. Since report year 2011, the relevant production quantities were estimated by experts and the resulting estimates used to determine the emissions. The estimates are made in light of comparable production facilities in other European countries. In 2019, the assumptions were reviewed with the responsible industry representative. Since 2020, the company has been sending data on HCFC-22 and HFC-23 production not only to the EU, but also confidentially to the German Environment Agency.

Activity data

There is only one HCFC-22 producer in Germany. As a result, the company's data are subject to confidentiality. Until 2010, the emissions and production quantities were only reported to the German Environment Agency in aggregated form. For the period 2011 to 2019, experts estimated the quantities of HCFC-22 and HFC-23 that were produced. Due to the higher uncertainty caused by the estimate, an unavoidable formation level of 3% was still assumed. However, the data available for 2020 to 2022 show that the unavoidable formation level is actually less than 2%, which is why a recalculation was carried out this year for the years 2011 to 2021.

The activity data for HFC-23 are reported together with those for HFCs, PFCs and SF_6 as an *unspecified mix* in 2.B.9.

Emission factors

Since 2011, it was assumed that unwanted quantities of HFC-23 on the order of 0.03 kg per kg of HCFC-22 were being produced. More recent data confirm that the unwanted quantities actually amount to 0.02 kg HFC-23 per kg of HCFC-22.

Through 2010, the emission factor was based on the quantities of HCFC-22 produced. As of 2011, the emission factor referred to the quantities of HFC-23 produced, which amounted to 0.05% until 2019. Since the relevant plant is connected to a pipeline network that is connected directly to an HCFC cracking plant, the resulting emissions quantities are very small. As exact production figures have been available since 2020, the emission factor has now been set to 0.004%. This is in line with the 2019 Refinements, ((IPCC, 2019), Vol. 3, page 3.19): *"Should the vent gas be collected for treatment, thermal oxidation has been shown to reduce HFC-23 emission by 99.996 percent (Irving & Branscome, 1999)."*

Emissions

Until 2010, the HFC-23 emissions were reported by the producer. Since 2011, expert estimates and the guidelines described in the previous section have been used.

Since there are fewer than three producers in Germany, the emissions data are confidential. The HFC-23 emissions are reported under 2.H.3.

4.3.9.1.3 Uncertainties and time series consistency (2.B.9.a)

The assumptions on which the emissions calculations are based are reviewed with the industry at long, regular intervals. With uncertainties of 3%, they are considered to be quite precise.

4.3.9.1.4 Category-specific QA/QC and verification (2.B.9.a)

General quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

No data sources are available to review the F gas quantities gathered for emissions reporting as a basis for verification other than the data provided by the Federal Statistical Office and the producer. Comparisons with other countries do not show any need for improvements. The emission factors are of the same order of magnitude as those for other European countries.

4.3.9.1.5 Category-specific recalculations (2.B.9.a)

No recalculations were required.

4.3.9.1.6 Category-specific planned improvements (2.B.9.a)

No improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.3.9.2 Production-related emissions (2.B.9.b)

4.3.9.2.1 Category description (2.B.9.b)

In Germany, two companies currently produce HFC at two locations. One of the companies also produces SF_6. Emissions trends are tied to trends in amounts produced. While SF_6 and HFC-134a

are produced in Germany, until 2008 no complete synthesis of HFC-227ea was carried out in Germany. Part of the HFC-227ea produced in Tarragona, Spain, undergoes subsequent distillation, in Germany, to pharmaceutical purity (use in dosing aerosols). That process results in emissions from minor gas losses.

HFC-227ea has been produced since 1996.

Emissions of HFC-227ea have been increasing since 2009, in parallel with increases in production quantities. An exception is seen in 2012 in which less HFC-227ea was sold, and thus the emissions level was lower.

CF_4 (PFC-14) was also produced in Germany between 1990 and 1994, and HFC-134a was produced from 1994 to 2021.

4.3.9.2.2 Methodological issues (2.B.9.b)

Emission factors

Emission factors have been calculated from the emissions and production quantities reported by the producer until 2009. Emissions-reducing measures (including the installation of a plasma torch) have lowered the emission factor for SF_6 for the period as of 2014. In 2019, all emission factors were reviewed during discussions with industry representatives.

The emission factor for SF_6 production was increased as part of a research project and after consultation with the company. A recalculation is not possible here on confidentiality grounds.

Activity data

Since only a maximum of two manufacturers exist in Germany, the relevant companies' data are confidential. Until 2010, the emissions and production quantities were reported to the German Environment Agency, but only in aggregated form. Since 2011, data of the Federal Statistical Office have been used. This still applies to SF_6. To ensure the data are available in time, the companies have reported directly to the German Environment Agency the CFC-22 and HFC-23 production volumes since report year 2020, and the production volume for HFC-227ea since 2021.

Emissions

Since there are fewer than three producers in Germany, HFC emissions data are confidential. HFC emissions from production are reported under 2.H.3.

Only SF_6 emissions are reported under 2.B.9.b.

4.3.9.2.3 Uncertainties and time series consistency (2.B.9.b)

The production figures used as a basis for emissions calculation may be considered highly accurate since they come directly from the producer's internal records or from official statistical surveys. The uncertainties for the emissions are assumed to be 3%.

4.3.9.2.4 Category-specific QA/QC and verification (2.B.9.b)

General quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

No data sources are available to review the F gas quantities gathered for emissions reporting as a basis for verification other than the data provided by the Federal Statistical Office. Comparisons with other countries do not show any need for improvements. The emission factors are of the same order of magnitude as those for other European countries.

4.3.9.2.5 Category-specific recalculations (2.B.9.b)

New research findings meant that recalculations were needed for SF_6 emissions for report years 2014 and 2023.

4.3.9.2.6 Category-specific planned improvements (2.B.9.b)

No improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.3.10 Chemical industry - other: emissions from other production processes (2.B.10)

KC	Category	Activity	EM of	1995 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1995-2024
-/-	2 B 10, Other Chemical Industry		CH_4	3.87	0.01	1.11	0.01	-71.26
-/-	2 B 10, Other Chemical Industry		N_2O	C	C	C	C	C

The category “Other: emissions from other production processes” is not a key category.

4.3.10.1 Category description (2.B.10)

The GHG precursor substances from production of fertilisers and sulphuric acid are reported in this category. While N_2O emissions from production of 1,12-dodecanedioic acid (DDDA) are described here, for reasons of confidentiality they are actually recorded in 2.B.3 Adipic acid production. Like adipic acid, 1,12-dodecanedioic acid is a dicarboxylic acid whose production entails use of nitric acid. There is one producer in Germany.

In addition, “Storage of chemical products” includes all petroleum products not used as fuels (cf. in this regard Chapter 3.3.2.1.5). While fuels are reported under 1.B.2, chemical products are reported under 2.B.10.

This category also includes the cleaning of crude oil and petroleum product tank-storage facilities and transport tanks. Inland waterway tankers, pipelines, railway tank cars and road tankers are used for transport and transfer purposes.

4.3.10.2 Methodological issues (2.B.10)

N_2O emissions

Until 2004, N_2O emissions from dodecanedioic acid production were treated only by way of exhaust gas recirculation and flue gas scrubbing. As of 2005, nitrous oxide has been treated using thermal decomposition. In 2013, a second (redundant) plant for thermal decomposition of N_2O went into operation. In 2021, a new thermal afterburning plant went into operation. The N_2O emissions have been greatly reduced as a result of waste gas treatment. The N_2O emissions data for the years 1998 to 2024 were provided by the producer. For the years 1990 to 1997, N_2O emissions were calculated by averaging data for the years 1998 to 2004 as thermal decomposition of nitrous oxide emissions was not available at that time. Data collection at the producer’s facility has made production quantity data available, on a confidential basis, for selected years.

CH_4 emissions

A review of several research projects provided new insights. The calculation method and emission factors were published separately (Böttcher, 2025).

4.3.10.3 Uncertainties and time series consistency (2.B.10)

Data collection at the producer's facility improved the database on N_2O emissions from production of 1,12-dodecanedioic acid - especially with regard to the trend and consistency of the time series. The uncertainty for the N_2O emissions data was estimated to be ±40%. This figure could change, however, because a number of details remain unclarified.

In terms of storage and cleaning, the uncertainties are estimated at 177% for emission factors and 65% for activity data. These figures are based on estimates from national experts as well as on some research reports, (Bender, 2009), (Theloke et al., 2013) and (Zimmermann et al., 2025).

4.3.10.4 Category-specific QA/QC and verification (2.B.10)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents. No data from other countries or other sources were found to compare the data received or to verify the nitrous oxide emissions from the production of dodecanedioic acid.

4.3.10.5 Category-specific recalculations (2.B.10)

The results of the research project led to recalculations that were published in (Böttcher, 2025).

4.3.10.6 Category-specific planned improvements (2.B.10)

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.4 Metal production (2.C)

Category 2.C is divided into the subcategories 2.C.1 to 2.C.7. In the CSE emissions database, the subcategory Iron and steel production (2.C.1) includes sinter production, pig iron production, production of direct reduced iron (DRI), iron and steel production and production of tempered castings. Production of ferroalloys (2.C.2) has only minor importance in Germany and is not broken down further in this report as a result. Aluminium production (2.C.3) is subdivided into primary aluminium and resmelted aluminium. Use of SF_6 in aluminium and magnesium production (2.C.4) is not further subdivided. In the Central System of Emissions (CSE), sub-point (2.C.5) comprises lead production. (2.C.6) comprises zinc production. (2.C.7) includes copper production (2.C.7a), nickel production (2.C.7b) and other production (2.C.7c). No greenhouse gas emissions result in Germany from these categories.

4.4.1 Metal production: Iron and steel (2.C.1)

4.4.1.1 Category description (2.C.1)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
L/T	2 C 1, Iron and Steel Production		CO_2	22,810.29	1.77	16,386.42	2.32	-28.16
-/-	2 C 1, Iron and Steel Production		CH_4	5.22	0.01	5.04	0.01	-3.51
-/-	2 C 1, Iron and Steel Production		N_2O	23.60	0.01	12.92	0.01	-45.26

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2	NS	CS

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 2	NS	CS
N_2O	CS	NS	CS
NO_X, CO, NMVOC, SO_2	Tier 2	NS	CS

The category "Iron and steel production" is a key source of CO_2 emissions in terms of emissions level and trend. Along with carbon dioxide, slight emissions of methane and nitrous oxide also occur in this category. The methane emissions result from production of rolled steel. The nitrous oxide originates in primary steel production, in connection with use of blast furnace gas in hot-blast stoves.

Since the CRF Reporter software does not allow nitrous oxide to be allocated to 2.C.1, it is reported under 2.C.7 instead.

In 2024, a total of 26.5 million t of raw steel was produced from ore in Germany in six integrated steel works. Electric steel production amounted to 10.8 million t.

4.4.1.2 Methodological issues (2.C.1)

This sector comprises process-related emissions from primary steel production (via sinter plants, blast furnaces and oxygen steel plants), electric steel plants and the production of rolled steel.

Other structural elements in this category (foundries: iron and steel production and production of tempered castings) are used for calculation of other pollutant emissions (not greenhouse gas emissions).

Process-related CO_2 emissions from primary steel production in integrated smelters result primarily from use of reducing agents in blast furnaces. Also, CO_2 emissions from limestone inputs in sinter plants, pig iron production (including the CO_2 emissions from the lime kilns operated by the steel industry) and CO_2 emissions from electrode consumption in electric steel production are added to the process-related emissions in sector 2.C.1.

Very little direct reduced iron (DRI; sponge iron) is produced in Germany (less than 0.6 million t. per year). Annual production quantity data are available for the entire time series, but they are confidential as so far they only involve a single installation.

The CO_2 emissions that occur in DRI production are the result of using natural gas or a reducing agent mixture comprising H_2 and CO obtained from natural gas. The relevant quantities of natural gas used are included throughout the entire time series in the natural gas inputs in the steel industry that are reported under 1.A.2.a. Consequently, the CO_2 emissions resulting from DRI production are also included throughout the entire time series in the emissions reported under 1.A.2.a.

The process-related CO_2 emissions from DRI production cannot be listed separately under 2.C.1, because a) no separate data on the natural gas quantities consumed are available for reasons of confidentiality; and b) because these disclosures could be used to derive the confidential production quantity data for the relevant installation.

Method for calculating the CO_2 emissions resulting from use of reducing agents in blast furnaces

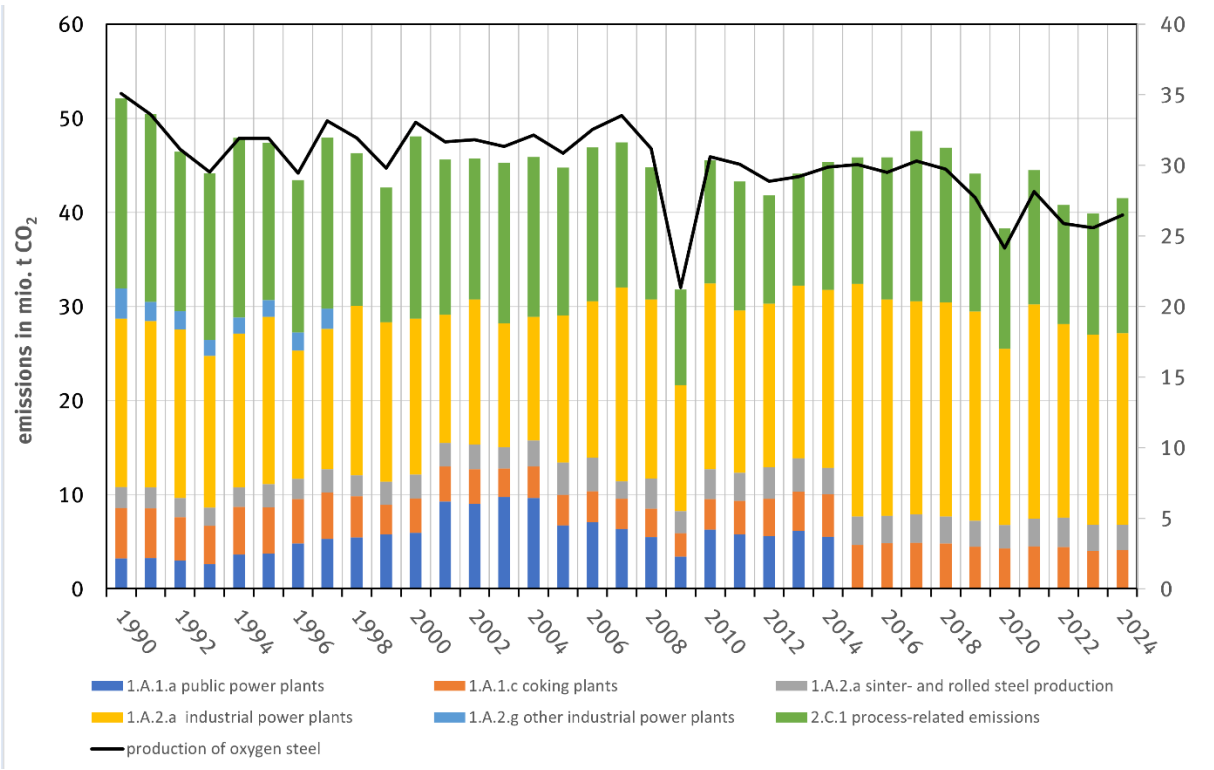
Pursuant to the *IPCC Guidelines*, the CO_2 emissions in category 2.C.1 are to be determined by a carbon balance. The reason for this requirement is that virtually all of the carbon used in blast furnaces for primary steel production is subsequently released into the atmosphere as CO_2 in

later energy-related use or flaring of the blast furnace gas that forms in the blast furnace or of the basic oxygen furnace gas that forms in the oxygen steel converter. The fraction of pig iron that is not converted into steel is at most 1%. For this reason, the carbon fraction it contains (about 0.1%) is not relevant when compared with the CO_2 emissions linked to inputs of reducing agents. The same applies to the carbon fraction in the steel produced, which, according to rough estimates, is around 60,000 tonnes per annum and thus corresponds to the carbon input from the raw materials used (ores and scrap).[56].

The inputs of reducing agents in blast furnaces and material inputs in converters are statistically recorded in great detail. The German Steel Federation (WV Stahl) provides the relevant data to the German Environment Agency on an annual basis. The carbon content in the various materials used is calculated from emissions trading data. CO_2 emission factors for use of blast furnace gas and basic oxygen furnace gas are also available from emissions trading. The input gas quantities are taken from energy statistics. Calculation on the basis of a) carbon inputs and of b) carbon removals from using blast furnace gas/basic oxygen furnace gas yields a difference. These CO_2 emissions are reported in category 2.C.1. Only part of all energy-related use of blast furnace gas and basic oxygen furnace gas takes place in category 2.C.1 (this is mainly the energy-related use in hot-blast stoves in blast furnaces). This gas is also used for other process combustion in the iron and steel industry (1.A.2.a); in coking plants, for bottom heating of coking furnaces (1.A.1.c); and for electricity generation in public power stations (1.A.1.a) and industrial power stations (1.A.2.f). Energy statistics provide data on consumption of blast furnace gas and basic oxygen furnace gas in all of the aforementioned categories. Consequently, the CO_2 emissions resulting from reducing agent inputs for primary steel production are divided among all categories in which blast furnace gas and basic oxygen furnace gas are burned and CO_2 is actually emitted (cf. the following figure).

[56] The average carbon fraction in the more than 2,000 types of steel produced in Germany is not recorded statistically. According to the steel plants taking part in emissions trading, the average carbon content of manufactured raw steel is estimated to be 0.15%. A rough calculation indicates that the non-energy-related carbon discharge from the manufactured steel is equivalent to the carbon input from iron ore (carbon content of about 0.1%) and recycled scrap (carbon content of about 0.15%).

Figure 44: Trend and category allocation of the CO_2 emissions resulting from use of reducing agents for primary steel production and from use of blast furnace gas



Source: own illustration, German Environment Agency

The sum of the CO_2 emissions shown correlates well with the activity data reported for primary steel production (cf. the black line). Annual fluctuations in the individual categories are likely due to changes in allocation of individual plants in the official statistics. These fluctuations have practically no impact on the total sum of reported emissions, however.

Table 176: CO_2 emissions from primary steel production (including use of blast-furnace gas), in [Mt]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
1.A.1.a Public power stations	3.244	3.764	5.956	6.738	6.276	0.013	0.000	0.000	0.000	0.000
1.A.1.c Coking plants	5.340	4.924	3.652	3.247	3.245	4.648	4.872	4.910	4.809	4.479
1.A.2.a Sinter and rolled-steel production	2.228	2.445	2.520	3.461	3.198	3.015	2.912	2.990	2.872	2.752
1.A.2.a Industry power stations	17.886	17.759	16.573	15.607	19.714	24.735	22.955	22.653	22.756	22.224
1.A.2.g Other industrial power stations	3.206	1.770	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.C.1 Process emissions	20.228	16.736	19.379	15.711	13.126	13.436	15.101	18.088	16.451	14.669

	2020	2021	2022	2023	2024
1.A.1.a Public power stations	0.000	0.000	0.000	0.000	0.000
1.A.1.c Coking plants	4.275	4.537	4.436	4.016	4.144
1.A.2.a Sinter and rolled-steel production	2.501	2.926	3.153	2.804	2.691
1.A.2.a Industry power stations	18.736	22.749	20.544	20.197	20.337
1.A.2.g Other industrial power stations	0.000	0.000	0.000	0.000	0.000
2.C.1 Process emissions	12.788	14.282	12.669	12.882	14.350

In the iron and steel industry, secondary fuels were basically used only in the period 1996 to 2019 for production of pig iron in blast furnace processes. Recently, they have been used in very small quantities by only one plant. To date, these materials have not yet been included in national statistics and the Energy Balance. For this reason, the data provided by the steel industry association have been used. Since the secondary fuels are used solely as substitute reducing agents in place of coke, the CO_2 emissions resulting from their use are also included in the CO_2 emissions determined via inputs of blast furnace gas and basic oxygen furnace gas and do not have to be calculated separately.

Determination of CO_2 emissions from limestone inputs in pig iron production

CO_2 emissions from limestone use are determined in accordance with Tier 1 (Lechtenböhmer, Nanning, et al. (2006a), FKZ 20541217/02). The steel industry uses limestone ($CaCO_3$) in sintering plants and in pig iron production in blast furnaces. By contrast, oxygen steel and electrical steel plants use burnt steelworks lime (CaO) as a slag former, typically purchased from the lime industry. The CO_2 emissions released in production of the purchased burnt lime are already reported under 2.A.2.

Only one steel mill meets its lime requirements by using lime kilns of its own whose production quantities and related CO_2 emissions are not included in the data reported under 2.A.2. The quantities produced by these lime kilns were estimated on the basis of available figures for the mill's crude steel production and compared with figures from carbon emissions trading. As the figures are consistent with the emissions data verified and published by the German Emissions Trading Authority (DEHSt) (cf. the annual Evaluations (VET reports)), the production volume of the lime kilns from 2005 onwards is considered to be equivalent to the VET data. In a procedure similar to that used for 2.A.2, (cf. Table 177), only the CO_2 emissions for raw materials calculated using a stoichiometric EF are reported in 2.C.1 from the activity data determined in this manner. The CO_2 emissions from energy inputs in steel mills' own lime kilns, i.e. emissions which are not separately listed in the Energy Balance, are included in the emissions reported under 1.A.2.a.

Until 2004, limestone inputs in sinter and pig iron production were published as part of iron and steel statistics (Statistisches Bundesamt, FS 4, R 8.1). Since then, they have to be calculated from the production quantities of sinter and pig iron reported by the association using specific input factors (i.e. kg of limestone per tonne of sinter or pig iron) (reported in the framework of the so-called "BGS form" (Fuel, gas and electricity industries of blast furnaces, steelworks and rolling mills; and forging plants, press works and hammer mills, including the various other plants (without their own coking plants)). Multiplying the activity data for limestone inputs by the stoichiometric emission factor for limestone produces the CO_2 emissions figures specified in Table 177.

Table 177: Limestone inputs in the steel industry; and the steel industry's own production of burnt lime and resulting CO_2 emissions, in [t/a]

Year	AD: Limestone inputs		AD: Own production	CO_2 emissions		
	Blast furnace	Sinter plant	Burnt lime	Limestone inputs (EF = 440 kg/t)	Lime production (EF = 746 kg/t)	TOTAL
1990	755,737	4,680,775	153,918	2,392,065	114,823	2,506,888
1995	751,000	4,600,000	139,973	2,354,440	104,420	2,458,860
2000	924,000	4,273,000	144,991	2,286,680	108,163	2,394,843
2005	787,724	4,306,067	136,510	2,241,268	101,836	2,343,105
2010	799,679	4,045,042	133,254	2,131,677	99,407	2,231,085
2015	794,999	3,987,196	147,863	2,104,166	110,306	2,214,472
2016	780,445	3,750,267	130,871	1,993,514	97,630	2,091,143
2017	797,856	4,120,243	152,537	2,163,964	113,793	2,277,756
2018	779,356	3,926,906	153,036	2,070,755	114,165	2,184,920
2019	727,895	4,003,122	142,501	2,081,647	106,306	2,187,953
2020	644,097	3,375,375	127,174	1,768,568	94,872	1,863,439
2021	733,223	3,865,442	153,749	2,023,412	114,697	2,138,109
2022	672,161	3,637,592	129,985	1,896,292	96,969	1,993,260
2023	661,780	3,604,823	131,481	1,877,305	98,085	1,975,390
2024	684,082	3,551,268	124,745	1,863,554	93,060	1,956,614

Source: Until 2004: Calculation of limestone inputs by the "limestone balance" project ((Lechtenböhmer, Nanning, et al., 2006a), FKZ 20541217/02), as of 2005: Calculation using the product-specific factors determined in the aforementioned project

Determination of CO_2 emissions from electrode consumption in production of electrical steel

In electrical steel production, CO_2 emissions occur directly from consumption (combustion) of graphite electrodes. These emissions must also be allocated to process-related CO_2 emissions for steel production. They are calculated from the quantity of produced electrical steel using an emission factor (7.4 kg/t) that was updated in a research project(Hensmann et al., 2012) in 2009 and is based on the specific electrode consumption per tonne of electrical steel (2.06 kg/t), its carbon content (98%) and the relevant stoichiometric factor (3.667 t CO_2/t C). The contribution from electrode combustion in electrical steel production is insignificant at about 0.2% of total CO_2 emissions from iron and steel production.

Determination of the total CO_2 emissions from iron and steel production to be reported under 2.C.1

The total process-related emissions to be reported under 2.C.1 consist of the following:

1. the CO_2 emissions resulting from use of reducing agents in primary steel production, where the blast furnace gas and basic oxygen furnace gas is not used in other categories and is thus reported there as CO_2 emissions,
2. the CO_2 emissions from limestone inputs in pig iron production and from the steel industry's own production of burnt lime, and
3. the CO_2 emissions from electrode consumption in electrical steel production.

The emissions quantities determined as described above are shown in Table 178.

Table 178: Total process-related emissions to be reported under 2.C.1, in [t/a]

Year	CO_2 emissions from use of reducing agents, where not reported in other categories	CO_2 emissions from limestone inputs and from the steel industry's own production of burnt lime	CO_2 emissions from electrode consumption	2.C.1 total
1990	15,713,306	2,506,888	75,242	18,295,436
1995	16,736,415	2,458,860	75,058	19,270,333
2000	19,378,699	2,394,843	98,598	21,872,139
2005	15,710,560	2,343,105	101,136	18,154,800
2010	13,125,861	2,231,085	97,792	15,454,738
2015	13,435,683	2,214,472	93,401	15,743,556
2016	15,100,984	2,091,143	93,193	17,285,321
2017	18,088,074	2,277,756	96,250	20,462,081
2018	16,451,045	2,184,920	94,002	18,729,967
2019	14,669,497	2,187,953	88,099	16,945,549
2020	12,787,503	1,863,439	85,360	14,736,302
2021	14,281,570	2,138,109	89,474	16,509,153
2022	12,668,622	1,993,260	81,305	14,743,187
2023	12,882,079	1,975,390	72,645	14,930,114
2024	14,349,724	1,956,614	80,087	16,386,424

4.4.1.3 Uncertainties and time series consistency (2.C.1)

The time series is consistent since the activity data have been determined for all plants and the same method has been used to determine the emissions for all years concerned. Due to problems under competition law, the German Steel Federation was unable to provide the activity data for the year 2017 as agreed. For this reason, aggregated data from emissions trading have been used as substitutes for 2017. The consistency of the emissions trading data was verified using comparative values from previous years; the discrepancies are less than 1%, with the exception of those for sinter production which are slightly higher (up to a maximum of +8%).

Regarding CO_2 emissions from limestone inputs, a discontinuity in methods occurred from 2004 to 2005 since the data source used until 2004 was no longer available after that time. The time series trend seems plausible in spite of this discontinuity. Due to the calculation required, the uncertainty for the activity data here is ±10%. The uncertainty is also relatively high for the activity data for the steel industry's own production of burnt lime, which have been estimated on the basis of verified emissions data from carbon emissions trading. The associated CO_2 emissions are relatively insignificant, however.

The uncertainty of the emission factor for electrode consumption is ±3%, while the uncertainty for the other data is ±5%. These uncertainties are due entirely to measurement and analysis inaccuracies.

4.4.1.4 Category-specific QA/QC and verification (2.C.1)

General and category specific quality control and quality assurance, have been carried out in conformance with the requirements of the QSE-manual and its associated applicable documents, by the Single National Entity.

Pursuant to a cooperation agreement, the German steel industry association compiles the activity data and sends them to the German Environment Agency on an annual basis. The time series seems plausible and shows no inconsistencies. It is assumed that collection of these data conforms to quality assurance criteria as agreed.

Determining emissions in categories 1.A.2.a and 2.C.1 is a complex task as the Energy Balance, emissions reporting, emissions trading and association statistics differ widely in terms of their underlying methods. In the interest of data quality assurance and when appropriate, industry experts and experts from the Single National Entity carry out regular expert discussions where they compare and evaluate data. As a result of the methodological differences, plausibility checks of the determined emissions quantities using data of the German emissions trading authority are only possible at a highly aggregated level.

The implied emission factors (IEFs) obtained by the Climate Secretariat cannot be used to check the emissions determined for this category for their plausibility.

1. The reasons for this include the very different proportions of CO_2-intensive primary steel production in total steel production from country to country;
2. the differences in the ways that different countries allocate the resulting emissions to categories 1.A.2.a, 2.C.1 and any other categories in which the process gases occurring in connection with iron and steel production are used for energy generation; and
3. differences in the ways that countries report activity data under 2.C.1; and the fact that in some cases these data are added, even though this addition is inappropriate.

The aforementioned factors result in extreme scattering of the IEFs obtained for the stated categories, meaning the IEFs do not support any conclusions regarding the “correctness” of the determined emissions.

4.4.1.5 Category-specific recalculations (2.C.1)

Recalculations were carried out for the year 2023 to account for the replacement of data from the provisional Energy Balance with data from the final Energy Balance.

4.4.1.6 Category-specific planned improvements (2.C.1)

No further improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.4.2 Metal production: Ferroalloys (2.C.2)

4.4.2.1 Category description (2.C.2)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
-/-	2 C 2, Ferroalloys Production		CO_2	429.00	0.04	5.74	0.01	-98.66
-/-	2 C 2, Ferroalloys Production		CH_4	9.61	0.01	1.75	0.01	-81.75

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	IS	CS
NO_X, CO, NMVOC, SO_2			NE

The category "Production of ferroalloys" is not a key category.

Ferroalloys are aggregates that are alloyed with steel. There are five ferroalloy producers in Germany; ferrochromium, ferrosilicon and silicon metal are each produced by only one company, and other ferroalloys are produced only in small quantities. The only process in use since 1995 is the electric arc process, which releases only small amounts of process-related CO_2 during electrode consumption.

Until 1995, the blast-furnace process, which produces relatively higher CO_2 emissions, was used to some extent.

4.4.2.2 Methodological issues (2.C.2)

The CO_2 emission factor for the aforementioned two processes (blast furnace and electric arc processes) was determined in the research project "NEW CO_2" (FKZ 203 41 253/02, Weiß et al. (2006)).

The emission factor used is considerably lower than the standard emission factor pursuant to the 2006 IPCC Guidelines. The reason for this is that only process-related CO_2 emissions from electrode consumption are included in 2.C.2. In view of the structure of the national Energy Balance, the remaining CO_2 emissions from consumption of reducing agents are listed in 1.A.2. Use of the standard emission factor would therefore lead to impermissible double-counting.

The standard emission factor as per the 2006 IPCC Guidelines is used to calculate methane emissions.

The activity data for the years 1990 to 1994 were taken from official production statistics of the Federal Statistical Office. Since 1995, data of the *British Geological Survey* (Idoine et al., 2025) have been used because the official production statistics no longer contain usable data for this context. The currently available data are from 2021. The activity data have been carried forward into 2024.

4.4.2.3 Uncertainties and time series consistency (2.C.2)

The activity data provided by the British Geological Survey are based partly on estimates and thus are subject to relatively large uncertainties. The uncertainty for the activity data is estimated at ±50%.

The data of the British Geological Survey are regularly compared with those of the *U.S. Geological Survey* (USGS). While the USGS data are of the same order of magnitude as those of the British Geological Survey, they are less detailed and have a higher degree of aggregation. For this reason, we prefer to use the British Geological Survey data.

Data of the Federal Statistical Office on sales of ferroalloys are available for the period 2001 to 2006. However, these data are lower by a factor of 0.7 than the production data of the British Geological Survey. In the interest of consistency for the time series, the British Geological Survey data have therefore also been used for these years.

The considerable decrease in the CO_2 emission factor that took place from 1994 to 1995 is not an inconsistency, but the result of the change to the production process. Throughout the years, the uncertainty is ±50%.

4.4.2.4 Category-specific QA/QC and verification (2.C.2)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

The activity data used, which come from the British Geological Survey, have been verified with data of the Federal Statistical Office and the USGS (see above).

4.4.2.5 Category-specific recalculations (2.C.2)

No recalculations are required.

4.4.2.6 Category-specific planned improvements (2.C.2)

No further improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.4.3 Metal production: Aluminium (2.C.3)

4.4.3.1 Category description (2.C.3)

KC	Category	Activity	EM of	1990/1995 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990/1995-2024
-/-	2 C 3, Aluminium Production		CO_2	1,011.92	0.08	302.62	0.05	-70.09
-/-	2 C 3, Aluminium Production		SF_6	C	C	C	C	C
-/-	2 C 3, Aluminium Production	0	CF_4	1385.67	0.11	69.98	0.01	-94.95
-/-	2 C 3, Aluminium Production	0	C_2F_6	233.10	0.02	14.17	0.01	-93.92

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 3	AS	CS
CH_4	-	-	NE
PFC	Tier 2	AS	CS
SF_6	CS	NS	CS
NO_X	-	-	NE
CO, SO_2		AS	CS

Primary aluminium - by-product emissions

According to its classification in category 2.C.3 Aluminium production, the category Primary aluminium production is not a key category.

In Germany, aluminium is produced at three foundries, in electrolytic furnaces with pre-burnt anodes. The principal emission sources are the waste gases from the electrolytic furnaces and

fugitive emissions from the roofs of the plants. CO, CO_2, SO_2, CF_4 and C_2F_6 are among the most important climate-relevant substances and air pollutants that are emitted.

Production of primary aluminium continues to be the largest source of PFC emissions in Germany in spite of the considerable reductions that have been achieved since 1990. Thanks to extensive modernisation measures in German aluminium foundries, and as a result of reducing production capacities from decommissioning, absolute emissions from this sector have fallen by more than 90% since 1995. As to the future development of PFC emissions, stagnation at a low level can be expected.

Secondary aluminium - use of F gases in foundries

According to its classification in category 2.C.3 Aluminium production, the category "Use of SF_6 in secondary aluminium production" (aluminium foundries) is not a key category for SF_6 emissions.

Generally speaking, inert gases without additives are sufficient for rinsing secondary molten aluminium. A purification system of inert gases, with added SF_6 at a concentration of 1 or 2.5%, has been used in the past, however, in a few - usually smaller - aluminium foundries and in laboratories. These systems were last used in 1999 (no sales have taken place in Germany since 2000). From 1990 to 1999, SF_6 consumption remained relatively constant at 0.5 t/a.

Since 1999, pure SF_6 has occasionally been used again as a purification gas.

4.4.3.2 Methodological issues (2.C.3)

Primary aluminium - by-product emissions

The activity data are reported annually to the German Environment Agency by the WirtschaftsVereinigung Metalle metal industry association or, on occasions, by the industrial companies themselves. The average anode consumption in production of primary aluminium is 430 kg of petrol coke per tonne of aluminium. Table 179 shows the process-related emission factors.

The total quantity of waste gas incurred per tonne of aluminium during the production of primary aluminium was multiplied by an average concentration value formed from several individual figures, from various different plants, with appropriate weighting. The emission factors also allow for fugitive emission sources, such as emissions from plant roofs. The emission figures used for CO are the results of emission measurements as part of investment projects.

The SO_2 and CO_2 emission factors were calculated from the specific anode consumption. The anodes consist of petrol coke; this material has specific sulphur concentrations of about 1.2%, from which an SO_2 emission factor of 10.4 kg/t aluminium can be calculated. The CO_2 emission factor is calculated on the basis of the specific carbon content of petrol coke, 857 kg per t (cf. Annex 6.6). Multiplying the average anode consumption by the mean carbon content and carrying out stoichiometric conversion to CO_2 results in a CO_2 emission factor of 1,367 kg/t aluminium. Theoretically, the emission factor should be reduced by the proportion resulting from a CO fraction of 180 kg/t aluminium since CO can also only form from consumption of anodes. The CO_2 factor listed below does not take this into account. The procedure corresponds to the Tier 2 method pursuant to the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 2006a).

The emission factors shown in Table 179 were checked against the emission data in Best Available Techniques Reference Documents (BREF)[57] and other sources (such as VDI Guideline 2286 VDI (2013) Sheet 1) and the data from the EU Emissions Trading System (ETS) .

Table 179: AD and process-related EFs (in [kg/t]) for primary aluminium production in 2013

		Emission factors				
Number of smelters	AD (production)	CO_2	NO_X	SO_2	C, total	CO
3	221,373.4	1,367	NA	10.4	NA	180

Emissions data are available for PFC emissions from primary aluminium smelters thanks to a voluntary commitment on the part of the aluminium industry. Since 1997, the aluminium industry has reported annually on the development of PFC emissions from this sector. The measurement data are not published, but they are made available to the German Environment Agency.

The measurements conducted in all German smelters in the years 1996 and 2001 form the basis for calculation of CF_4 emissions. In this context, specific CF_4 emission figures per anode effect[58] were calculated according to the technologies used. The number of anode effects is recorded and documented in the foundries. The total CF_4 emissions were calculated by multiplying the total anode effects determined for the year by the specific CF_4 emissions per anode effect determined in 2001. The total emission factor for CF_4 is obtained by adding the CF_4 emissions of the smelters and then dividing the sum by the total aluminium production of the smelters. C_2F_6 and CF_4 occur in a constant ratio of about 1:10. The above method was applied to the time series until 2010, and the emissions for the years 1990 to 1996 were added by way of recalculation. For purposes of emissions trading, the aluminium industry has made a transition to the IAI method for calculating PFC emissions (corresponds to UNFCCC default Tier 2). The default slope factor used with that method is used by all other European operators, and it is accepted in the framework of European emissions trading. In the interest of consistency, as of 2010 the aluminium industry has also used the IAI method to determine emissions data for purposes of emissions reporting.

Secondary aluminium - use of F gases in foundries

For aluminium foundries, plant-specific measurements were used to determine the emission factor and thus the emissions.

Reports and archived survey records from 1996 were used as a basis for the report years 1990 to 1994.

For reasons of confidentiality, the SF_6 emissions are reported together with figures in 2.C.4 Magnesium production.

Emission factor for secondary aluminium

On the basis of confidential measurement records certified by the licensing authority, the SF_6 emission factor for aluminium foundries for the period 1999 to 2008 was reduced from 100% to 3%. Additional analyses yielded an emission factor of 1.5% for the period as of 2009. This value

[57] See http://www.bvt.umweltbundesamt.de/kurzue.htm

[58] "...Organic fluorides occur only under certain conditions, and such conditions occur in the furnace repeatedly at intervals of hours to several days. These conditions are referred to as the anode effect. ... The gas at the anode changes in composition from CO_2 to CO and 5 to 20% CF_4...." Schwarz, W., & Leisewitz, A. (1996). *Aktuelle und künftige Emissionen treibhauswirksamer fluorierter Verbindungen in Deutschland* [Forschungsbericht 106 01 074/01](Gutachten im Auftrag des Umweltbundesamtes, Issue. U.-. Umweltbundesamt.

was also confirmed by confidential measurement reports that have been approved by the licensing authority. The most recent measurement took place in 2022 and yielded an emission factor of 0.08%. Since this is only a single measurement, an emission factor of 1.5% is retained.

Activity data for secondary aluminium

SF_6 consumption data was determined by surveying gas sellers, with the survey for the 2000 report year finding that the gas mixture has not been sold since 2000.

Data on the SF_6 used in pure form since 1999 were obtained by direct surveys of users and compared with data of gas sellers.

Since the 2006 report year, the data have been obtained by the Federal Statistical Office by surveying gas sellers about SF_6 sales figures (UStatG 2005).

4.4.3.3 Uncertainties and time series consistency (2.C.3)

Primary aluminium - by-product emissions

The figures for PFCs, CO, CO_2 and SO_2 emissions are in line with the Tier 3b approach and are thus considered very accurate. The time series for CO, CO_2 and SO_2 are consistent.

On the other hand, no survey was conducted of the plant-specific number of anode effects in 1991, 1992, 1993 and 1995 as part of voluntary commitments, and no calculation was carried out for these years.

In addition, the years 1991 to 1994 represent years of deep crisis in the German aluminium industry due to sharp drops in world market prices for primary aluminium. A number of plants were decommissioned as a result of this price decline. While all smelter types were affected, smelters that had recently been modernised with point-feeder technology were most affected. Their capacity decreased by 43% compared with that of 1990. This also explains the sudden increase and stagnation in the implied emission factor for CF_4 during these years. In absolute terms, the primary smelters emitted only 26 tonnes of CF_4 in 2007, while they emitted 45 tonnes in 2005. This drop was due to a decrease in production. With regard to 2006, production increased slightly, however, because partial shutdowns of furnaces at the Stade plant were more than offset by production increases at the Hamburg production site. In 2009, the economic crisis and other factors led to drastic reductions of production at the Rheinwerk Neuss site. Due to the difficult economic situation facing all German primary smelters, process instability repeatedly occurred in the following period as a result of frequent start-up and shutdown processes. This instability led to higher numbers of anode effects and, thus to higher PFC emissions. The economic situation stabilised considerably in 2010. That made it possible to maintain continuous, stable processes. As a result, the numbers of anode effects decreased to such a degree that despite the production increases, absolute PFC emissions decreased by comparison to their level in 2009. That trend continued in subsequent years. In 2018, PFC emissions rose slightly for the first time since 2010. One smelter converted its anode format, and this triggered a temporary increase in numbers of anode effects. Another smelter was forced to use lower quality aluminium oxide for a limited time due to delivery problems caused by low water levels in the Rhine River that hampered shipping, and as a result of temporary shutdowns of aluminium oxide (alumina) refineries. This also led to higher numbers of anode effects.

Due to economic problems, the activity data for primary aluminium slumped from 2022 to 2024. In one installation, production ceased entirely in 2023, resulting in a significant drop in PFC emissions. The increase in PFC emissions in 2024 is attributable to ramping up electrolysis production again at the three remaining facilities.

The uncertainty in the CO_2 emission factor corresponds to +/-5% pursuant to the Tier 2 method of the *IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 2006a).

Secondary aluminium - use of F gases in foundries

As studies have shown, part of the SF_6 used in aluminium production is broken down during use. For the aluminium industry, the emission factor has been applied to the highest measured emissions level and an uncertainty of 50% assumed for lower levels since measurements have shown that emissions are often considerably lower than the maximum levels.

4.4.3.4 Category-specific QA/QC and verification (2.C.3)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

The activity data for primary aluminium production are based on surveys taken by the WirtschaftsVereinigung Metalle metal industry association. They are reported to the German Environment Agency annually. The time series seems plausible and shows no inconsistencies. It is assumed that these data are collected in conformance with quality assurance criteria.

4.4.3.5 Category-specific recalculations (2.C.3)

No recalculations were required.

4.4.3.6 Category-specific planned improvements (2.C.3)

No further improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.4.4 Metal production: Magnesium (2.C.4)

4.4.4.1 Category description (2.C.4)

KC	Category	Activity	EM of	1995 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1995-2024
-/-	2 C 4, Magnesium Production		SF_6	C	C	C	C	C
-/-	2 C 4, Magnesium Production		HFC-134a	0.00	0.00	7.19	0.01	0.00

Gas	Method used	Source for the activity data	Emission factors used
SF_6	D	PS	D
HFC	D	PS	CS

The category "SF_6 and HFC-134a in magnesium production" is not a key category.

No primary magnesium is produced in Germany. Only cast parts made of magnesium alloys are produced. In magnesium casting, since the mid-1970s, SF_6 has been used as a cover (protective) gas over molten magnesium to prevent the magnesium's oxidation and ignition. The amount of SF_6 used per tonne of magnesium (specific SF_6 coefficient) has decreased sharply from its level in 1995. This is due to the fact that HFC-134a has increasingly been used as a substitute since 2003. SF_6 is used in a) the sand casting process for production of prototypes, individual parts and small series, and b) the pressure casting process in which it serves as a cover gas.

Pursuant to Article 13 of Regulation (EU) No 517/2014 on fluorinated greenhouse gases, the use of SF_6 in magnesium pressure die casting has been prohibited, even in small production installations, since 1 January 2018. As of 1 January 2008, magnesium die casting foundries with an annual SF_6 consumption exceeding 850 kg were already prohibited from using SF_6 as a cover gas. The German installations affected by this ban have gradually switched to HFC-134a.

4.4.4.2 Methodological issues (2.C.4)

Use of SF_6 as a cleaning agent and cover gas in magnesium production is an open use, i.e. all of the SF_6 used in the process is emitted into the atmosphere. The practice of assuming the equivalence between consumption (activity data) and emissions conforms to the method set forth in the *2006 IPCC Guidelines* (IPCC (2006a): Vol. 3, Chapter 4.5).

The *2006 IPCC Guidelines* do not contain any information about the emission factor for use of HFC-134a. For this reason, the emission factor previously chosen has been identical with that for use of SF_6 in magnesium production. In 2018, the emission factor was retroactively set to 50% for the entire time series.

For reasons of confidentiality, the SF_6 emissions from 2.C.3.b Secondary aluminium are also reported here.

Emission factors

For magnesium foundries, a default emission factor of EF_{use} = 100% is assumed for SF_6 due to a continuing lack of precise destruction rate data that would support a more precise estimate.

As of report year 2017, the emission factor has been retroactively set to 50% for the entire time series (i.e. for the period as of 2003). In 2017, the IPCC Emission Factor Data Base (EFDB) added "Destruction rates of cover gas HFC-134a" of 71 and 77% as non-binding guidelines for the national emissions inventories. These values correspond to emission rates of 29 and 21%. In 2007, studies commissioned by the U.S. Environmental Protection Agency (EPA) found that the destruction rates of HFC-134a depend on a range of parameters, including the temperature of the melt, the carrier gas used, the flow rate of the cover gas and the concentration of the HFC-134a. As there no further studies available on this subject, the experts have proposed an emission factor of 50% that includes a safety margin (Gschrey et al., 2018).

Activity data for magnesium production

In 1996, the German Environment Agency commissioned a survey of all domestic magnesium foundries that use SF_6. This survey determined the amounts consumed in the years 1990 to 1995.

Until report year 2007, data on the amounts used were obtained directly from users. Since the 2006 report year, the data have been obtained by surveying gas sellers with regard to SF_6 sales figures. In report year 2006, the two methods were compared.

Since report year 2007, data of the Federal Statistical Office (UStatG 2005) have been used for SF_6.

In terms of HFC-134a use, data are gleaned by way of company surveys.

4.4.4.3 Uncertainties and time series consistency (2.C.4)

As studies have shown, part of the SF_6 and HFC-134a used in magnesium production is broken down during use. As a result of the assumptions regarding the emission factors, the SF_6 emissions and, to some degree, those of HFC-134a, are probably too high.

4.4.4.4 Category-specific QA/QC and verification (2.C.4)

General quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

No data sources are available to review the F gas quantities gathered for emissions reporting as a basis for verification other than the data provided by the Federal Statistical Office. Comparisons with other countries do not show any need for improvements. The emission factor for SF_6 corresponds with the default emission factor specified in the *2006 IPCC Guidelines* (IPCC, 2006a). To ensure that all emissions are covered, the emission factor for HFC-134a is higher than the corresponding factors in the *IPCC Emission Factor Data Base* (EFDB).

4.4.4.5 Category-specific recalculations (2.C.4)

No recalculations are required.

4.4.4.6 Category-specific planned improvements (2.C.4)

No further improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.4.5 Metal production: Lead (2.C.5)

4.4.5.1 Category description (2.C.5)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
-/-	2 C 5, Lead Production		CO_2	157.87	0.02	64.89	0.01	-58.89

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1	AS	D/CS

The category “Metal production: lead” is not a key category.

In Germany, lead is produced from primary lead concentrates and secondary raw materials such as scrap containing lead and lead acid batteries.

All primary lead production in Germany involves the direct smelting (DS) process, either in bath smelting furnaces (Isasmelt-Ausmelt) or in QSL reactors. Process-related CO_2 occurs primarily from addition of carbon-containing reducing agents (such as coal dust). The imperial smelting process (in imperial smelting furnaces (ISFs)) is no longer used in Germany.

Recycling of lead acid batteries is the key factor shaping secondary lead production in Germany. Either short rotary furnaces or shaft furnaces are used. Process-related CO_2 emissions occur primarily from addition of carbon-containing reducing agents (for example, coke).

The activity data are reported annually to the German Environment Agency by the WirtschaftsVereinigung Metalle metal industry association.

4.4.5.2 Methodological issues (2.C.5)

The emission factors used were taken from the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC (2006a): values from Table 4.21) and correspond with Tier 1 methods. The only lead-production processes used in Germany are the direct smelting (DS) process for primary lead production, and the secondary lead production (S) process.

4.4.5.3 Uncertainties and time series consistency (2.C.5)

The default uncertainties set forth in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 2006a) have been used.

4.4.5.4 Category-specific recalculations (2.C.5)

No recalculations are required.

4.4.5.5 Category-specific QA/QC and verification (2.C.5)

General quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

The activity data are based on confidential surveys taken by the WirtschaftsVereinigung Metalle metal industry association. They are reported to the German Environment Agency annually. The time series seems plausible and shows no inconsistencies. It is assumed that these data are collected in conformance with quality assurance criteria.

4.4.5.6 Category-specific planned improvements (2.C.5)

No further improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.4.6 Metal production: Zinc (2.C.6)

4.4.6.1 Category description (2.C.6)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
-/-/2	2 C 6, Zinc Production		CO_2	670.80	0.06	81.65	0.02	-87.83

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1	AS	D

The category “Metal production: zinc“ is a key category as per method 2 analysis.

In Germany, zinc is produced from primary zinc concentrates and secondary raw materials such as scrap and steel mill dust containing zinc.

All primary zinc production in Germany involves the hydrometallurgical process. The imperial smelting process, a pyrometallurgical process, is not used.

In this sector in Germany, process-related greenhouse gas emissions occur primarily in secondary zinc production. Process-related CO_2 emissions occur when using coke as a reducing agent, especially when processing secondary materials containing zinc in rotary kilns.

The activity data are reported annually to the German Environment Agency by the WirtschaftsVereinigung Metalle metal industry association.

4.4.6.2 Methodological issues (2.C.6)

The CO_2 emission factor specified in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC (2006a): default factor) has been used. It corresponds to the Tier 1 method.

4.4.6.3 Uncertainties and time series consistency (2.C.6)

The default uncertainties specified in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 2006a) have been used.

Due to economic problems, there was a temporary shutdown of major production capacities in 2023. The emissions also therefore decreased substantially in this period. In 2024, production increased again, albeit to a lower level.

4.4.6.4 Category-specific recalculations (2.C.6)

No recalculations are required.

4.4.6.5 Category-specific QA/QC and verification (2.C.6)

General quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

The activity data are based on confidential surveys taken by the metal industry association (WirtschaftsVereinigung Metalle). They are reported to the German Environment Agency annually. The time series seems plausible and shows no inconsistencies. It is assumed that these data are collected in conformance with quality assurance criteria.

4.4.6.6 Category-specific planned improvements (2.C.6)

No further improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.4.7 Metal production: Other (2.C.7)

Since the CRF Reporter software does not allow nitrous oxide emissions to be allocated to 2.C.1, these emissions are reported under 2.C.7 instead. Otherwise, no greenhouse gas emissions are reported in category 2.C.7; that category is of relevance only for other pollutant emissions.

4.4.7.1 Category description (2.C.7)

The nitrous oxide emissions reported under 2.C.7 result from use of blast furnace gas and basic oxygen furnace gas in hot-blast stoves of blast furnaces (category 2.C.1).

In Germany, this category primarily includes copper production and hot-dip galvanising. The greenhouse gas emissions that occur in connection with hot-dip galvanising originate solely in process combustion, however; they are reported under 1.A.2 as a result.

The majority of greenhouse gas emissions in the copper industry also originate from process combustion and are reported under 1.A.2.b. Process emissions from fire refining in anode furnaces are also reported under 1.A.2.b since the reducing agent used for this purpose, natural gas, is not recorded separately from process combustion in the manufacturing industry

statistics. Furthermore, the greenhouse gas emissions that do not originate from process combustion are very low by comparison.

4.4.7.2 Methodological issues (2.C.7)

The nitrous oxide emissions, which should actually be allocated to 2.C.1, are calculated using statistical data on the use of blast furnace gas and basic oxygen furnace gas in hot-blast stoves of blast furnaces and an emission factor for combustion systems in Germany that was developed as part of a research project of the German Environment Agency (Rentz et al., 2002).

No emission factors are available for other greenhouse gas emissions in 2.C.7.

4.4.7.3 Uncertainties and time series consistency (2.C.7)

No information.

4.4.7.4 Category-specific recalculations (2.C.7)

No recalculations are required.

4.4.7.5 Category-specific QA/QC and verification (2.C.7)

The activity data are based either on confidential surveys taken by the metal industry association (WirtschaftsVereinigung Metalle), or on information provided by the industrial companies themselves. These data are reported to the German Environment Agency annually. The time series seems plausible and shows no inconsistencies. It is assumed that these data are collected in conformance with quality assurance criteria.

4.4.7.6 Category-specific planned improvements (2.C.7)

No further improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.5 Use of non-energy-related products from fuels and solvents (2.D)

4.5.1 Lubricant use (2.D.1)

4.5.1.1 Category description (2.D.1)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
-/-	2 D 1, Lubricant Use		CO_2	188.64	0.02	191.41	0.03	1.47

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2	NS	CS

The category “Lubricant use” is not a key category for CO_2 emissions.

Lubricants are used to reduce friction and wear in moving machine parts. They can also be used for transmission of power and heat. Furthermore, lubricants are used as sealants as a means of preventing build-up of deposits and to protect against corrosion. Process oils, which are also considered to be lubricants, are also used as raw materials and as auxiliary and working materials. In addition, various other industrial oils are used in non-lubrication applications.

The level of lubricant consumption in stationary applications remained relatively constant in Germany until 2019. Since then, consumption has declined. The only significant falls in consumption were in the crisis years of 2009 and 2020, and consumption recovered each time in the following year. In 2024, consumption amounted to 539,605 t, not including mobile applications.

4.5.1.2 Methodological issues (2.D.1)

Due to the different calculation methods involved, lubricant use is divided into two major areas: 1) use in motor vehicles, including other mobile sources, and 2) use in industry.

The German greenhouse gas inventory covers CO_2 emissions from co-combustion of lubricants for all mobile sources. As per emissions reporting requirements, emissions from two-stroke petrol engines are allocated directly to the corresponding emission sources as lubricants are considered part of the fuel (fuel mixtures for two-stroke engines) in these cases. A description of the relevant calculation methods is provided in Annex 7.1.3. By contrast, all co-combustion emissions that are not caused by two-stroke engines are considered to result from product use and are reported under section 2.D.1, along with emissions from stationary lubricant use in industrial sectors.

Stationary lubricant use

The activity data for lubricant use in industry consist of domestic delivery data (units: tonnes) provided by the "Official Mineral Oil Statistics for the Federal Republic of Germany" (Amtliche Mineralöldaten für die Bundesrepublik Deutschland) of the Federal Office for Economic Affairs and Export Control (BAFA) (Table 10j). These statistics differentiate the following groups of lubricant types:

- Compressor oils
- Turbine oils
- Gear oils
  - Car oils
  - Automatic transmission fluid (ATF)
  - Industrial gear oils
- Hydraulic oils
- Electrically insulating oils
- Machine oils
- Other industrial oils not used for lubrication
- Process oils
- Metal processing oils
  - Hardening oils
  - Water-miscible
  - Not water-miscible
  - Anticorrosive oils
- Greases

  - including for passenger cars
- Basic oils
- Extracts from lubricant refining

For these type groups, the Federal Office for Economic Affairs and Export Control (BAFA) regularly publishes sales figures (monthly and annual) based on companies' reports. A list of the companies that report these sales figures can be seen in the "survey-group list" (Erhebungskreisliste)[59].

The 2006 IPCC Guidelines do not specify which emission sources the lubricant use category includes. Losses can occur on the input side (filling), during use and on the output side (removal). In the interest of clarity and to increase the accuracy of the emission calculation, an expert opinion was commissioned (Zimmermann & Jepsen, 2018). In this project, the various lubricant-type groups were considered individually and emission factors derived that would permit use of a Tier 2 method. The study showed that while various types of losses occur among the different lubricant type groups, these losses only partially result in emissions into the air.

The typical losses on the input side, i.e. in connection with filling at the planned site of use (for example, the filling of an car motor, a transmission, or a machine (machine parts)) include:

- drip losses and other handling-related losses,
- residues in containers

Many different types of losses can occur during product use. They comprise:

- evaporation
- (co-)combustion
- leakage
- exports (applies especially to car lubricants)
- conversions into products
- adhesion to products

On the output side, i.e. in connection with the removal of used lubricants, the following types of losses can occur:

- drip losses and other handling-related losses,
- residues adhering to some part of the usage site

With respect to gaseous emissions, the most significant emissions include releases of greenhouse gases from (co-) combustion of lubricants, the formation of VOC as a result of leakage and emissions from open applications that depend on prevailing usage conditions in each case (especially temperature).

When the standard emission factor specified in the 2006 IPCC Guidelines is used, it is not possible to differentiate between a) uses in which primarily CO_2 emissions occur from co-

[59] http://www.bafa.de/SharedDocs/Downloads/DE/Energie/Mineraloel/moel_erhebungskreisliste.xls;jsessionid=8F5CC4170FEBCC89A69DE21218062873.2_cid378?__blob=publicationFile&v=4

combustion of lubricants and b) uses that lead mainly to NMVOC emissions. The CO_2 emissions from the industrial use of lubricants would double if a Tier 1 method were used.

On the basis of the analyses carried out in the project, the following emission factors were derived for the lubricant-type groups:

Table 180: Emission factors for specific lubricant-type groups, in percent

Lubricant-type group	Shares of total sales for the period as of 1990, expressed as ranges	NMVOC		
		Average	Min	Max
Compressor oils	≤1%	1.5%	*1%*	*2%*
Turbine oils	<1%	0.5%	*0%*	*1%*
Car transmission oils	5-10%	1%	*0%*	*2%*
Industrial gear oils	2-3%	1.5%	*1%*	*2%*
Hydraulic oils	6-15%	1.5%	*1%*	*2%*
Machine oils	1-7%	2.5%	*0%*	*5%*
Other industrial oils not used for lubrication	2-7%	25%	*0%*	*50%*
Metal processing oils	5-9%	5%	*0%*	*10%*
Basic oils	4-16%	10%	*5%*	*15%*
Electrically insulating oils	1-2%			
Process oils	4-20%			
Greases	2-4%			
Extracts from lubricant refining	≤5%			

The NMVOC emissions are calculated using a Tier 2 method in which the emission factors are applied to the entire time series.

In the interest of conformity with the 2006 IPCC Guidelines and EU emissions reporting, the NMVOC emissions are converted into CO_2 emissions. The same carbon content as described in 2.D.3 is used as a basis.

For purposes of reporting of air pollutants in the *Informative Inventory Report* (IIR), the NMVOC emissions are allocated to section 2.G.

In 1995, a number of Mineral Oil Statistics categories were changed. Three groups of varieties listed from 1995 onwards did not exist in the Mineral Oil Statistics prior to 1995, whereas four other categories were included. This required a slight adjustment to the procedure for the years 1990 to 1994. The following table shows the affected categories for the years 1990 to 1994, as well as how they were handled in the calculation.

Table 181: Handling of categories in BAFA statistics, 1990-1994

Category	Remarks about procedure	Emission factor
Other lubricating oils, specialty Other lubricating oils, non-specialty	These are handled like the “machine oils” group, for which data is not available between 1990 and 1994. This group includes various specialty and non-specialty lubricating oils.	2.5%

Category	Remarks about procedure	Emission factor
Other mineral oils for special applications	This category contains no lubricating oils. It is handled like the category "Other industrial oils not used for lubrication", for which data is not available between 1990 and 1994.	25%
Light-coloured plasticisers and extender oils	Extender oils and plasticisers are classified with the process oils. They are handled accordingly.	0%

Mobile lubricant use

The data on the total lubricant quantities used for lubricant co-combustion in four-stroke gasoline engines and in other engines in vehicles and mobile sources are incomplete. As a result, the co-combusted quantities are calculated largely from the fuel quantities on the basis of figures provided by the Verband Schmierstoff-Industrie e. V. (VSI; the association of the German lubricant industry) Wallfarth (2014).

Pursuant to Wallfarth (2014), the following co-combustion fractions are achieved in the various usage areas based on the respective fuel quantities used:

Table 182: Overview of the specific co-combustion fractions used

Sector	Fuel	Fraction	Source/remark
1.A.2.g vii	OK	0.00 %	Assumption, based on Wallfarth (2014)
	DK	0.10 %	Assumption, based on Wallfarth (2014)
1.A.3.a, 1.D.1.a, 1.A.5.b ii	Ke & FB	0.01 %	Aviation gas: like kerosene
1.A.3.b	All	-	Calculation using TREMOD
1.A.3.c	DK	0.05 %	Assumption, based on Wallfarth (2014)
1.A.3.d, 1.D.1.b., 1.A.4.c iii, 1.A.5.b iii	DK, HEL & HOS	0.15 %	Heavy fuel oil: like diesel fuel
1.A.4.a ii	DK	0.10 %	Assumption, based on Wallfarth (2014)
	LPG	0.10 %	Assumption, based on Wallfarth (2014)
1.A.4.b ii	OK	0.00 %	Assumption, based on Wallfarth (2014)
1.A.4.c ii	OK	0.00 %	Assumption, based on Wallfarth (2014)
	DK	0.10 %	Assumption, based on Wallfarth (2014)
1.A.5.b i	OK	0.00 %	Assumption, based on Wallfarth (2014)
	DK	0.15 %	Like 1.A.3.d; takes account of armoured vehicles

OK: gasoline (including bioethanol), only four-stroke engines; DK: diesel fuel (including biodiesel), Ke: kerosene; FB: aviation gas; HOS: heavy fuel oil; LPG: Liquefied petroleum gas

The quantities of co-combusted lubricants are calculated with the energy quantities used in some sectors in non-two-stroke engines, as well as with the aforementioned co-combustion fractions. A unified emission factor of 73,300 kg CO_2/TJ is then applied to the lubricant quantities to calculate the sector-specific unintended carbon dioxide emissions from lubricant co-combustion.

Table 183: Carbon dioxide from lubricants co-combusted unintentionally in mobile non-two-stroke engines, in [kt]

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024
1.A.2.g vii	2.44	1.35	1.18	1.00	1.51	2.14	2.41	2.36	2.25	2.24	2.26
1.A.3.a	0.23	0.23	0.25	0.23	0.23	0.21	0.09	0.07	0.10	0.11	0.11
1.A.3.b	86.1	104	114	118	121	129	117	120	121	122	124
1.A.3.c	1.41	1.14	0.93	0.71	0.57	0.51	0.43	0.43	0.41	0.40	0.37
1.A.3.d	4.43	3.58	2.38	3.10	2.83	2.73	2.47	2.27	1.86	1.93	2.02
1.A.4.a ii	0.69	0.54	0.57	0.57	0.69	0.76	0.78	0.75	0.73	0.73	0.71
1.A.4.b ii		*Here, only use of two-stroke gasoline engines*									
1.A.4.c ii	5.27	5.53	5.53	5.17	5.14	5.40	5.49	5.50	5.31	5.27	5.23
1.A.4.c iii	0.04	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.02	0.02	0.03
1.A.5.b	1.99	1.04	0.26	0.42	0.16	0.11	0.12	0.08	0.10	0.09	0.12
National	**103**	**117**	**126**	**129**	**132**	**141**	**129**	**132**	**132**	**133**	**135**
1.D.1.a	1.20	1.49	1.94	2.30	2.43	2.45	1.37	1.82	2.72	2.84	2.72
1.D.1.b	9.91	8.26	8.88	10.52	11.90	10.02	5.02	5.38	5.79	5.07	4.93

Source: Own calculations

4.5.1.3 Uncertainties and time series consistency (2.D.1)

The uncertainties for the type group-specific emission factors for stationary lubricant uses result from the emission factor ranges shown in Table 180.

On the basis of an estimate by experts as part of a study of incorrect notifications in the Mineral Oil Statistics, the uncertainties for the activity data are assumed to be 5%.

Since the co-combusted lubricant quantities tied to mobile lubricant use are calculated using a conservative approach, a considerably higher uncertainty of ±25% is assumed here. The same applies to the default emission factor used for CO_2, whose uncertainty is assumed to be ±10% due to the relatively heterogeneous product group of lubricants.

In 1995, a change was made to the Mineral Oil Statistics' lubricant-type classification, but this has not had any noticeable impacts on the lubricant quantities recorded. The change solely involved moving lubricants from categories for unspecified applications into categories for specified applications. This may mean that the emissions calculated for the years 1990 to 1994 are 5-25% too high.

4.5.1.4 Category-specific recalculations (2.D.1)

No recalculations were carried out for the area of stationary lubricant uses.

By contrast, the unintentionally co-combusted quantities were adjusted for the mobile use of lubricants for every year as of 2023:

Table 184: Revised unintentionally co-combusted quantities of lubricants, in terajoules [TJ]

	2003	2004	2005	2010	2015	2020	2021	2022	2023
Mobile uses, in terajoules [TJ]									
2026 submission	1,754	1,784	1,757	1,803	1,922	1,757	1,796	1,797	1,818
2025 submission	1,754	1,784	1,757	1,804	1,922	1,770	1,801	1,803	1,811
Absolute change	-0.13	-0.35	-0.44	-0.29	-0.32	-13.3	-4.58	-5.99	7.11
Relative change	-0.01%	-0.02%	-0.02%	-0.02%	-0.02%	-0.75%	-0.25%	-0.33%	0.39%

Source: TREMOD and TREMOD MM

The emissions from this unintentional co-combustion have been recalculated accordingly for the listed years and the total emissions from lubricant use have been adjusted:

Table 185: Revised CO_2 emissions from the use of lubricants, in kilotonnes

	2003	2004	2005	2010	2015	2020	2021	2022	2023
2026 submission	189	190	188	194	219	181	202	200	195
2025 submission	189	190	188	194	219	182	202	200	195
Absolute change	-0.01	-0.03	-0.03	-0.02	-0.02	-0.98	-0.34	-0.44	0.52
Relative change	-0.01%	-0.01%	-0.02%	-0.01%	-0.01%	-0.53%	-0.17%	-0.22%	0.27%

Source: Own calculations; stationary uses: CO_2, calculated from released NMVOC

4.5.1.5 Category-specific QA/QC and verification (2.D.1)

For stationary uses: The Federal Office for Economic Affairs and Export Control (Bundesamt für Wirtschaft und Ausfuhrkontrolle) did not supply any data on domestic deliveries of metal processing oils and turbine oils for 2024 in its official mineral-oil data for that year. As a result, the value from 2023 was used instead.

General quality control and quality assurance, have been carried out in conformance with the requirements of the QSE-manual and its associated applicable documents, by the Single National Entity.

Extensive quality controls were carried out in the aforementioned studies and described in section 4.5.1.5 of the 2021 NIR.

For mobile uses: General quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

4.5.1.6 Category-specific planned improvements (2.D.1)

No improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.5.2 Paraffin wax use (2.D.2)

4.5.2.1 Category description (2.D.2)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
-/-/2	2 D 2, Paraffin Wax Use		CO_2	242.70	0.02	442.71	0.07	82.41
-/-	2 D 2, Paraffin Wax Use		N_2O	0.62	0.01	1.13	0.01	82.41

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1	NS	D
N_2O	Tier 1	NS	D

The category “Paraffin wax use” is a key category for CO_2 emissions pursuant to Approach 2 analysis.

The most important use of waxes is in candles. Packaging, synthetic wood and hot melt adhesives also represent significant areas of application.

Surveys of industry experts carried out as part of a research project (Zimmermann & Jepsen, 2018) have confirmed the assumption that, apart from candles, no other wax uses are relevant to emissions reporting because, apart from the burning of candles, no other uses under normal conditions can be expected to produce emissions. For this reason, the inventory continues to take account only of wax use in candles. The research project also evaluated two studies from 2002 and 2010 that estimated the fractions of renewable resources in candles at 15% (Matthäi & Petereit, 2004)and 22% (Matthäi et al., 2010). In addition to beeswax (2%), the renewable resources involved include animal and vegetable fats (12%) and stearins (8%), which are produced primarily from palm oils.

Germany is an important market for candles within the European Union. In 2016, its share of the overall market amounted to nearly 27% (European Candle Association, 2017). From 1990 to 2013, and in contrast to the trend in Europe as a whole, demand for candles grew in Germany. After that and until 2019, demand in Germany receded. In 2023, the trend seems to continue, whereas the years from 2020 to 2022 saw a significant increase in candle burning, probably due to the crisis.
With exports remaining constant and production in decline, demand has been met primarily by imports since 2013.

4.5.2.2 Methodological issues (2.D.2)

The calculation model is based on the assumption that all candles are consumed within a year of their purchase and are burned completely.

The CO_2 and N_2O emissions are calculated using a Tier 1 method.

Activity data

The production quantity data and the data on imported and exported quantities of candles for the years as of 1996 were obtained from the Federal Statistical Office (Statistisches Bundesamt (jährlich - FS 4, R. 3.1), manufacturing industry; production in the manufacturing industry and foreign trade statistics (Produzierendes Gewerbe, Produktion im Produzierenden Gewerbe sowie Außenhandelsstatistik).

The quantities consumed are calculated with the formula Production + Imports – Exports. A fixed biogenic fraction of 15% is deducted when determining CO_2 emissions. The N_2O emissions, however, include the biogenic fraction. Consumption in 2022 amounted to 224,978.8 t wax, including the biogenic fraction.

For the years 1990 to 1995, the quantities consumed are calculated from the per-capita consumption derived from data for the years 1996 to 2013. In the process, it is assumed that consumption also grew on a linear basis in these years.

Emission factors

The emission factor for CO_2 is 2.9467 t/t product; for N_2O, the factor is 0.024 kg/t product.

Standard values were used to derive the emission factors applied to the entire time series (IPCC (2006a): Vol. 2 Chapter 1 table 1.2 and IPCC, 2006: Vol. 2, Chapter 2, Table 2.4).

4.5.2.3 Uncertainties and time series consistency (2.D.2)

As a Tier 1 method with standard values from the 2006 IPCC Guidelines was used, the corresponding uncertainties for activity data and emission factors also apply. (IPCC (2006a): Vol. 3, Chapter 5).

Due to the fixed biogenic share for all years, the uncertainty for the activity data is estimated at +30%/-10%.

4.5.2.4 Category-specific recalculations (2.D.2)

The CO_2 and N_2O emissions had to be corrected for 2023 owing to adjustments to foreign trade statistics. However, the usage quantities only decreased by 0.6% for that year, with the CO_2 and N_2O emissions decreasing accordingly. As these changes are so minor, they are not shown in a table.

4.5.2.5 Category-specific QA/QC and verification (2.D.2)

General and category specific quality control and quality assurance, have been carried out in conformance with the requirements of the QSE-manual and its associated applicable documents, by the Single National Entity.

Apart from the data provided by the Federal Statistical Office, no other national data are available to review the import, export and production quantities with a view to verifying the consumption quantity data. The official Mineral Oil Statistics do not list uses in candles as a separate category. Furthermore, the *European Candle Association* (ECA) relies on EUROSTAT data. A comparison with the EUROSTAT data was carried out.

A comparison with the calculation methods of other countries was carried out in connection with the 2018 report. Differences were only found in the recorded wax quantities.

4.5.2.6 Category-specific planned improvements (2.D.2)

No further improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.5.3 Other: Solvents – NMVOC (2.D.3 Solvents)

4.5.3.1 Category description (2.D.3 Solvents)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
-/-	2 D 3, Other		CO_2	2,551.10	0.20	1,224.63	0.18	-52.00

Gas	Method used	Source for the activity data	Emission factors used
CO_2	D	NS	D
NMVOC	Tier 2	NS	CS

The category indirect CO_2 from NMVOC emissions in the category "Solvent and other product use" (CRF 2.D.3) is not a key category due to its inclusion in the key category "2.D.3 – Other". The CO_2 emissions from the key category contain 896.31 kt CO_2-eq. from the use of solvents and 328.32 kt CO_2 from the use of AdBlue. The following information only refers to the use of solvents. The release of CO_2 as a result of using AdBlue is described separately in Chapter 4.5.6.

The NMVOC emissions released through the use of solvents and products containing solvents all belong to subcategories of this category.

The four reporting categories of this category vary widely in structure. To take account of this variation, inventory data were calculated in accordance to the UNECE/EMEP substructures based on the CORINAIR97 (CORINAIR: COordination d' INformation Environmentale; sub-project AIR) SNAP system[60].

The categories 2.D.3.a, d, e, f, g, h and i include the following applications and activities:

2.D.3.a: Domestic solvent use including fungicides

a) Domestic solvent use

- Soaps
- Detergents, dishwashing agents and cleansers (softeners; general-purpose detergents; detergents; auxiliary washing preparations; dishwashing detergents; cleansers for floors and carpets; cleansers for cars; window cleaners; cleaning agents for toilets and bathrooms);
- Shoe polishes, shoe care and leather care products, furniture and floor polishes; car care washes and waxes
- Preparations for polishing metal
- Fragrances (for rooms, perfumes, eau de toilette, aftershaves)
- Cosmetics and make-up (make-up; preparations for hand, nail and foot care; face care products; body care products; sunscreen products and other preparations)

[60] here in the details of the SNAP Level 3

- Shampoos and hair care products (shampoos; perm care products and hair straighteners; hairsprays; hair cremes and brilliantines; tinting shampoos, hair-colouring agents, hair bleaching agents and other care products)
- Other personal care products (shaving creams; body deodorants and antiperspirants; bath essences; intimate-care products, hair removers, beauty products and other)
- Anti-freeze for cars

b) Household use of pharmaceutical products

2.D.3.d: Use of paints and lacquers

a) Decorative paints and lacquers, architectural coatings

- Car repair
- Professional uses of paints and lacquers in structures and buildings (emulsion paints for interiors; facade paints/silicate; polymer plasters/silicate; architectural paints/glazes; primers/coatings; other applications)
- Do-it-yourself uses of paints and lacquers in structures and buildings (emulsion paints for interiors; facade paints/silicate; polymer plasters/silicate; architectural paints/glazes; primers/coatings; other applications)
- Wood coatings (wooden interiors; carpentry and cabinet-making)

b) Industrial coatings

- Car manufacturing (primers, fillers, topcoats and clearcoats)
- Repair of commercial vehicles and other vehicles
- Coil coatings
- Coatings for maritime applications
- Wood coatings (furniture)
- Other industrial coatings (spray paints (without propellants); electrical fittings and appliances/household; machine tools; auto accessories/metal; metal products, sheet metal packaging; wire enamels; impregnation and casting materials; structural elements without strip coatings; plastics; paper/foil; other processing)

c) Other non-industrial colour coatings (marking paints; anti-corrosives; other)

2.D.3.e Degreasing

- Metal degreasing
- Production of electronic components

- Other industrial cleaning (precision mechanics, optics, watch-making)

2.D.3.f Dry cleaning

- Dry cleaning

2.D.3.g Production and processing of chemical products

- Processing of polyester
- Processing of polyvinyl chloride
- Processing of polyurethane
- Processing of polystyrene foam
- Rubber processing (tyre manufacturing)
- Production of pharmaceutical products
- Production of paints and lacquers
- Production of printing inks and dyes
- Manufacture of glues
- Production of adhesives, magnetic tape, films and photographs
- Production of products containing solvents
- Production of wood preservatives
- Production of building-material additives
- Production of consumer goods containing solvents
- Production of surface-cleaning agents
- Production of anti-freezes and de-icing agents
- Production of waxes and wax removers
- Production of paint strippers
- Treatment of bitumen (asphalt blowing)

2.D.3.h Printing industry - printing applications

- Coldset offset printing (newspaper printing)
- Sheet-fed offset printing (conventional, UV-bases)
- Heatset offset printing
- Endless offset printing
- Book printing
- Flexographic printing for packaging (solvent-based, water-based)
- Gravure printing for packaging (solvent-based, water-based)
- Illustration gravure printing
- Screen printing
- Other printing applications
- Paints for artists, in sets
- Paints for artists, not in sets
- Inks for writing and drawing, etc., including inks in concentrate or solid form (not including printing inks)

2.D.3.i: Other applications

- Treatment of glass and rock wool
- Extraction of oils and fats
- Use of glues and adhesives (paper and packaging; construction, wood; transport; shoes; do-it-yourself applications; other)
- Use of wood preservatives
- Undersealing and wax treatments for vehicles
- Car wax stripping
- Other
  - Use of pesticides
  - Dichloromethane for paint stripping
  - Paint and varnish removal (improperly coated aluminium components, steel parts and steel hangers)
  - Concrete additives

- De-icing (aircraft; working spaces; other)
- Scientific laboratories

"NMVOC" is defined in accordance with the VOC definition found in the EC solvents directive (European Parliament (EP), 2010)[61]. To provide a more specific definition of the term *solvent use,* the EC Solvent Directive is also used for the definition of solvents [62].

It is important to note that some volatile organic compounds are used both as solvents and as chemical reactants - for example, toluene, which is used as a solvent in lacquers and glues and as a reactant for production of toluenediisocyanate (TDI), and methyl ethyl ketone (butanone), which is used as a solvent in printing inks and as a base material for synthesis of methyl ethyl ketone peroxide. Consequently, VOCs (either substances or fractions of substances or products) used as chemical reaction components are not included in this category.

The definition outlined above covers a very heterogeneous field of emission-causing processes. This applies to:

- Concentrations and volatility of VOCs used.
  (The range spans the use of volatile individual substances as solvents, e.g. in cleansing; use of products with solvent mixtures, e.g. in paints and lacquers; and applications in which only small parts of mixtures used (also) have solvent properties (as is the case, for example, in polystyrene foam production)).
- The considerable differences in emissions conditions.

Solvent uses can be open to the environment, as is the case when using cosmetics, or largely closed to the environment, as is the case when extracting essential oils or using chemical dry cleaning systems.

4.5.3.2 Methodological issues (2.D.3 Solvents)

Except in the area of asphalt blowing, NMVOC emissions are calculated using a product consumption-based approach where the NMVOC input quantities allocated to these source categories from solvents or solvent-containing products are determined before the NMVOC emissions (for each source category) are calculated from these quantities using specific emission factors. This method is explicitly listed under "consumption-based emissions estimating" as one of two methods that are to be used for emissions calculation for this category.

This method can only be used with valid input figures, differentiated by source categories, in the following areas:

- the quantities of (pre-)products and agents containing VOCs used in the report year,
- the VOC concentrations in these products (substances and preparations),
- the relevant application and emission conditions (or the resulting specific emission factor).

To take account of the highly diverse structures throughout this category, these input figures are determined on the level of 37 differentiated emissions-causing processes (as noted above, in a

[61] In this definition, volatile organic compounds (VOCs) include all organic compounds that are volatile at 293.15 K, at a vapour pressure of at least 0.01 kPa or under the usual conditions for their use.

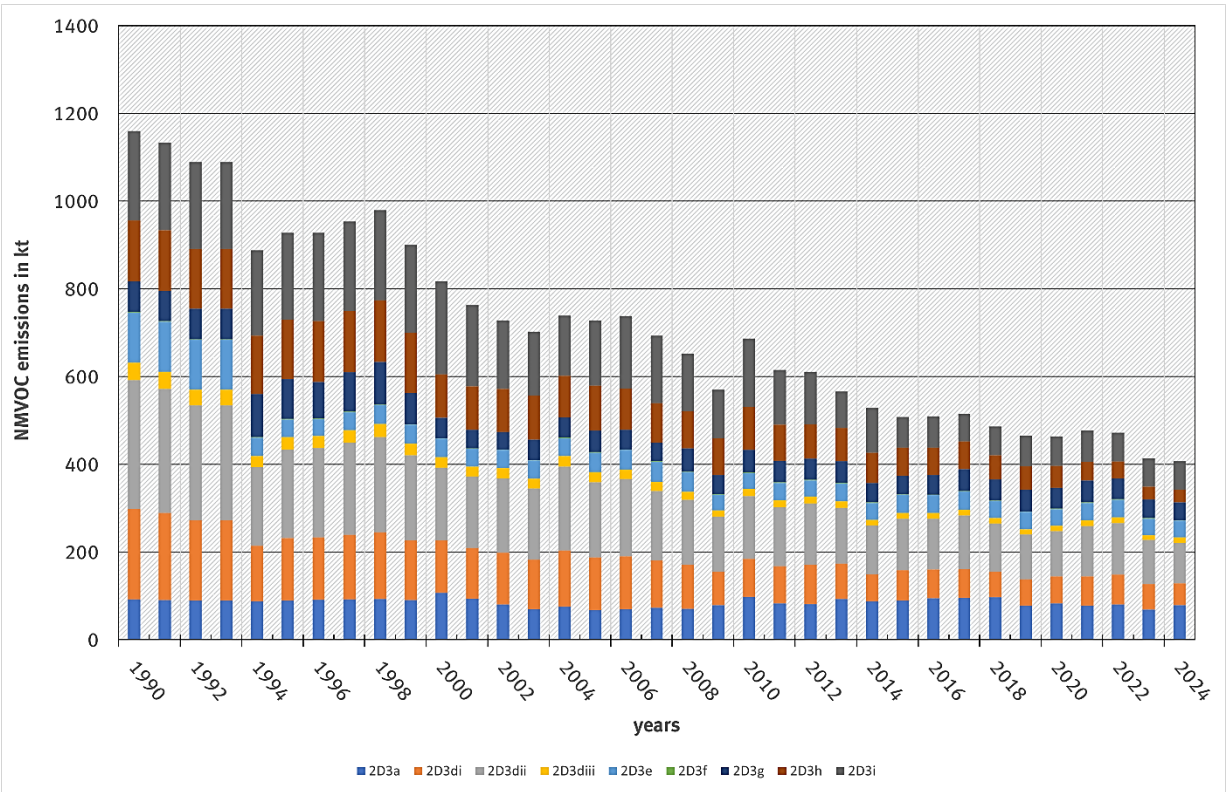
[62] According to this definition, an organic solvent is a volatile organic compound that, either by itself or in combination with other raw materials, products or waste substances, and without changing chemically, either dissolves or is used as a cleanser for dissolving dirt accumulations, as a solvent, as a dispersing agent, as an agent for adjusting viscosity or surface tension, or as a softener or preservative.

manner similar to that used for CORINAIR SNAP Level 3), and the calculated NMVOC emissions are then aggregated. The product/substance quantities used are determined at the product-group level using production and foreign trade statistics. Where possible, the domestic consumption quantities determined by this method are then further verified by cross-checking them with industry statistics.

The values used for the average VOC concentrations of the input substances and the emission factors used are based on expert assessments and industry dialogue for the various categories and category areas. Not all of the necessary basic statistical data required to calculate the NMVOC emissions for the current year are available in final form; as a result, the data determined for the previous year are used as a basis for a forecast for the current report. As soon as the basic statistical data are available for the current year in their final form, the inventory data for NMVOC emissions from solvent use are recalculated and documented.

Since 1990, NMVOC emissions from use of solvents and products containing solvents have decreased by more than 50% overall.

Figure 45: NMVOC emissions from solvents-based products and applications (2.D.3.a, d-i)



Source: own illustration, German Environment Agency

The majority of emissions were reduced between 1999 and 2009. This reduction was achieved in particular through regulatory measures such as the Ordinance under chemicals law for limiting emissions of volatile organic compounds (VOC) by limiting the placing on the market of paints and varnishes containing solvents (Chemikalienrechtliche Verordnung zur Begrenzung der Emissionen flüchtiger organischer Verbindungen (VOC) durch Beschränkung des Inverkehrbringens lösemittelhaltiger Farben und Lacke (Lösemittelhaltige Farben- und Lack-Verordnung - ChemVOCFarbV), the 31st Ordinance on the Implementation of the Federal Immission Control Act (Ordinance on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain facilities – 31. BImSchV, (BfJ, 2024)), the 2nd such

ordinance (Ordinance on the limitation of emissions of highly volatile halogenated organic compounds – 2. BImSchV, (1990)) and the Technical Instructions on Air Quality Control (TA Luft). The German "Blauer Engel" (Blue Angel) environmental quality seal, which is used to certify a range of products, including paints, lacquers and glues with low solvent concentrations, has also played an important role in this development.

As of the 2009 report, CO_2 emissions are calculated from NMVOC.

Since compatibility with EU greenhouse gas reporting is the primary methodological backdrop for conversion of NMVOC emissions into CO_2 emissions, for the current report we used the Reference Approach proposed in Vol. 1 *Chapter 7 Precursors and Indirect Emissions* of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories:

Equation 7:

$$EM_{\text{indirektes } CO_2} = EM_{NMVOC} \times Molmasse_{CO2} / Molmasse_C \times 60/100$$

The solvent content levels of various paints, coatings and printing inks were adapted to the current state of the art and reduced accordingly as part of an expert assessment and based on technical discussions with the affected sectors in the years 2013, 2015 and 2017. In addition, the NMVOC emissions from use of metal processing oils (cooling lubricants) and other lubricants (industrial lubricants) were assigned to another category (2.D.1. "Lubricant use") (cf. Chapter 4.5.3.1).

The NMVOC emissions that result from asphalt blowing are calculated with an emission factor based on the quantity of treated bitumen. The NMVOC emission factor was derived with the maximum permitted levels and reduction-measures requirements specified in the Technical Instructions on Air Quality Control (TA Luft). The emission factor, which remains constant for all years in question, amounts to 27.2 mg/t.

The applicable quantities of treated bitumen are calculated from the total bitumen production figures published annually by the Federal Office for Economic Affairs and Export Control (BAFA) in its official mineral oil data (Amtliche Mineralöldaten) (BAFA, 2025a). The applicable percentage share of blown asphalt (bitumen) was obtained from a one-time data survey of the Arbeitsgemeinschaft der Bitumenindustrie e. V. (bitumen industry working group) that was carried out for the year 1994 as part of a project commissioned by the German Environment Agency (UBA). The percentage remains constant for all years and amounts to 10%.

A more detailed explanation of the methods used to determine and analyse trends for NMVOC emissions from solvent-based products and applications is available in the Informative Inventory Report (IIR)[63].

4.5.3.3 Uncertainties and time series consistency (2.D.3 Solvents)

At the time of the report, errors had been estimated for NMVOC emissions; this was carried out using the error propagation method and estimates by experts for all input figures (in all 37 differentiated categories). The uncertainties lie primarily in the lack of precision in the basic statistics (production and foreign trade statistics) when categorising products containing or free of VOC, and with regard to use in different categories with highly differing emissions conditions.

Experts carried out an assessment where they checked the consistency of the inventory in this area using documentation of the database and the calculation methods for the 37 SNAP codes. The emissions time series from 2005 on were reviewed with regard to major jumps (>10% from

[63] Informative Inventory Report – Germany http://iir.umweltbundesamt.de

year to year) and the causes of any jumps analysed. Explanations were provided for all of the identified jumps. As a result, we concluded that there are no inconsistencies in the time series.

The uncertainties for the subcategory "Asphalt blowing" have been quantified using estimates from experts. As a result of the poor data situation, a large uncertainty of up to 100% must be assumed for the percentage applicable to blown asphalt with respect to total bitumen production and the emission factor for NMVOC.

4.5.3.4 Category-specific QA/QC and verification (2.D.3 Solvents)

General quality control and quality assurance, have been carried out in conformance with the requirements of the QSE-manual and its associated applicable documents, by the Single National Entity. Due to the differing levels of detail, data from other countries cannot be used for comparison or verification purposes. To determine NMVOC emissions, federal statistics and association data are used along with data surveys. No other sources were identified which could provide data to be used for comparison or verification purposes.

4.5.3.5 Category-specific recalculations (2.D.3 Solvents)

The data used in the emissions inventory for the NMVOC emissions of the previous year undergo routine category-specific recalculations. This procedure is based on and necessary for the methodology of the product consumption-based approach, as the final data for foreign trade statistics are only available after the reporting for the relevant reporting year has been completed.

4.5.3.6 Category-specific planned improvements (2.D.3 Solvents)

No further improvements are planned at present; cf. the first paragraph under "category-specific recalculations".

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.5.4 Other: Bitumen for roofing (2.D.3 Bitumen)

Gas	Method used	Source for the activity data	Emission factors used
NMVOC	Tier 1	AS	CS
CO_2	NE	NE	NE

As far as is currently known, the category "Bitumen for roofing" produces no greenhouse gas emissions[64] and is not a key category as a result.

4.5.4.1 Category description (2.D.3 Bitumen)

Bitumen is used in production and laying of roof and sealing sheeting.

The quantities of roof and sealing sheeting that are produced and used in Germany are shown in Table 186, whereby any deviation between the two figures depends on the export surplus. (only until and including 2021). During production, liquid bitumen is processed as a saturating or coating agent at temperatures of 150 to 220°C. This process produces emissions of organic substances (summarised here as NMVOC).

[64] Cf. the discussion relating to indirect CO_2 emissions under "Methodological issues".

Roof and sealing sheeting is laid by means of both hot and cold processes. The hot process, involving welding of sheeting, produces significant emissions of organic substances. The emissions trends depend primarily on trends in quantities of polymer bitumen sheeting produced. Use of primers containing solvents is not considered here; it is covered by the solvents model, cf. Chapter 4.5.1.

Emissions from production of roof and sealing sheeting remain about the same, and production quantities have hardly decreased at all. Emissions from laying roof and sealing sheeting can increase slightly, even when the quantities of sheeting used decrease, because use of bitumen roofing sheets accounts for a growing share of this sector.

Substances other than NMVOC are only of secondary importance in terms of emissions (cf. footnote [64] [65]).

4.5.4.2 Methodological issues (2.D.3 Bitumen)

Data on produced and used quantities of roof and sealing sheeting (activity data) are provided by the VDD association of the bitumen, roof sheeting and sealing sheeting industry (VDD, 2025) on the basis of a cooperation agreement dating from 2009. No data additions or projections are currently being made. To obtain internationally comparable figures, production quantities are converted into quantities of input bitumen, however (the conversion relationship, depending on the type of sheeting concerned, varies from 1.3 to 3.3 kg bitumen/m^2).

Due to their dominant relevance in terms of emissions, only NMVOC emissions are considered and included in the emissions inventory, with a distinction being made between emissions from production and emissions from the installation of roofing and sealing sheeting.

The emission factor for production of roof and sealing sheeting is based on a calculation in accordance with the current technological standards of German manufacturers (VDD, 2009). The emission factor for laying of polymer bitumen sheeting was taken from a life cycle assessment (Kreißig, 1996). This emission factor was also adopted for sheeting glued primarily with hot bitumen. Thin sheeting is nailed rather than glued, meaning that there are no emissions. The implied emission factor for the category has been increasing slightly as a result of the increasing importance of polymer bitumen sheeting.

NMVOC emissions are calculated in accordance with a Tier 1 method since no detailed data are available.

Table 186: Production and laying of roof and sealing sheeting with bitumen, and relevant activity data and emission factors

	Produced or used area in 2024 [millions of m^2]	EF/IEF [kg/m^2]
Production of roof and sealing sheeting with bitumen	113	NMVOC 0.000358
Laying of roof and sealing sheeting containing bitumen	113	NMVOC 0.000027-0.000044

The carbon dioxide emissions, which can be obtained by multiplying the NMVOC emissions by a carbon content factor of 80% and then converting to CO_2, are negligible. These are therefore not reported, but designated as “NE” in the CRF.

[65] Issues involving other air pollutants in the context of CLRTAP are not discussed here.

4.5.4.3 Uncertainties and time series consistency (2.D.3 Bitumen)

Information on the uncertainty of the data of the VDD was agreed on by the VDD and the German Environment Agency. The total uncertainty for the activity data for production and laying of sheeting is estimated to be about ±1%. This leads to a higher uncertainty of about ±2.5% for the calculated bitumen consumption relative to total production.

The uncertainty for the combined emission factors for production and laying of roof and sealing sheeting is estimated to be about ±5%.

4.5.4.4 Category-specific QA/QC and verification (2.D.3 Bitumen)

Due to resource limitations and the area's minimal relevance, no QC/QA is carried out for reporting precursors. A QC/QA checklist was completed and confirmed under the agreement with the VDD.

How the activity data were determined is considered plausible. The emission factors are consistent with findings from German Environment Agency research projects and are plausible. In particular, the validity of the emission factors is justified in that no emissions from use of solvent-containing coatings and primers have to be taken into account in this section (that takes place in the solvents model, see above).

4.5.4.5 Category-specific recalculations (2.D.3 Bitumen)

No recalculations are required.

4.5.4.6 Planned improvements, category-specific (2.D.3 Bitumen)

No improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.5.5 Other: Road paving with asphalt (2.D.3 Asphalt)

Gas	Method used	Source for the activity data	Emission factors used
NO_x, NMVOC, SO_2	Tier 1	AS	CS
CO_2	NE	NE	NE

As far as is currently known, the category Road paving with asphalt produces no greenhouse gas emissions[66] and is therefore not a key category.

4.5.5.1 Category description (2.D.3 Asphalt)

Currently, the report tables list the production quantities of mixed asphalt products and NMVOC, NO and SO_2 emissions (with regard to CO_2, cf. Chapter 4.5.5.2).

In 2024, a total of about 38 million t of asphalt (DAV, 2025) was produced in Germany in a total of about 600 asphalt mixing plants (DAV, 2016). Asphalt is used primarily in road construction where it competes directly with hydraulically bound concrete. In 1991, total production increased considerably; since 2000 it has been decreasing again.

The emissions trend depends primarily on trends in production quantities, with production stagnating in recent years.

4.5.5.2 Methodological issues (2.D.3 Asphalt)

No special calculation procedure is available to calculate the fuel inputs in category 1.A.2. Nonetheless, fuel inputs are taken into account by the Energy Balance evaluation and coupled with suitable emission factors.

The quantity of mixed asphalt products produced (activity data) was taken from communications of the Deutscher Asphaltverband (DAV; German asphalt association).

The emission factors were determined for each federal state in accordance with Tier 2 criteria. Emission factors for substances other than CO_{22} were determined by emissions for over 400 asphalt mixing plants measured between 1989 and 2000. The majority of the emissions occur during drying of the mineral substances. Almost all of the NMVOC emissions originate in the organic raw materials used and are released primarily during parallel drum operation and from mixers and loading areas. On average, about 50% of the NO_X and SO_2 involved come from the mineral substances used (proportional process emissions). CO is generated primarily in incomplete combustion processes. CO emissions are calculated solely for fuel inputs.

Table 187: Emission factors for production of mixed asphalt products

	NOx	NMVOC	SO_2
EF [kg/t]	0.015	0.030	0.030

Only emissions from asphalt production are reported. Figures related to emissions released during laying of asphalt have not yet been adequately reviewed.

The carbon dioxide emissions, which can be obtained by multiplying the NMVOC emissions by a carbon content factor of 80% and then converting to CO_2, are negligible. These are therefore not reported, but designated as “NE” in the CRF.

4.5.5.3 Uncertainties and time series consistency (2.D.3 Asphalt)

As the extensive measurement data show, the emissions lie within a comparatively narrow range. The large volume of measurement data available allow for highly reliable mean values. The only greater uncertainties are found in breakdown of emissions amounts into fuel-related and process-related emissions.

Data on production quantities can be considered very accurate since the product is ready for sale and operators report the amounts to the DAV.

4.5.5.4 Category-specific QA/QC and verification (2.D.3 Asphalt)

Due to resource limitations and the area’s minimal relevance, no QC/QA is carried out for reporting precursors.

4.5.5.5 Category-specific recalculations (2.D.3 Asphalt)

No recalculations are required.

4.5.5.6 Category-specific planned improvements (2.D.3 Asphalt)

No improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.5.6 CO_2 emissions from use of AdBlue® (2.D.3 Other: AdBlue®)

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS/M	CS/M	D

4.5.6.1 Category description (2.D.3 Other: AdBlue)

Since 2004, increasing numbers of vehicles in Germany have been equipped with *selective catalytic reduction* (SCR) catalytic converters. An aqueous urea solution[67] is used in these catalytic converters for the reductive mitigation of NO_x emissions, whereby carbon dioxide is released during its chemical conversion. In Germany, the product AdBlue® is used almost exclusively for this purpose (VDA, 2013).

4.5.6.2 Methodological issues (2.D.3 Other: AdBlue)

Since no comprehensive statistics or market studies on AdBlue® sales are currently available, the input AdBlue® quantities and the resulting CO_2 emissions are calculated within TREMOD (Knörr, Heidt, et al., 2025) on the basis of fuel consumption data for vehicles equipped with SCR catalytic converters.

Table 188: Modelled quantities of AdBlue® used, in tonnes

	2004	2005	2010	2015	2020	2021	2022	2023	2024
Passenger cars	0	0	3,031	53,918	251,719	274,965	289,671	291,123	293,190
Light commercial vehicles	0	0	0	607	65,524	80,274	87,697	93,555	100,201
Heavy commercial vehicles: trucks	203	7,637	344,649	574,915	725,285	748,694	735,377	698,991	700,500
Heavy commercial vehicles: buses	50.8	199	17,345	38,307	39,751	44,456	52,703	55,955	57,290
Road transport	**254**	**7,836**	**365,024**	**667,746**	**1,082,279**	**1,148,389**	**1,165,447**	**1,139,624**	**1,151,181**
Construction industry	0	0	0	6,016	75,446	90,623	99,515	109,609	126,588
Commercial and institutional	0	0	0	334	7,552	9,089	9,745	9,651	9,055
Agriculture	0	0	0	915	10,859	12,996	14,691	16,443	18,629
Forestry sector	0	0	0	2,668	35,840	44,990	53,172	62,402	72,109
NRMM	**0**	**0**	**0**	**9,933**	**129,697**	**157,697**	**177,124**	**198,104**	**226,382**
Total	**254**	**7,836**	**365,024**	**677,679**	**1,211,975**	**1,306,086**	**1,342,571**	**1,337,728**	**1,377,563**

Source: Heidt et al. (2025); Knörr, Heidt, et al. (2025)

[67] Average urea concentration pursuant to DIN 70070: 32.5%

The resulting CO_2 emissions are calculated using the following formula pursuant to the 2006 IPCC guidelines (IPCC (2006a): Volume 2, Chapter 3.2 - Road Transportation, p. 3.12, Formula 3.2.2):

$$EM_{CO_2} = AR_{AdBlue®} \times \frac{12}{60} \times \frac{32{,}5}{100} \times \frac{44}{12}$$

The following table shows the calculated CO_2 emissions.

Table 189: CO_2 emissions resulting from use of AdBlue®, in kilotonnes

	2004	2005	2010	2015	2020	2021	2022	2023	2024
Passenger cars	0.00	0.00	0.72	12.9	60.0	65.5	69.0	69.4	69.9
Light commercial vehicles	0.00	0.00	0.00	0.14	15.6	19.1	20.9	22.3	23.9
Heavy commercial vehicles: trucks	0.05	1.82	82.1	137	173	178	175	167	167
Heavy commercial vehicles: buses	0.01	0.05	4.13	9.13	9.47	10.6	12.6	13.3	13.7
Road transport	**0.06**	**1.87**	**87.0**	**159**	**258**	**274**	**278**	**272**	**274**
Construction industry	0.00	0.00	0.00	1.43	18.0	21.6	23.7	26.1	30.2
Commercial and institutional	0.00	0.00	0.00	0.08	1.80	2.17	2.32	2.30	2.16
Agriculture	0.00	0.00	0.00	0.22	2.59	3.10	3.50	3.92	4.44
Forestry sector	0.00	0.00	0.00	0.64	8.54	10.7	12.7	14.9	17.2
Σ NRMM	**0.00**	**0.00**	**0.00**	**2.37**	**30.9**	**37.6**	**42.2**	**47.2**	**54.0**
Total	**0.06**	**1.87**	**87.0**	**162**	**289**	**311**	**320**	**319**	**328**

Source: Heidt et al. (2025); Knörr, Heidt, et al. (2025)

In the German GHG inventory, these emissions are reported pursuant to footnote (6) in CRF Table 2(I).A-Hs2, under *2.D.3 – Non-energy products from fuels – Other*.

4.5.6.3 Uncertainties and time series consistency (2.D.3 Other: AdBlue®)

The uncertainty figures used here are based on expert estimates. The data sources, methods and emission factors are used consistently throughout the entire time series.

In a conservative approach, an uncertainty of ±20% is assumed for the activity data. For the emission factor, an uncertainty of ±10% is assumed.

4.5.6.4 Category-specific QA/QC and verification (2.D.3 Other: AdBlue®)

General quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

The data cannot be verified on the basis of inventories comparable to the German inventory. The last comparison with inventories of other countries was carried out in 2018, in the framework of an EU-wide exchange on new emission sources.

4.5.6.5 Category-specific recalculations (2.D.3 Other: AdBlue®)

Table 190: Revised annual fuel consumption of vehicles with SCR systems, in terajoules

	2012	2013	2014	2015	2020	2021	2022	2023
2026 submission	598,371	715,207	845,969	983,590	1,315,096	1,388,620	1,406,713	1,387,686
2025 submission	598,376	715,212	846,260	983,596	1,325,796	1,395,269	1,416,654	1,394,691
Absolute change	-4.71	-4.98	-291	-5.69	-10,700	-6,650	-9,941	-7,005
Relative change	0.00%	0.00%	-0.03%	0.00%	-0.81%	-0.48%	-0.70%	-0.50%

Source: Own calculations based on Heidt et al. (2025); Knörr, Heidt, et al. (2025)

The quantities of AdBlue® used were recalculated to take account of revision of the fuel consumption of SCR vehicles. It should be noted that these quantities do not change exactly in line with fuel consumption. This is because the off-road vehicles (NRMM) surveyed use more urea solution on average per litre of diesel than road vehicles do.

Table 191: Revised quantities of AdBlue® used, in tonnes

	2012	2013	2014	2015	2020	2021	2022	2023
2026 submission	465,628	511,079	578,352	677,679	1,211,975	1,306,086	1,342,571	1,337,728
2025 submission	465,634	511,086	578,360	677,689	1,221,502	1,314,916	1,356,419	1,352,956
Absolute change	-6.49	-6.94	-7.44	-9.50	-9,527	-8,830	-13,848	-15,228
Relative change	-0.001%	-0.001%	-0.001%	-0.001%	-0.78%	-0.67%	-1.02%	-1.13%

Source: Own calculations based on Heidt et al. (2025); Knörr, Heidt, et al. (2025)

The corrected AdBlue® quantities result in the CO_2 emissions adjustments shown below.

Table 192: Revised CO_2 emissions, in kilotonnes

	2012	2013	2014	2015	2020	2021	2022	2023
2026 submission	111	122	138	162	289	311	320	319
2025 submission	111	122	138	162	291	313	323	322
Absolute change	-0.002	-0.002	-0.002	-0.002	-2.27	-2.10	-3.30	-3.63
Relative change	-0.001%	-0.001%	-0.001%	-0.001%	-0.78%	-0.67%	-1.02%	-1.13%

4.5.6.6 Category-specific planned improvements (2.D.3 Other: AdBlue®)

At present, no improvements are planned on top of the general maintenance of the underlying TREMOD and TREMOD MM models that is normally carried out.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.6 Electronics industry (2.E)

KC	Category	Activity	EM of	1995 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1995-2024
-/-	2 E, Electronics Industry		N_2O	0.66	0.01	36.00	0.01	5,333.96
-/-	2 E, Electronics Industry		CF_4	92.06	0.01	72.53	0.02	-21.21

KC	Category	Activity	EM of	1995 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1995-2024
-/-	2 E, Electronics Industry		C_2F_6	147.83	0.02	37.63	0.01	0.00
-/-	2 E, Electronics Industry		C_3F_8	0.00	0.00	14.58	0.01	0.00
-/-	2 E, Electronics Industry		cC_4F_8	0.00	0.00	5.15	0.01	0.00
-/-	2 E, Electronics Industry		C_6F_{14}	21.57	0.01	0.00	0.00	-100.00
-/-	2 E, Electronics Industry		HFC23	14.34	0.01	13.14	0.01	0.00
-/-	2 E, Electronics Industry		HFC32	0.00	0.00	0.10	0.01	0.00
-/-	2 E, Electronics Industry		SF_6	48.73	0.01	63.92	0.01	31.16
-/-	2 E, Electronics Industry		NF_3	4.95	0.01	20.45	0.01	0.00

Gas	Method used	Source for the activity data	Emission factors used
HFC	Tier 3	AS, NS	PS
PFC	CS	AS, NS	CS
SF_6	CS	AS, NS	CS
NF_3	CS	AS, NS	CS

The category “Electronics industry” is not a key category.

4.6.1 Semiconductor and circuit board production (2.E.1)

4.6.1.1 Category description (2.E.1)

A variety of chemicals and gases are used in the manufacturing processes of semiconductor technology. Not all of them are significant greenhouse gases. Currently, the following are recorded PFCs (CF_4, C_2F_6, C_3F_8, c-C_4F_8), CFCs (CHF_3, CH_2F_2, CH_3F), nitrogen trifluoride (NF_3), sulfur hexafluoride (SF_6), and nitrous oxide (N_2O, laughing gas). These gases are used for etching structures on thin layers and for cleaning reaction chambers by way of chemical vapour deposition (CVD). In the production process, some of the PFCs fed into plasma chambers are partially converted into CF_4.

The semiconductor industry’s emissions depend on the extent to which the industry uses waste gas scrubbing equipment, and on annual semiconductor production levels. As a result of these dependencies, emissions tend to fluctuate from year to year.

In printed circuit board (PCB) production, drilled holes are cleaning with systems that use CF_4. As a repeat survey carried out in 2019 found, this area of application undergoes few changes.

4.6.1.2 Methodological issues (2.E.1)

Emission factors

During the etching process, only about 15% of the added CF_4 reacts chemically. The emission factor, an inverse reaction quota, thus amounts to 85% of the CF_4 consumption.

The emissions of fluorinated greenhouse gases cannot be determined solely on the basis of input quantities (sales by gas vendors) because the difference between consumption and emissions depends on a number of factors, including partial chemical conversion in plasma reactors and, in particular, the effects of downstream waste gas scrubbing systems. The industrial association aggregates and reports the figures for each plant. This also applies to nitrous oxide.

Activity data

The quantities of SF_6 used (since report year 2006) and NF_3 use (since report year 2015) are determined by the Federal Statistical Office by surveying gas sellers (UStatG, 2005). Data on usage quantity of the other substances are collected by the Federal Statistical Office, assigned to the semiconductor industry and confirmed by that industry.

Reliable emissions data are available for 1990 and 1995. Linear interpolation was carried out for the years 1991 to 1994.

Until report year 2000, emissions data were based on surveys carried out by the EECA-ESIA (European Electronic Component Manufacturers Association – European Semiconductor Industry Association). National manufacturers were asked about production capacities, amounts of substances used and waste gas treatment equipment.

As the result of a voluntary commitment by the semiconductor industry, emissions figures are available for this subcategory for all individual substances from the year 2001 onwards. A standardised calculation formula (Tier 3 approach) is applied to the annual consumption for each production site to calculate and aggregate the emissions data before the German Electrical and Electronic Manufacturers Association (Zentralverband Elektrotechnik- und Elektroindustrie eV. – ZVEI; Electronic Components and Systems Division) reports them to the German Environment Agency.

The association also provided a one-off report on the quantities of nitrous oxide used for the years 1990, 1995, 2000, 2001, and 2008. Data between these years is interpolated. In 2020, the ZVEI reported emissions data retrospectively to 2015. This annual reporting has been incorporated into a data supply agreement, thus ensuring the long-term availability of the emissions data.

Depending on the substances involved, the emissions from the semiconductor industry either increase or remain constant. The emissions from printed circuit board (PCB) production have remained constant.

4.6.1.3 Uncertainties and time series consistency (2.E.1)

The uncertainties for the semiconductor industry have been determined in full. According to the association, the uncertainties for the emissions amount to U_{max}= 12% and U_{min} = 7%.

The uncertainties (U_{min}/U_{max}) for emissions from printed circuit board (PCB) production are 15%.

4.6.1.4 Category-specific recalculations (2.E.1)

No recalculations were required.

4.6.1.5 Category-specific QA/QC and verification (2.E.1)

General quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

The data have undergone the above association's internal quality assurance and quality control process.

Quality control (pursuant to Tier 1) and quality assurance have been carried out as per the requirements of the QSE manual and its associated applicable documents.

No data sources are available to review the F gas quantities gathered for emissions reporting as a basis for verification other than the data provided by the Federal Statistical Office. Comparisons with other countries do not show any need for improvements. The emission factors are of the same order of magnitude as those of other countries.

4.6.1.6 Category-specific planned improvements (2.E.1)

No improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.6.2 TFT (2.E.2)

No TFT flat screens are produced in Germany.

4.6.3 Photovoltaics (2.E.3)

4.6.3.1 Category description (2.E.3)

In wafer production in Germany, SF_6 and other fluorine compounds were used for structure etching and for cleaning of reaction chambers during production processes. Since the purity of the process gas is lower than that of the gas used in the corresponding production process in the semiconductor industry, use for photovoltaics is reported separately. In Germany, use of SF_6 in solar technology began in 2003.

The time series shows a continuous emissions increase between 2003 and 2006; this is due to increases in production. A large jump occurred in 2007 and 2008 when quantities of produced wafers and, accordingly, the quantities of SF_6 used, increased sharply. As of 2010, decreases in produced quantities have led to decreases in emissions. From 2014 onward, there has been no wafer production with SF_6 in Germany.

From 2008, NF_3 replaced SF_6 in all new production lines for production of Si thin-film cells. Production of the substance was phased out by 2015.

In addition, in 2002/2003 the perfluorinated hydrocarbon CF_4 was introduced for “edge insulation” of crystalline solar cells. However, it was soon replaced by a more easily manageable procedure. Consumption of CF_4, which peaked in 2004, has been decreasing sharply since then. In 2014, production was largely discontinued.

4.6.3.2 Methodological issues (2.E.3)

Like emissions in the semiconductor industry, emissions in photovoltaics occurred during production. It was not possible to determine the production emissions solely on the basis of the quantities used (sales by the gas trade). The differences between consumption and emissions resulted from a) the fact that chemical conversion in plasma reactors was only partial, and b) the effects of downstream waste gas scrubbing systems.

Emission factors

In 2009, only one producer in Germany did not have a waste gas scrubbing system. For this reason, the IPCC default emission factor of 40% was used only for the first year of use, 2003. Thereafter, the emission factor decreased as the percentage of wafer production connected to downstream waste gas scrubbing systems increased. In 2010, it was just under 6%. As of 2011, all production facilities that used SF_6 had waste gas scrubbing systems in place, and the emission factor has remained at 4% since that year.

In wafer production with NF_3, the emission factor had a value of 4% since all national production facilities operated waste gas scrubbing systems. It was thus considerably lower than the IPCC default emission factor of 20%.

The emission factor for edge insulation with CF_4 was 7%. For reasons of confidentiality, emissions from edge insulation are reported under 2.H.3.

Activity data

To determine annual consumption quantities, the Federal Statistical Office surveyed gas suppliers (UStatG, 2005) to determine their domestic sales. In addition, the data were reviewed in a separate study (Schwarz, 2009).

4.6.3.3 Uncertainties and time series consistency (2.E.3)

The uncertainties were fully identified. According to estimates by experts, the uncertainties for the emissions (U_{min}/U_{max}) are 10% for SF_6, 20% for NF_3 and 50% for CF_4.

4.6.3.4 Category-specific recalculations (2.E.3)

No recalculations were required.

4.6.3.5 Category-specific QA/QC and verification (2.E.3)

General quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

No data sources are available to review the F gas quantities gathered for emissions reporting as a basis for verification other than the data provided by the Federal Statistical Office and the research contractor. Comparisons with other countries do not show any need for improvements. The emission factors are of the same order of magnitude as those of other countries that operate production facilities with waste gas scrubbing systems.

4.6.3.6 Category-specific planned improvements (2.E.3)

No improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.6.4 Heat transfer fluids (2.E.4)

4.6.4.1 Category description (2.E.4)

The PFC C_6F_{14} was used as a heat transfer fluid in the semiconductor industry and in some ICE power cars. The used of C_6F_{14} in the semiconductor industry was widespread in the 1990s, but was discontinued in 2015, replaced by hydrofluorinated ethers. Emissions are thus only generated from existing applications and during disposal. Until 2009, C_6F_{14} was used as a coolant in ICE power cars.

4.6.4.2 Methodological issues (2.E.4)

The emission factors are assumed to be 1% for filling, 5% for emissions from existing applications and 15% for disposal. The 2006 IPCC Guidelines (IPCC, 2006a) do not provide default emission factors for a Tier 2 approach.

The quantities used and the emission factors were determined by surveys of sector experts (Deutsche Bahn, ZVEI) and studies of available reference materials during a research project conducted by (Gschrey et al., 2015).

The average service life of installations with heat transfer fluids in the semiconductor industry is 12 years.

For reasons of confidentiality, the source category is reported under CRF 2.H.3.

4.6.4.3 Uncertainties and time series consistency (2.E.4)

The uncertainties were fully identified. According to estimates by experts, the uncertainties for the activity data and emission factors (U_{min}/U_{max}) amount to 20%.

4.6.4.4 Category-specific recalculations (2.E.4)

No recalculations were required.

4.6.4.5 Category-specific QA/QC and verification (2.E.4)

General quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

No data sources are available to review the F gas quantities gathered for emissions reporting as a basis for verification other than the data provided by the research contractor. Comparisons with other countries do not show any need for improvements. The emission factors are of the same order of magnitude as the factors used in other countries.

4.6.4.6 Category-specific planned improvements (2.E.4)

No improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.7 Product uses as substitutes for ODS (2.F)

KC	Category	Activity	EM of	1995 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1995--2024
-/-	2 F, Product Uses as Substitutes for ODS		HFC-23	13.62	0.01	36.76	0.01	169.95
-/-	2 F, Product Uses as Substitutes for ODS		HFC-32	0.76	0.76	262.22	0.76	0.76
-/-	2 F, Product Uses as Substitutes for ODS		HFC-43-10mee	C	C	C	C	C
L/T	2 F, Product Uses as Substitutes for ODS		HFC-125	135.68	0.02	1604.04	0.23	1082.21
L/T	2 F, Product Uses as Substitutes for ODS		HFC-134a	2062.32	0.16	3863.22	0.55	87.32
-/T	2 F, Product Uses as Substitutes for ODS		HFC-143a	76.48	0.01	988.39	0.14	1192.35
-/-	2 F, Product Uses as Substitutes for ODS		HFC-152a	100.24	0.01	0.00	0.01	-100.00

KC	Category	Activity	EM of	1995 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1995--2024
-/-	2 F, Product Uses as Substitutes for ODS		HFC-227ea	0.67	0.67	106.84	0.67	0.67
-/-	2 F, Product Uses as Substitutes for ODS		HFC-236fa	C	C	C	C	C
-/-	2 F, Product Uses as Substitutes for ODS		HFC-245fa	C	C	C	C	C
-/-	2 F, Product Uses as Substitutes for ODS		HFC-365mfc	C	C	C	C	C
-/-	2 F, Product Uses as Substitutes for ODS		C_2F_6	0.00	0.00	3.32	0.01	0.00
-/-	2 F, Product Uses as Substitutes for ODS		C_3F_8	20.07	20.07	0.49	20.07	20.07
-/-	2 F, Product Uses as Substitutes for ODS		C_6F_{14}	C	C	C	C	C

Gas	Method used	Source for the activity data	Emission factors used
HFC, PFC	cf. Table 193/Table 194	cf. Table 193/Table 194	cf. Table 193/Table 194

The category “Product uses as substitutes for ODS” is a key category for HFC-134a and HFC-125 emissions in terms of level and trend, and a key category for HFC-143a emissions only in terms of trend.

Category 2.F includes Refrigeration and air conditioning systems (2.F.1), Foam production (2.F.2), Fire extinguishing agents (2.F.3), Aerosols (2.F.4), Solvents (2.F.5) and other applications using ODS substitutes (2.F.6). In the interest of more precise data collection, these subcategories are broken down further, as described in the following subchapters.

The use of substances as refrigerants in stationary and mobile refrigeration applications, which accounts for over three-quarters of the emissions, is the largest source of HFC emissions in this category. The remaining emissions are distributed among the sources foams and aerosols and, in small amounts, fire extinguishers and solvents.

The PFC emissions originate in use of certain refrigerant mixtures in refrigeration and air-conditioning systems.

Table 193: Methods and emission factors used for the current report year in category 2.F.1 - Refrigeration and air-conditioning systems

			Gas		Service life	Production	Use	Disposal	
	SC	Method	HFC	PFC	[years]	Emission factor (dimensionless)	Emission factor (dimensionless)	Residual charge level (dimensionless)	Recovery rate (dimensionless)
Air-conditioning and refrigeration systems	**2.F.1**								
Commercial refrigeration	2.F.1a								
- Plug-in appliances		Tier 2a	HFC		10 (D)	0.005 (D)	0.01-0.014 (D)	0.90 (CS)	0.326-0.6 (D)
- Condensing units					12 (D)	0.01 (D)	0.049-0.097 (CS)	0.85 (D)	0.475-0.8 (D, CS)
- Central systems				PFC	12-14 (D)	0.01 (D)	0.0805-0.195 (D, CS)	0.875 (D)	0.429-0.8 (D, CS)
Household refrigeration	2.F.1b								
- Household refrigeration appliances		Tier 2a	HFC		15 (D)	NO	0.003 (D)	0.955 (CS)	0.733 (CS)
- Ice cream machines		Tier 2a	HFC		15 (CS)	NO	0.003 (CS)	0.955 (CS)	0.53-0.65 (CS)
Industrial refrigeration	2.F.1c								
- Plug-in appliances		Tier 2a	HFC		10 (CS)	0.005 (D)	0.01-0.014 (CS)	0.9 (D)	0.337-0.6 (D)
- Large refrigeration systems				PFC	10-30 (D)	0.01 (D)	0.0455-0.088 (D)	0.85 (D)	0.45-0.8 (D)
Refrigerated transports	2.F.1d								
- Refrigerated vehicles		Tier 2a	HFC	PFC	10 (CS)	5 g/system (CS, D)	0.15-0.3 (D)	0.875 (CS)	0.657 (D)
- Refrigerated containers					14 (CS)	NO	0.05-0.1 (CS)	0.875 (CS)	0.657 (D)
Mobile air conditioning systems	2.F.1e								
- Commercial vehicles		Tier 2a	HFC		15 (D)	5 g/system (CS, D)	0.15 (D)	0.34 (D)	0.38-0.5 (D)
- Passenger cars					15 (D)	3 g/system (CS, D)	0.1 (D)	0.34 (D)	0.38-0.5 (D)
- Buses					15 (D)	50 g/system (D)	0.15 (D)	0.34 (D)	0.38 (D)
- Ships					25 (CS)	0.01 (CS)	0.1-0.35 (CS)	NO	NO
- Railway vehicles					25 (CS)	0.005 (D)	0.06 (CS)	0.875 (CS)	0.756-0.8 (CS)
- Agricultural machines					10 (CS)	5 g/system (CS)	0.15-0.25 (CS)	0.34 (CS)	0.117 (CS)

			Gas		Service life	Production	Use	Disposal	
- Aircraft					-	NO	0.05 (CS)	NO	NO
Stationary air conditioning systems	2.F.1f								
- Large air conditioning systems		Tier 2a	HFC		15-25 (D)	0.005 (D)	0.028-0.06 (D)	0.9 (D)	0.658-0.8 (D)
- Heat pumps					15 (D)	0.005 (D)	0.01-0.025 (D)	0.75 (D)	0.5-0.65 (D)
- Heat-pump dryers					15 (CS)	0.005 (CS)	0.003 (CS)	0.955 (CS)	0.65 (CS)
- Dishwashers					12 (CS)	0.01 (CS)	0.003 (CS)	0.955 (CS)	0.82-0.85 (CS)
- Mobile Room air conditioners					10 (D)	NO	0.025-0.034 (D)	0.75 (D)	0.242-0.4 (D)
- Single-split units					10 (D)	0.1 (CS)	0.05-0.069 (D)	0.875 (CS)	0.379-0.6 (D)
- Multi-split units					10 (D)	0.01 (D)	0.042-0.079 (D)	0.875 (CS)	0.62-0.8 (D)
- VRF devices					10 (D)	0.01 (D)	0.049-0.081 (D)	0.875 (CS)	0.72-0.8 (D)

Table 194: Methods and emission factors used for the current report year in 2.F.2 (Foam blowing), 2.F.3 (Fire extinguishers), 2.F.4 (Aerosols), 2.F.5 (Solvents) and 2.F.6 (Other applications that use ODS substitutes)

	SC	Method	Gas		Service life	Emission factor (dimensionless)		
			HFC	PFC	[years]	Production	Use	Disposal
Foam production	2.F.2							
closed-cell	2.F.2a							
- PUR hard foam with 134a		Tier 2a	HFC		50 (D)	0.1 (D)	0.005 (D)	NO
- PUR hard foam with 41/227ea/245fa/365mfc					50 (D)	0.1-0.15 (D)	0.01 (D)	NO
- XPS foam with 134a/1234ze					50 (D)	C	0.0066 (CS)	NO
open-cell	2.F.2b							
- XPS foam with 152a		Tier 2a	HFC		-	1 (CS)	NO	NO
- PUR integral foam with 134a/227ea/245fa/365mfc /1233zd/1336mzz		Tier 2a			-	1 (CS)	NO	NO
- PU one-component foam with 134a/152a		Tier 2a			-	0.5-1.5 g/can (CS)	1 (CS)	NO
Fire extinguishers	2.F.3	CS	HFC		20 (D)	0.001 (CS)	0.01-0.004 (CS, D)	0.01-0.09 (CS)
Aerosols	2.F.4							
Metered dose inhalers	2.F.4a	Tier 2a	HFC		-	0.015 (CS)	1 (CS)	NO
Other aerosols / novelties	2.F.4b/c	Tier 2a			-	0.015 (CS)	1 (CS)	NO
Solvents	2.F.5	Tier 2a	HFC		-	NO	0.5 (D)	NO
Other applications that use ODS substitutes	2.F.6					NO	NO	NO

Halocarbons are used in a number of different applications. Whereas in some "open" applications the consumed quantities are emitted in full and in the same year, in other applications large quantities are stored (stocks). The substances are then emitted, partially or fully, from these stocks over their entire use phase and during disposal. Most of the emission factors (EFs) used are either country-specific (CS) or IPCC default (D).

The quantities of HFCs and PFCs slowly escaping from the "stock" during a reporting year and emitted during production and disposal represent the emissions as specified in the inventory tables.

In general, the emissions data collected for the various product groups comprise emissions from production, use and waste disposal. Unless otherwise specified for the respective methods, they are calculated as follows:

1. Production emissions are determined using new domestic consumption as activity data:

Equation 8:

$$EM_{production} = \text{New domestic consumption} * EF_{production}$$

2. Application emissions are based on the final stocks of pollutants (as activity data) and calculated as follows:

Equation 9:

$$EM_{use} = \text{Final stocks} * EF_{use}$$

The final stocks for the current year are calculated by adding annual new additions from the first report year to the current one. The new additions for a given year consist of the new domestic consumption for that year, minus production emissions and losses from removals. The calculation thus requires consideration of foreign trade.

3. Disposal emissions refer to new additions for the year that is x years (based on product service life x) prior to the current report year n:

Equation 10:

$$EM_{disposal} = \text{New additions}(n\text{-}x) * EF_{disposal}$$

4. For refrigeration and air conditioning systems, the disposal emissions are calculated as per Vol. 3, Equation 7.14 of the 2006 IPCC Guidelines:

Equation 11:

$$EM_{disposal} = \text{New additions}(n\text{-}x) * \text{Residual charge level} * (1 - \text{recovery factor})$$

In this chapter, the sections "Uncertainties and time series consistency, Category-specific QA/QC and verification, Category-specific recalculations" and "Planned improvements" sometimes refer to the entire category, sometimes to the subcategory and sometimes to only a part of a subcategory. In each case, the reference is apparent from the CRF number in the section heading.

4.7.1 Refrigeration and air conditioning systems (2.F.1)

4.7.1.1 Category description (2.F.1)

This category is divided into the subcategories of commercial refrigeration, household refrigeration, industrial refrigeration, transport refrigeration, mobile air conditioning systems and stationary air conditioning systems (cf. Table 193).

In Germany, the most common HFC refrigerants by far are HFC-134a and HFO-1234yf and the mixtures R-404A, R-407C and R-410A. HFO-1234yf is not subject to reporting obligations under the UN Framework Convention on Climate Change. However, it is reported voluntarily as an *additional greenhouse gas* (Chapter 4.9.3).

To calculate HFC emissions from the subcategories of refrigeration and air conditioning systems, individual data is collected or refrigerant models are used and described in the respective method.

The emission factors used were obtained by surveying experts. Disposal emissions in this category first occurred in 2000 in the subcategories 2.F.1.a (commercial refrigeration) and 2.F.1.e (mobile air conditioning systems).

4.7.1.2 Methodological issues (2.F.1)

4.7.1.2.1 Commercial refrigeration (2.F.1.a)

Commercial refrigeration is the largest and most diverse area of HFC/PFC application. It is subdivided into plug-in devices, condensing units and central systems. The diversity in central systems with regard to model, size, refrigerant type and emissions tightness results from the fact

that most systems are customised. There is less diversity among plug-in devices and condensing units.

Use of HFCs/PFCs as refrigerants grew only gradually. For example, HFC-134a was not used on any significant scale until 1993. Use of the refrigerant mixtures R-404A and R-407C also did not begin until 1993. The various R-422 mixtures, which served as drop-in refrigerants in conversions of HCFC-22 systems, were used between 2009 and 2013. In addition, from 1993 on, small quantities of refrigerant mixtures containing PFCs, such as R-403A/B, R-413A, Isceon 89 and R-508A/B, were also used as drop-in refrigerants. Since 2007, R-410A has been used in small central systems. Refrigerant mixture R-449A has been used for the conversion of R-404A central systems since 2013, and R-448A has also been used since 2014. R-449A, R-452A and R-513A have also been used in condensing units since 2016, and since 2019, uHFKW-1234ze (which is not subject to reporting obligations) as well as R-454C and R-455A have also been used, the latter two also in plug-in units. CO_2 (R-744) has also been used as a halogen-free alternative since 2002 and propane (R-290) since 2010.

Along with HFC-134a, the mixtures R-404A and R-449A are the most important HFC refrigerants found in existing stationary commercial refrigeration units. R-744, a halogen-free refrigerant, also plays an important role. The EU F Gas Regulation has prohibited sales of commercial refrigerators and freezers that use HFC refrigerants with a Global Warming Potential (GWP) of 2,500 or greater since 2020. As of 2022, the GWP limit in this regard has been reduced to 150. Sales of stationary refrigeration units with refrigerants with GWPs of 2,500 or more were also banned as of 2020. From 2030, the GWP limit for these units and appliances is 150 (EU, 2024b). The effects of these bans are already apparent as new units and appliances have not been filled with R-404A since 2019. No HFC refrigerants have been used in new central supermarket systems since 2023. From that time forward, refrigerant emissions in this area will only result from the operation and disposal of these systems.

Due to the extremely large number of companies specialising in refrigeration, detailed statistical surveys of refrigerant stocks are not practical so a different calculation method is used.

To calculate the emissions from central systems for commercial refrigeration in the food retail sector, the following refrigerant model is used (Schwarz et al., 2012):

- Foreign trade with locally installed refrigeration systems plays a negligible role, and thus annual HFC consumption for new systems is the same as new HFC additions in new systems.
- The starting point for the calculations is not the number of plants involved or the installed cooling capacity, but the sales floor area of the food retail stores since that figure is recorded on an annual basis. For discount stores, whose sales areas in Germany are relatively constant in size at 800 m^2, it is assumed that the cooling requirements and thus the amount of refrigerant are the same for all stores. This is why the number of discount stores serves as the basis for further calculations. The numbers of discount stores are also statistically recorded on an annual basis.
- On the basis of a study by the EPEE[68] (SKM Enviros, 2010), the coefficient "kilogrammes per square metre of sales floor area" 0.23 kg/m^2 is derived for a typical, average-size supermarket. For discount stores, the coefficient "kilogrammes per discount store" is determined. It has the value 80 kg/store. With these coefficients, the annual refrigerant

[68] EPEE: The European Partnership for Energy and the Environment.

stocks are calculated for the three store classes: discount stores, small supermarkets and large supermarkets.

- The refrigerant stocks of the various market formats, broken down by refrigerant type, are determined using the percentage shares of the refrigerant types used. The refrigerant shares are derived with static calculation models based on estimates by experts. A distinction is made here between large supermarkets (with sales floor areas greater than 1,500 m^2), small supermarkets (with sales floor areas between 400 and 1,500 m^2) and discount stores (sales floor areas of 800 m^2).
- Division of refrigerant stocks by the systems' average service life (12 years for discount stores; 14 years for all other types of stores) yields the HFC additions in new systems.
- The production emissions and emissions from units in service are calculated with Equation 8 and Equation 9. Production normally takes place at the relevant sites.
- Replacement of CFCs and HCFCs in old systems is considered separately.
- Disposal emissions from central systems occurred the first time in 2000. Removals of refrigerants are calculated using the average service life - 12 years for central systems in discount stores and 14 years for central systems in all other types of stores. The nominal quantity for disposal corresponds to the added new quantity a system had when it was commissioned. In practice, however, the quantities of refrigerants that systems contain when they are disposed of are lower than the corresponding nominal charges since systems are normally not recharged before they are decommissioned. For this reason, the actual charge upon disposal, the "effective quantity for disposal", is determined by percentage values for residual charges. The most important factor that enters into the determination of residual charges is the refrigerant loss level at which a system has to be recharged in order to maintain its proper function. The effective charge at the end of a device's/system's service life is larger than the minimum "technical" charge by 50% of the difference between the minimum "technical" charge and the nominal charge. For central systems, it amounts to 87.5% of the nominal charge.
- The disposal emissions are calculated by multiplying the "effective quantity for disposal" by the inverse of the recovery factor, using Equation 11:
- Emissions of HFO-1234yf and HFO-1234ze from the refrigerant mixtures R-448A and R-449A are not subject to reporting obligations. Germany voluntarily reports these emissions under "additional greenhouse gases" pursuant to the recommendations of the 2014 UNFCCC Reporting Guidelines (FCCC/CP/2013/10/Add.3, Decision 24/CP.19). These emissions are aggregated with other emissions not subject to reporting obligations and listed in Chapter 4.9.3. The CRT tables do not contain any data on emissions that are voluntarily reported.

Also in the case of condensing units for commercial refrigeration, the refrigerant stocks are the central point of reference for the refrigerant model for emissions calculation:

- The calculations are based on the number of companies in the many sectors that use condensing units, selected on the basis of a study conducted by the German Engineering Federation VDMA (2011). These sectors include cash-and-carry beverage stores, filling station shops, nurseries (garden centres), flower shops, flower wholesalers, cafeterias, caterers, hospitals, nursing homes, restaurants and hotels, butcher shops and franchise outlets for meat products, bakeries and franchise bakery outlets, discount stores, small food

retailers and specialty food retailers. The number of sites involved is updated annually, from publicly accessible statistics.

- The refrigerant stocks for the various individual sectors are calculated as the product of the relevant number of operational sites, the sector-specific charges (as determined from the literature and expert surveys) and the percentage shares for the refrigerant types that are used. The percentage shares for the refrigerants are derived by a static calculation model (Schwarz et al., 2012).
- Division of total refrigerant stocks by the average lifetime of condensing units (12 years) yields the HFC additions in new systems.
- The production emissions and emissions from units in service are calculated with Equation 8 and Equation 9.
- The disposal emissions are calculated using Equation 11. The nominal quantity for disposal is identical to the corresponding initial-charge quantity from 12 years earlier in terms of quantity and refrigerant shares. For condensing units, the effective charge at the end of a unit's service life amounts to 85% of the nominal charge.
- Emissions of HFO-1234yf and HFO-1234ze from the refrigerant mixtures R-448A, R-449A, R-452A, R-454C, R-455A und R-513A or used as individual substances are not subject to reporting obligations. Germany voluntarily reports these emissions under "additional greenhouse gases" pursuant to the recommendations of the 2014 UNFCCC Reporting Guidelines ((UNFCCC, 2014), FCCC/CP/2013/10/Add.3, Decision 24/CP.19). These emissions are aggregated with other emissions not subject to reporting obligations and listed in Chapter 4.9.3. The CRT tables do not contain any data on emissions that are voluntarily reported.

The application sectors for hermetically sealed plug-in units are largely the same as those for condensing units. This group also includes vending machines, such as beverage coolers, and refrigerated centrifuges. Emissions for these appliances are calculated in accordance with the refrigerant model approach described for condensing units. The appliances have an average service life of 10 years and their residual charge upon disposal amounts to 90% of the nominal charge.

Emission factors

The emission factors used are the result of surveys of experts and literature evaluations and were most recently revisited in 2023 (Warncke & Gschrey, 2024).

Charging of refrigeration systems generally produces only small quantities of emissions. For *initial emission* in Vol. 3, Table 7.9, the 2006 IPCC Guidelines give values of 0.5 to 3% of the initial charge for plug-in devices and for medium-sized and large commercial refrigeration systems. The country-specific $EF_{production}$, at 0.5% for plug-in devices and at 1% for central systems and condensing units, are within this range.

Ongoing HFC/PFC emissions from stationary refrigeration systems in the commercial refrigeration category vary greatly depending on the type of system. The refrigerant loss ranges from 1 to 1.4% for plug-in individual units, from 4.9 to 9.7% for condensing units and from 8.1 to 19.5% for central systems. The emission factors for application have decreased continuously since 1993 for all commercial refrigeration appliances and systems (cf. Table 193), which reflects the increasing degree of care taken with HFC refrigerants. Measured against the value ranges given in the 2006 IPCC Guidelines (IPCC (2006a): Vol. 3, Table 7.9), 1 to 15% for

individual units and 10 to 35% for medium-sized and large commercial refrigeration systems, the emission factors used either are within low bands of the ranges (individual units and central systems until report year 2014) or below the ranges (condensing units and central systems as of report year 2015).

The average service life prior to disposal is 10 years (individual units), 12 years (condensing units and central systems in discount stores) and 14 (central systems in all types of stores other than discount stores). The service life figures used are therefore within the relevant ranges given in the 2006 IPCC Guidelines (IPCC, 2006a), i.e. 10 to 15 years (individual units) and 7 to 15 years (medium-sized and large commercial refrigeration systems).

In relation to the initial charge, the residual charges in the units and systems at the end of their service life are 90% (individual units), 85% (condensing units) and 87.5% (central systems). The 2006 IPCC Guidelines give value ranges of 0 to 80% (individual units) and 50 to 100% (medium-sized and large commercial refrigeration systems). The residual charge applied for individual units thus lies above the specified value range. All other values are default values.

The recovery factors have continuously increased, meaning that the losses during disposal in relation to initial charge/residual charge have decreased over the years. For plug-in individual units, the recovery factor was 32.6% in 2003 and 60% as of 2020. For condensing units, the recovery factor was 47.5% in 2005 and 80% as of 2013, while for central systems the recovery factor increased from 42.9% in 2000 to 80% in 2020. As a result, most of the recovery factors used are within the range given in the 2006 IPCC Guidelines (IPCC (2006a): 3, Table 7.9), 0 to 70%. Only the recovery factors used for central systems as of report year 2009 and those used for condensing units as of report year 2016 exceed the IPCC values.

Activity data

The sales floor areas of grocery stores are surveyed annually by two market research institutes[69]. The EHI Retail Institute also monitors the numbers of discount stores. In addition, the applicable numbers of commercial sites are updated annually from various publicly available statistics (Schwarz et al., 2012).

The annual new additions of PFC-116 (C_2F_6), PFC-218 (C_3F_8), HFC-125 and HFC-23, which are contained in the refrigerant mixtures R-508A, R-508B, Isceon MO 89 and R-413A (HFC-23 is also used as a single-component refrigerant), are obtained from the annual national survey pursuant to the Environmental Statistics Act (Umweltstatistikgesetz) (UStatG, 2005).

The quantities and types of refrigeration and freezer systems typically used commercially are determined from literature and estimates by experts. The coefficients “kilogrammes per square metre of sales floor area” and “kilogrammes per discount store” was determined semiempirically by experts using the relevant technical literature (SKM Enviros (2010), Clodic and Barrault (2011), Clodic et al. (2012)). The charges for condensing units and plug-in appliances were determined on the basis of technical discussions with German manufacturers of refrigeration and freezer systems and by studying the relevant literature.

4.7.1.2.2 Household refrigeration (2.F.1.b)

In 1994, domestic producers of household refrigerators and freezers in Germany switched from CFC-12 to HFC-134a. A short time later, they then moved to isobutane (R-600a). Small numbers of devices containing HFC-134a, representing a small share of all relevant appliances, were imported between 1993 and 2014. Under the EU F Gas Regulation, imports of household

[69] EHI – EHI Retail Institute, Cologne; The Nielsen Company GmbH, Frankfurt am Main.

refrigerators and freezers that use refrigerants with GWPs of 150 or higher were prohibited as of 2015 (EU, 2024b).

Production losses and new consumption for domestic purposes do not have to be determined since all filling with HFC took place abroad.

Equation 9 is used to calculate annual HFC emissions on the basis of final stocks. This is done by determining and aggregating the annual HFC new additions since 1993 and then subtracting the aggregated annual removals by disposal.

Disposal emissions occurring as of the year 2008, following an average service life of 15 years, are calculated with Equation 11.

In Germany, a number of foreign companies have marketed ice cream machines for home use since the end of the 1990s. Compressor-operated ice cream machines function just like regular refrigeration systems that use refrigerants. Since 1997, the refrigerants used have been HFC-134a and the refrigerant mixture R-404A. Since 2015, increasing numbers of appliances with isobutane (R-600a) are also being used. Depending on the machines' sizes, ice cream machines' HFC-refrigerant charges range from about 30 g to over 100 g. This results in an average HFC charge of about 75 g.

Since no domestic production takes place, no domestic production emissions occur.

The annual HFC emissions are calculated with Equation 9 on the basis of final stocks. The final stocks are calculated from the aggregated annual new HFC additions since 1997, less the aggregated annual removals during disposal.

Units have an average service life of 15 years, and thus disposal began in 2012. The resulting emissions are calculated with Equation 11.

Emission factors

Current HFC emissions from household refrigerators and freezers are estimated at 0.3%, which is within the value range given by the 2006 IPCC Guidelines (IPCC (2006a): Vol. 3, Table 7.9), 0.1 to 0.5%.

The average service life prior to disposal is 15 years. The system service life used is therefore within the range of 12 to 20 years given by the 2006 IPCC Guidelines.

The residual charges in devices with respect to initial charge average 95.5%. The relevant values given in the 2006 IPCC Guidelines range from 0 to 80%. The value used is thus higher than the range given in the 2006 IPCC Guidelines. This value is justified in light of the low refrigerant losses that occur during the use phase (0.3% per year; 4.5% throughout the entire use phase); these losses do not substantiate use of lower values for the residual charge level.

The recovery factor is 73.3%, which is slightly above the range given in IPCC (2006a): Vol. 3, Table 7.9), 0 to 70%. The higher recovery factor has been brought about by legislation (the Electrical and Electronic Equipment Act - Elektrogesetz) (ElektroG, 2015) governing the disposal of household appliances.

In this area as well, the 2006 IPCC Guidelines (IPCC, 2006a) provide no specifications. All of the values used for the calculation are thus country-specific (cf. Table 193). The emissions from units in service are estimated to be 0.3%. The average service life is 15 years. As is the case for household refrigeration appliances, the residual charge with respect to the initial charge is 95.5%. The recovery factor is estimated to range from 53% (2012) to 65% (as of 2020).

Activity data

The figure of 1% for annual new additions of household refrigerators and freezers is an estimate of leading refrigerator manufacturers.

Based on information provided by a leading manufacturer of ice cream machines, the number of ice cream machines in Germany in 2016 was estimated to be 1.5% of the total number of households. The annual new additions are at a constant level of 6.7% (Warncke et al., 2018).

4.7.1.2.3 Industrial refrigeration (2.F.1.c)

The "industrial refrigeration" sector refers to industrial refrigeration for production of products - mostly food and drink - that are refrigerated or frozen. As in commercial refrigeration, refrigeration equipment is not usually standardised but individually adapted, meaning that a refrigerant model must be used to calculate emissions.

Use of fluorine-based refrigerants has not yet become standard practice in industry, especially the food industry. In addition, natural refrigerants, primarily ammonia (NH3), are used much more frequently in this sector than they are in other sectors. Fluorine-based refrigerants R-404A, HFC-134a, R-407C, R-507A and R-422D are used in industrial refrigeration as a substitute refrigerant for converted HCFC-22 systems. HFC-23 und PFC-116 are also used in low-temperature systems, while the refrigerant HFC-227ea is used in air conditioning systems for cranes and in high-temperature heat pumps.

Use of fluorine-based refrigerants began in Germany in 1993. Disposal emissions began occurring in 2002 due to the conversion of CFC-12 and HCFC-22 systems.

The following refrigerant model is used for industrial refrigeration:

- The refrigerant stocks serve as the central point of reference for the model. It is broken down into twelve major industrial refrigeration sectors: beer breweries, wine production, meat production, dairies, cold storage facilities, chocolate production, production of frozen foods and of juices, skating rinks, milk refrigeration in the agricultural sector, other industry (80% chemical industry) and hermetically sealed appliances in manufacturing. The basis for calculation of the refrigerant stocks consists of the quantities of produced goods, which are updated annually from publicly accessible merchandise statistics.
- In the three smaller sectors of industrial refrigeration, air conditioning for cranes, high-temperature heat pumps and low-temperature refrigeration with HFC-23 (primarily in the plastics industry) and R-508A/B, the annual new additions are used as the starting value to calculate stocks and all emissions.
- Conversion to the installed cooling capacity for cooling goods and products in the twelve major sectors is based on the relevant production quantities. The key factors required for that conversion, "installed cooling capacity per units of annual goods production", were determined empirically on the basis of the technical literature.
- The refrigerant quantities required for the resulting cooling capacity are estimated on the basis of refrigerant use rates for plus and minus refrigeration and for direct and indirect refrigeration. The refrigerant use rates were also determined by a review of the literature, including Clodic and Barrault (2011) and Clodic et al. (2012). They range from 2 kg/kW for indirect plus refrigeration to 8.8 kg/kW for direct minus refrigeration. The typical charges per installed unit of cooling capacity for the twelve sectors are calculated by combining these values with the applicable sector-specific weightings for the four basic forms of refrigeration.

- Foreign trade with locally installed refrigeration systems plays a negligible role, and thus annual HFC consumption for new systems is the same as new HFC additions in new systems.
- The refrigerant stocks also provide the basis for calculating the quantity for disposal. For each sector, that quantity is calculated by dividing the stocks by the service life of the systems. For most sectors, the applicable service life is 30 years. For dairy farms and skating rinks it is 20 years, and for plug-in appliances, air conditioners in cranes, high-temperature heat pumps and low-temperature applications, it is 10 years.
- The percentage shares for the types of refrigerants that are used, which vary over time for stocks, new additions and quantities for disposal, are derived for each sector by way of a static calculation model (Schwarz et al., 2012).
- Replacement of CFCs and HCFCs in old systems is considered separately.
- The production emissions and emissions from units in service are calculated with Equation 8 and Equation 9.
- Emissions from units disposal are calculated with Equation 11. The nominal quantity for disposal is identical with the initial fill quantity. The effective charge at the end of a device's service life is 85% of the nominal charge for all sectors except plug-in appliances, for which it is higher at 90%.

Emission factors

The emission factors on which the emissions data are based are listed in Table 193.

The emission factors used are the result of surveys of experts and literature evaluations.

As a rule, charging of industrial refrigeration systems only produces small quantities of emissions. In Vol. 3, Table 7.9, the 2006 IPCC Guidelines (IPCC, 2006a) state *initial emission* values of 0.5 to 3% for the initial charge quantity. The country-specific $EF_{production}$ for the sectoral application areas is 1%, while it is 0.5% for plug-in appliances. The EFs thus lie within the lower part of the range given by the Guidelines.

In all sectors except hermetically sealed appliances, ongoing HFC emissions from industrial refrigeration systems have continuously decreased from 8.8% in 1993 to 4.55% as of 2020, as refrigeration systems are becoming increasingly compact due to national and European legal regulations. These emissions now lie within the lower bands of the range, or even slightly below the 7 to 25% range provided in the 2006 IPCC Guidelines in Vol. 3, Table 7.9. For plug-in appliances, the decrease has been comparable to that seen in commercial refrigeration: from 1.4% in 1994 to 1% as of 2009.

The average applicable service life prior to disposal is as follows: 10 years (plug-in individual units, air conditioners in cranes, high-temperature heat pumps, low-temperature applications and plastics industry); 20 years (dairy operations, skating rinks); and 30 years (food industry, cold storage systems, chemical industry). Except for the 10-year service life for certain application areas, the service life used is within the range of 15 to 30 years given by the 2006 IPCC Guidelines (IPCC (2006a): Vol. 3, Table 7.9).

The residual charges in the devices and systems are 90% (individual units) and 8 % (sectoral application areas) at the end of their service life and with respect to the initial charge level. The 2006 IPCC Guidelines IPCC (IPCC (2006a): Vol. 3, Table 7.9) give values of 50 to 100% for industrial refrigeration systems. Consequently, all of the values used are within the range given in the 2006 IPCC Guidelines.

The recovery factors have continuously increased, meaning that the losses during disposal in relation to initial charge/residual charge have decreased over the years. For plug-in individual units, the recovery factor was 33.7% in 2004 and 60% as of 2020. For refrigeration systems of sectoral application areas, the recovery factor was 45% in 2002 and 80% as of 2020. As a result, the recovery factors used are within the range given in the 2006 IPCC Guidelines (IPCC (2006a): Vol. 3, Table 7.9), 0 to 90%.

Activity data

Numerous time series for food production quantities are found in statistics of the Federal Ministry of Agriculture, Food and Regional Identity (BMLEH) and the Federal Statistical Office (DESTATIS). In addition, data are available from industrial associations such as the German association of cold storage facilities and cold chain logistics companies (VDKL), the Association of the German Fruit Juice Industry (VdF) or the Association of the German Confectionary Industry (BDSI), as well as from specialised institutes, such as the German Frozen Food Institute (dti) and the German Wine Institute (DWI).

The unit number figures for plug-in appliances were taken from a study by the German Engineering Federation VDMA (2011) and statements provided by industry experts.

The annual new additions of HFC-227ea and HFC-23 (air conditioning in cranes, high-temperature heat pumps and low-temperature cooling) are obtained from the annual national survey conducted pursuant to the Environmental Statistics Act (Umweltstatistikgesetz) (UStatG, 2005).

The "installed cooling capacity per units of annual goods production" indices and the refrigerant use rates for plus and minus cooling and for direct and indirect cooling were determined by information provided in the relevant technical literature.

4.7.1.2.4 Transport refrigeration (refrigerated vehicles and containers) (2.F.1.d)

HFCs have been used as refrigerants in refrigerated vehicles since 1993. Today, HFC-134a, along with the refrigerant mixtures R-404A and R-410A, are most commonly used. Since 2015, R-452A has also been used frequently. The sizes and refrigerant charges of refrigeration systems vary according to the load volumes of the refrigerated vehicles.

Refrigerated containers are used primarily for transports of perishable goods by ocean-going ships. Since their emissions take place primarily in international waters, their refrigerant emissions are divided in each case in accordance with the relevant country's share of world trade. Germany is assigned 10% of global emissions from refrigerated containers. Since 1993, the most commonly used refrigerant has been HFC-134a. R-404A has also been used since 1997. The refrigerant mixtures R-452A and R-513A have been increasingly used since 2018. HFO-1234yf (which is not subject to reporting obligations) and carbon dioxide (an alternative, halogen-free refrigerant) (R-744) have been used since 2022.

The following refrigerant model is applied to refrigerated vehicles (Warncke et al., 2018):

- Refrigerated vehicles are divided into five weight-based size classes: Vans <3.5 t, vans weighing 3.5-7.5 t, trucks weighing 7.5-12 t, trucks >12 t and trailer >26 t gross vehicle weight.
- Refrigerant types, and specific refrigerant charge amounts, are assigned to the various size classes. Each refrigerant is also assigned a percentage share of each size class.
- For a long period, the refrigerant R-404A predominated in the class of trailers >26 t gross vehicle weight, with annual shares of 95% (1993-1994) and 85% (1995-2014). As of 2018,

R-404A's share has fallen to zero. R-452A has been used increasingly since 2015 and, since 2017, has even been dominating the market. In 2015, that refrigerant's share amounted to 13%, and by 2024 it had already reached 90%. In addition, HFC-134a (5%) was also used in new trailers from 1993 to 2022, and R-410A (10%) has been used since 1995.

- For trucks with a gross vehicle weight >12 t, the shares for R-404A were 90% (1993-1994) and 80% (1995-2014). Beginning in 2015, that refrigerant's share decreased continuously until it reached zero in 2019. The HFC-134a share amounted to 10% from 1993 to 2022, and has been at zero since 2024. As of 1995, the R-410A share was 10%. R-452A has been used increasingly since 2015, and since 2018 it has been the most frequently used refrigerant in this size class. Its share in 2024 amounted to 90%.
- Since 1993, R-404A and HFC-134a have been used in trucks with 7.5-12 t gross vehicle weight. The HFC-134a share amounted to 30% from 1993 to 2022, and has been at zero since 2024. Between 1993 and 1994, the share of R404A was 70% before dropping to 60% from 1995 to 2014. As of 2015 it continued to drop, reaching zero in 2019. As of 1995, R-410A was also used and had a share of 10%. In 2015, the share for R-452A still amounted to 1%. It then increased continuously until 2024, when it reached 90%.
- Since 1993, 70% R-404A and 30% HFC-134a have been used in vans with 3.5-7.5 t total weight. In 2018, R-404A's share was only 15% and its use was discontinued completely in 2019. In 2023, the share for HFC-134a dropped to 15% and then to 5% in 2024. As of 2018, R-452A was used instead; its share in 2024 was 95%.
- In vans with a gross vehicle weight of less than 3.5 t, only HFC-134a was used in the period 1993 to 2005. From 2006 to 2017, the refrigerant R-404A was used in 70% of all vans, while HFC-134a was used in the remaining 30%. Since 2018, the refrigerant R-452A has also been used. Its share had already reached 85% in 2024. On the other hand, R-404A's share decreased to zero in 2019.
- The number of newly licensed refrigerated vehicles and domestically charged refrigerated vehicles (broken down by refrigerant) are determined for each year.
- The production emissions are calculated using Equation 8 on the basis of the new consumption required for charging domestically produced refrigerated vehicles.
- The annual new additions of refrigerants result from the numbers of newly licensed refrigerated vehicles and the above assumptions.
- From 1996 to 1999, HFCs were substituted for CFC-12 in a certain number of old systems. These amounts have to be included in the annual new additions.
- The year-end final stocks are obtained by aggregating the annual HFC new additions since 1993 and then subtracting the removals from disposal.
- Equation 9 is used to calculate annual HFC emissions on the basis of final stocks.
- Disposal emissions occurred in connection with refrigerated vehicles for the first time in 2003. These are calculated using Equation 11. The nominal quantity for disposal is identical to the new additions 10 years earlier (or 7 years earlier in the case of converted CFC-12 systems). The effective charge level at the end of a system's service life amounts to 87.5% of the nominal charge level.

- HFO-1234yf emissions from refrigerant mixture R-452A are not subject to reporting obligations, but are voluntarily reported as "additional greenhouse gases" pursuant to the recommendations of the 2014 UNFCCC Reporting Guidelines (FCCC/CP/2013/10/Add.3, Decision 24/CP.19). These emissions are aggregated with other emissions not subject to reporting obligations and listed in Chapter 4.9.3. The CRT tables do not contain any data on emissions that are voluntarily reported.

For refrigerated containers, the following refrigerant model is used:

- The number of refrigerated containers produced worldwide is determined for each year.
- The worldwide HFC additions for refrigerated containers are determined on the basis of annual unit figures from global production, in combination with the relevant charges and charge percentages for the various relevant refrigerants.
- From 1993 to 1995, HFC-134a was increasingly used, in addition to HCFC-22, in refrigerated containers. In 1996, HFC-134a had a 100% share of refrigerants in new refrigerated containers. Starting in 1997, the refrigerant R-404A was then also used. Its share of refrigerants ranged from 10 to 20%. Since 2018, the refrigeration units of refrigerated containers have also been charged with the refrigerants R-452A and R-513A. However, their 2023 shares of 7% and 15% were still small. The shares of HFO-1234yf, which has been used since 2022, stood at 7.5% in 2024, while those of refrigerated containers using carbon dioxide (R-744) as a halogen-free alternative were 4%.
- The average charges in refrigerated containers depend on the refrigerants used. They cover the following range: 4 kg (R-452A), 4.5kg (R-513A, HFO-1234yf and R-744), 5kg (HFC-134a from 2012 and R-404A) to 6 kg (HFC-134a used in the years 1993 to 2011).
- Germany's HFC additions are determined from worldwide additions in accordance with Germany's 10% share of global trade.
- Since refrigerated containers are produced only outside of Germany, no emissions from charging occur in Germany.
- The year-end final stocks are obtained by aggregating the annual HFC new additions since 1993 and then subtracting the removals from disposal.
- Emissions from units in service are calculated with Equation 9.
- With an average service life of 14 years, disposal emissions from refrigerated containers first occurred in 2007. These are calculated using Equation 11.
- Pursuant to the recommendations of the 2014 UNFCCC Reporting Guidelines ((UNFCCC, 2014), FCCC/CP/2013/10/Add.3, Decision 24/CP.19), emissions of HFO-1234yf are not subject to reporting obligations but are voluntarily reported under "additional greenhouse gases". These emissions are aggregated with other emissions not subject to reporting obligations and listed in Chapter 4.9.3. The CRT tables do not contain any data on emissions that are voluntarily reported.

Emission factors

The emission factors on which the emissions data are based are listed in Table 193.

The emission factors used are the result of surveys of experts and literature evaluations.

Charging refrigerated vehicles generally only produces only small quantities of emissions. The losses of refrigerant during charging are estimated at 5 grams per system, regardless of system size. That is a standard value for hose losses during on-site charging. Emission factors between 0.06 and 0.25% result from calculating emissions from charging in relation to new consumption. For "initial emission" in transport refrigeration, Vol. 3, Table 7.9 of the 2006 IPCC Guidelines give figures of 0.2 to 1% of the initial charge. As a result, the great majority of the values used lie below the range recommended in the 2006 IPCC Guidelines (IPCC, 2006a).

Since there is no domestic production of refrigerated containers, there are no emissions from charging these containers.

The ongoing HFC emissions from new refrigeration units of refrigerated vehicles for the three size classes - trucks with 7.5-12 t, trucks >12 t and trailers >26 t (in each case, gross vehicle weight) - are estimated to be 15%. For vans in the weight classes (gross total weight) <3.5 t and 3.5-7.5 t, the emission factor is 30%. For old units in refrigerated vehicles (converted CFC-12 systems), the emission factor for emissions from units in service is estimated to average 25% for all unit size classes. The emission factors for refrigerated vehicles are therefore at the lower end of the 15 to 50% range given in Vol. 3, Table 7.9 of the 2006 IPCC Guidelines.

For refrigeration units of refrigerated containers, the emission factor for emissions from units in service remained at a constant 10% from 1993 to 2011. After that, it decreased continuously until reaching 5% (cf. Table 193) in 2020, which reflects the increasing degree of care being taken in managing and handling HFC refrigerants. All of the emission factors used are below the 15 to 50% range given in Vol. 3, Table 7.9 of the 2006 IPCC Guidelines. The comparatively lower country-specific emission factor for emissions from units in service aligns with information provided by leading manufacturers of refrigerated containers and industry experts (Warncke & Gschrey, 2021). The discrepancy with the IPCC Guidelines in this case can be justified in that, in transport refrigeration, it is necessary to differentiate between refrigerated vehicles and refrigerated containers: because refrigerated containers tend to cover far lower distances than refrigerated vehicles do, the emissions associated with them are also lower. This difference in emissions behaviour is not reflected in the default values of the 2006 IPCC Guidelines, which only provide a value range for transport refrigeration in general.

The service life of old systems in refrigerated vehicles is 7 years, while that of new systems in refrigerated vehicles is 10 years. The average service life for refrigerated containers prior to disposal is 14 years. The service life used – with the exception of those for old systems in refrigerated vehicles – is therefore within the range of 6 to 9 years specified in the 2006 IPCC Guidelines (IPCC (2006a): Vol. 3, Table 7.9).

The residual charges in refrigerated vehicles and refrigerated containers with respect to initial charge are an average of 87.5%. The values provided in the 2006 IPCC Guidelines (IPCC (2006a): Vol. 3, Table 7.9) for transport refrigeration systems range from 0 to 50%. The values used are all higher than those specified in the Guidelines since it must be assumed that transport refrigeration systems that only have 50% of their initial charges left no longer function properly and would thus compromise the continuity of the cold chain. This would violate German law.

The recovery factor for refrigerated vehicles and refrigerated containers is 65.7%. The recovery factors used are thus within the 0 to 70% range specified in Vol. 3, Table 7.9 of the 2006 IPCC Guidelines, which makes them default values.

Activity data

Until 2008 and as of 2011, the registration figures for refrigerated vehicles, broken down by weight class, were taken from statistical reports of the Federal Motor Transport Authority

(KBA). Since the Federal Motor Transport Authority did not carry out separate surveys of refrigerated vehicles in 2009 and 2010, the numbers of new refrigerated vehicles for those two years were extrapolated from the registration figures for commercial vehicles. Charges in refrigeration systems, information on refrigerants used, and details on CFC-12 replacement were provided by experts of the leading providers of refrigeration units for refrigerated vehicles.

New additions of refrigerants in the area of refrigerated containers are determined using a refrigerant model based on the numbers of refrigerated containers produced worldwide, with the numbers provided by the "World Cargo News" information service for the industry. A 10% share is allocated to Germany. The charges and refrigerant fractions were determined on the basis of surveys of experts carried out by leading manufacturers of refrigerated containers.

4.7.1.2.5 Mobile air conditioning systems (2.F.1.e)

The mobile air conditioning systems category includes air conditioning systems in/on passenger cars, trucks and commercial vehicles, buses, agricultural machinery (tractors, combines, field choppers), railway vehicles, ships, aircraft and helicopters. Hydrofluorocarbons (HFCs) have been used in mobile air conditioning systems since 1991. HFC-134a is commonly used as a refrigerant. Since 2012, uHFKW-1234yf has also been used in car air conditioning systems, and since 2016 in small commercial vehicles in the EC vehicle class N1. Cars produced in Germany since 2020 have only been fitted with air conditioning systems that use HFO-1234yf.

The time series show a significant increase in HFC-134a emissions from 1995 to 2015. This increase, which has occurred in spite of decreases in charge quantities, is a direct result of increased use of mobile air conditioning systems in vehicles. Thereafter, the emissions decreased as HFC-134a was replaced in new systems by HFO-1234yf, which is not subject to reporting obligations, in turn leading to reductions of HFC-134a stocks in service.

For passenger cars, the following refrigerant model is applied:

- Annual production figures for German passenger car production are available from the publicly accessible statistics of the German Association of the Automotive Industry (VDA). These figures provide the database for calculating consumption data for charging.
- The annual percentages of vehicles equipped with air conditioning systems are obtained from extensive surveys of manufacturers since they are not provided by any official or publicly available statistics. This also applies to the average refrigerant (charge) quantities, which are determined from the specifications for each vehicle type and the information provided by industry experts.
- The consumption quantity for charging is calculated by multiplying the number of units produced by the annual air conditioning rate and the average refrigerant charging quantities.
- Production emissions are calculated using Equation 8.
- The annual numbers of new vehicle registrations as recorded by the Federal Motor Transport Authority (KBA) are not used in determining annual new additions and the refrigerant stocks in car air conditioning systems since it is not possible to quantitatively estimate early departures of vehicles (i.e. prior to vehicles reaching the end of their average service life) from the registration cohorts that form the basic fleet. Instead, the refrigerant stocks are determined on the basis of the numbers of registered vehicles on the road, divided according to age since the initial registration. Relevant official data up to 2021 are available from the statistical communications (Statistische Mitteilung) (FZ 15) of the Federal Motor

Transport Authority (KBA) (Kraftfahrtbundesamt, Versch. Jahrgänge) for all required years, i.e. as of 1991. They make it possible to determine, on a continuous, chronological basis, the numbers of vehicles in the total fleet, divided by registration cohort. Since 2022, the Federal Motor Transport Authority has provided the German Environment Agency with an annual special evaluation containing the necessary registration figures.

- The annual percentages of newly registered cars equipped with air conditioning systems are also obtained from extensive surveys of manufacturers. These numbers are not identical with the corresponding percentages of passenger cars produced in Germany and equipped with air conditioning systems, since cars produced abroad also have to be taken into account. The necessary percentages are thus also obtained by surveying foreign companies. This also applies to strategies for determining the average per-unit refrigerant (charge) quantities in newly registered vehicles.
- The refrigerant stocks in each registration cohort are calculated by multiplying the specific charges for the year in question by the numbers of passenger cars equipped with air conditioners. The total stocks correspond to the sum of the refrigerant stocks for all registration cohorts since 1991.
- Emissions from units in service are calculated with Equation 9.
- Replacement of CFCs in old systems and air conditioner retrofits in older vehicles are considered separately.
- When determining quantities for disposal, only the old vehicles are taken into account that are handled each year by German dismantling facilities. These figures are obtained from the official data on numbers of old vehicles (Statistisches Bundesamt, jährlich - FS 19, R. 1). The refrigerant model does not take account of exports of used cars and old cars since the relevant disposal emissions occur in the destination countries and double-counting has to be prevented.
- An average service life of 15 years is assumed for dismantled vehicles. The total quantity of refrigerants that are disposed of is determined by multiplying the number of dismantled vehicles by the percentage of vehicles equipped with air conditioning systems and the average per-unit refrigerant (charge) quantity for the relevant new registration cohort of 15 years earlier.
- Disposal emissions occurred for the first time in 2002 and are calculated with Equation 11.
- Pursuant to the recommendations of the 2014 UNFCCC Reporting Guidelines ((UNFCCC, 2014), FCCC/CP/2013/10/Add.3, Decision 24/CP.19), Germany voluntarily reports emissions of HFO-1234yf not subject to reporting obligations under “additional greenhouse gases”. The HFO-1234yf emissions are aggregated with other emissions not subject to reporting obligations and listed in Chapter 4.9.3. The CRT tables do not contain any data on emissions that are voluntarily reported.

The refrigerant models for commercial vehicles and buses are structured similarly to the model for passenger cars. A detailed description of the methods is provided in (Schwarz et al., 2012).

The refrigerant model used for agricultural machinery, ships and railway vehicles is as follows:

- For ships and railway vehicles, refrigerant emissions are determined on the basis of annual new installations of air conditioning systems in ships (outset data: newly built ships for the

German fleet) and in railway vehicles (outset data: new procurements by German Railways (DB) and private companies) as well as the relevant charges.

- The refrigerant model for air conditioning systems in agricultural machinery is based on the number of new vehicle registrations for each year, the average percentage of vehicles equipped with air conditioning systems and the average charges in the various types of agricultural machinery concerned.
- The annual new additions of HFC-134a, as well as the final stocks, are determined for each area from the relevant previous set of data.
- Emissions from stocks are obtained as per Equation 9 by multiplying the final stocks for each area by the relevant EF_{use}.
- Domestic consumption of HFC-134a for production of mobile air conditioning systems is determined on the basis of unit number production data. Production emissions are calculated with Equation 8.
- Emissions from units disposal are calculated with Equation 11. In the agricultural machinery category, these emissions occurred for the first time in 2004 after their average service life of 10 years. In the railway vehicles category, disposal emissions occurred for the first time in 2017 after their average service life of 25 years.
- For ships, disposal theoretically begins in 2022 after their 25-year service life. However, proper disposal of ships in Germany was not possible up to and including 2024 as there was no ship breaking yard available with the required authorisation. Consequently, the ships were sent abroad for dismantling. The refrigerant model does not take account of these exported end-of-life ships since the relevant disposal emissions occur in the destination countries and double-counting has to be prevented.

For aircraft and helicopters, the following refrigerant model is applied:

- The refrigerant stocks in air conditioning systems of medium-sized, multi-engine aircraft (registration class I) and helicopters (registration class H), and in the on-board refrigeration systems of passenger aircraft in registration classes A, B and C, are determined using the relevant numbers of aircraft and helicopters registered in Germany. Official figures are available for all required years, i.e. as of 1993, in the statistics published annually by the German Federal Aviation Office (Luftfahrt-Bundesamt) (Luftfahrt-Bundesamt, Versch. Jahrgänge, Bestand an Luftfahrzeugen).
- In passenger aircraft of registration classes A, B and C, an average of three HFC-134a chillers, with per-unit charges of 500 grams, are used for on-board refrigeration during flights lasting longer than four hours.
- According to manufacturers, in aircraft of registration classes I and in helicopters, an average of 2 kilogrammes of HFC-134a are used per aircraft/helicopter for air conditioning and to cool instruments.
- The refrigerant stocks are calculated by multiplying the aircraft-specific charge by the number of registered air conditioned/refrigerated aircraft involved.
- Emissions from units in service are calculated with Equation 9.

- To date, no disposal emissions have occurred due to the long service life of the aircraft involved.

Emission factors

The emission factors on which the emissions data are based are listed in Table 193.

The emission factors used have been on the basis of the relevant literature (e.g Schwarz and Harnisch (2003); Siegl et al. (2002); Clodic and Barrault (2011); Clodic et al. (2012); (Schwarz et al., 2012), Hafner et al. (2019), (Wang et al., 2022)), measurements (passenger cars), evaluations of service centre records, extensive surveys of experts, car service centres and dismantling facilities. In addition to regular emissions during operation, emissions also arise as a result of accidents and other external influences.

Charging mobile air conditioning systems generally only produces small quantities of emissions. For passenger cars, the refrigerant losses upon charging are estimated as 3 grammes per system. For commercial vehicles and agricultural machinery, they are 5 grammes per system, and for buses they are considered to be 50 grammes per system. These figures are standard values for hose leakage in connection with on-site charging. Setting the emissions from charging in relation to new consumption results in the following emission factors: 0.25-0.63% (passenger cars), 0.36-0.66% (commercial vehicles), 0.28-0.35% (agricultural machinery) and 0.42-0.45% (buses). These ranges are the result of annual variations in initial charges. For railway vehicles, the emission factor for charging is 0.5%, while for ships it is 1%. Vol. 3, Table 7.9 of the 2006 IPCC Guidelines gives figures of 0.2 to 0.5% of the initial charge for "initial emission" for mobile air conditioning systems (passenger cars, commercial vehicles, buses and railway vehicles). Most of the values used for the vehicles described in the 2006 IPCC Guidelines (IPCC, 2006a) thus lie within the relevant ranges proposed by the Guidelines. The 2006 IPCC Guidelines provide no values for agricultural machinery, ships and aircraft.

Current HFC emissions are estimated at 10% for passenger cars, 15% for commercial vehicles and buses, 6% for railway vehicles, 15% for tractors and 25% for combines and field choppers (agricultural machinery); 10% for passenger ships on inland waterways, 20% for ocean liners, 35% for ocean-going cargo ships, and 5% for aircraft. The EF_{use} used thus lie largely within the 10 to 20% range proposed in Vol. 3, Table 7.9 of the 2006 IPCC Guidelines (IPCC, 2006a) for air conditioning systems in passenger cars, commercial vehicles, buses and railway vehicles. No proposals have been made for agricultural machinery, ships and aircraft.

The average service life prior to disposal is 15 years (passenger cars, commercial vehicles, buses), 10 years (agricultural machinery) and 25 years (railway vehicles). With the exception of those for systems in railway vehicles on ships, the service life is within the range of 9 to 16 years specified in the 2006 IPCC Guidelines for systems in passenger cars, commercial vehicles, buses and railway vehicles.

The residual charges remaining in air conditioning systems with respect to initial charge average 34% (passenger cars, commercial vehicles, buses, agricultural machinery). They average 87.5% for railway vehicles since the maintenance intervals are kept shorter in the interest of passenger comfort. The relevant values provided in the 2006 IPCC Guidelines (IPCC (2006a): Vol. 3, Table 7.9) range from 0 to 50%. All of the values used, except for the value for residual charges in railway vehicles, are default values.

As a result of the disposal and recycling of end-of-life vehicles as required by the End-of-Life Vehicles Ordinance (Altfahrzeug-Verordnung) since 2002, the recovery factors for passenger cars and commercial vehicles have been increasing continuously such that losses occurring upon disposal with respect to initial charge or residual charge have been decreasing over time. For

passenger cars and commercial vehicles, the recovery factors amounted to 38% in 2000 and 50% as of 2020. The estimated recovery factors are as follows: 38% for buses, 11.7% for agricultural machinery and 75.6% (2017) to 80% (as of 2020) for railway vehicles. The recovery factors used for passenger cars, commercial vehicles and buses are therefore within the 0 to 50% range in Vol. 3, Table 7.9 of the 2006 IPCC Guidelines (IPCC (2006a)). The country-specific value for railway vehicles is considerably higher than the default value because far greater care is taken during disposal. The 2006 IPCC Guidelines provide no proposals for agricultural machinery.

Activity data

The Federal Motor Transport Authority (KBA) reports numbers of registered cars, commercial vehicles and buses, and new registrations of agricultural tractors. The number of registered aircraft has been obtained from the German Federal Aviation Office (Luftfahrt-Bundesamt). The sources for production figures include the German Association of the Automotive Industry (VDA), the German Engineering Federation (VDMA), other statistics and surveys of manufacturers.

The charges in car air conditioners and the annual percentages of cars equipped with air conditioning systems are determined by direct surveys of car companies. For systems in other types of vehicles, the charges and percentages are obtained by combining official statistics, information from surveys of manufacturers and estimates by experts.

4.7.1.2.6 Stationary air conditioning systems (2.F.1.f)

This section on stationary air conditioning systems includes room air conditioners, chillers for air conditioning of buildings and industrial refrigeration of liquids, heat-pump systems, heat pump laundry dryers and commercial dishwashers with heat pump systems.

4.7.1.2.6.1 Room air conditioners

Room air conditioners are used to cool the interiors of individual rooms, entire floors or small-to-medium-sized buildings. Their performance levels tend to be lower than those of large air conditioning systems. The following refrigerants are in use: HFC mixture R-407C since 1998, mixture R-407C since 2003, and HFC-32 since 2014. Since 1997, R-290 has also been used in mobile room air conditioners as a halogen-free alternative.

There is no domestic production of room air conditioners. Room air conditioners are normally already filled when imported. Installation of factory-manufactured single-split, multi-split and VRF-multi-split units involves installation of refrigerant lines, and these have to be charged on site, however. This is not necessary for portable, plug-in room air conditioners.

Under the EU F Gas Regulation (EU, 2024b), imports of mobile room air conditioners that use refrigerants with GWPs of 150 or higher are prohibited as of 2020. Existing stocks of imported units with R-407C and R-410A were all sold off in 2020 and 2021. Now, since 2022, only units charged with propane (R-290), a halogen-free refrigerant, are sold on the German market. From 2027, the ban on placement on the market will also extend to monoblock air conditioners with a cooling capacity of up to 50 kW using refrigerants with a GWP of 150 or more (EU, 2024b). The import of mono-split systems with charges of up to 3 kg containing refrigerants with GWPs of 750 or higher is also prohibited from 2025. The EU F Gas Regulation (EU, 2024b) also provides for bans on placement on the market of other split air conditioners which have a major impact on the refrigerants that will be used in these appliances. There is already a clear trend towards the use of HFC-32. In the case of single split appliances, only appliances using HFC-32 have come onto the German market since 2021.

The following refrigerant model is used for room air conditioners:

- Room air conditioners are divided into four categories. The numbers of new systems produced each year in each category are determined by manufacturer surveys and the data published in international publications. The categories are: small mobile units, single-split units, multi-split units with constant-volume refrigerant flow and VRF-multi-split systems with variable-volume refrigerant flow.
- For each category, the charges and the percentage shares for the various types of refrigerants used are determined according to the numbers of new systems sold each year. The annual new consumption, which is identical to annual new additions of refrigerants, is obtained from sales statistics and the above assumptions. The year-end final stocks are obtained by aggregating the annual HFC new additions since 1993 and then subtracting the removals during disposal.
- No production emissions occur. Charging losses do occur, however, in installation of stationary single-split units, multi-split units and VRF multi-split systems. Surveys of experts have indicated that the losses during installation are 5 g per unit (10% of the initial charge) for single-split units, 20 g per unit (1% of the initial charge) for multi-split units and 45 g per system (1% of the initial charge) for VRF multi-split systems.
- Emissions from units in service are calculated with Equation 9.
- Disposal emissions occurred for the first time in 2008 after the 10-year average service life and is calculated using Equation 11.

Emission factors

The emission factors used were obtained by surveying experts and evaluating the literature; they are listed in Table 193.

The country-specific $EF_{production}$ = 1% for multi-split units and VRF multi-split units lies within the value range of 0.2 to 1% provided in Vol. 3, Table 7.9 of the 2006 IPCC Guidelines. For single-split units, the emission factor is 10%, which corresponds to a loss of 5 g of refrigerant per 50 g charge and is above the range specified in the Guidelines.

For all devices, the emission factors for use decrease continually throughout the time series, beginning with the first year of use (cf. Table 193). For mobile room air conditioners, they range from 3.4% (1999) to 2.5% (as of 2010); for single-split units, they range from 6.9% (1998) to 5% (as of 2010); for multi-split units, they range from 7.9% (1998) to 4.2% (as of 2020); and for VRF multi-split units, they range from 8.1% (2003) to 4.9% (as of 2020). The emission factors for use are therefore within the 1 to 10% range in Vol. 3, Table 7.9 of the 2006 IPCC Guidelines.

The estimated system service life of 10 years is therefore in the lower band of the range of 10 to 20 years specified in the 2006 IPCC Guidelines (Vol. 3, Table 7.9).

The residual charge upon disposal is 75% for mobile room air conditioners and 87.5% for all other types of units. The 2006 IPCC Guidelines (IPCC, 2006a), in Vol.3, Table 7.9, recommend values ranging from 0 to 80%. The residual charge figure used for mobile room air conditioners is thus a default value, while the values used for the other types of units are higher than the range provided in the Guidelines.

The recovery factors have continuously increased, meaning that the losses during disposal in relation to initial charge/residual charge have decreased over the years. For mobile room air conditioners, the recovery factor was 24.2% in 2009 and 40% as of 2020; for single-split units, it

was 37.9% in 2008 and 60% as of 2020; while for multi-split units, it was 62% in 2011 and 80% as of 2020. For VRF multi-split units, it was 72% in 2016 and 80% as of 2020. The recovery factors used are therefore within the range of 0 to 80% in Vol. 3, Table 7.9 of the 2006 IPCC Guidelines (IPCC (2006a)).

Activity data

The numbers of the various types of units and systems sold in Germany are determined on an annual basis by surveying sellers and researching technical publications (JARN, Versch. Jahrgänge).

4.7.1.2.6.2 Chillers

Chillers for air conditioning of buildings and industrial refrigeration of liquids are divided into four performance categories: chillers with a cooling capacity of less than 100 kW, chillers with a cooling capacity of more than 100 kW, chillers with a cooling capacity of more than 900 kW and turbo compressor systems (with cooling capacities above 1,500 kW). The types of compressors used in chillers include piston, scroll and screw compressors.

HFC-134a has been used in turbo compressor systems since 1993. HFO-1234ze, which is not subject to reporting obligations, has been used since 2013, while HCFC-1233zd, which is also not subject to reporting obligations, has been used since 2017. Units with the refrigerant mixture R-513A have been sold since 2018, while units with R-515B have been sold since 2022. In the years 1995 through 1999, HFC-134a was also used for conversions of CFC-12 turbo compressor systems. The most important refrigerants used in chillers include HFC-134a (used as of 1993), R-407C (as of 1998) and R-410A (as of 2004). HFC-1234ze, which is not subject to reporting obligations, has also been used since 2015, and the refrigerant mixture R-513A has been used since 2017. HFC-32 and R-454B have been used since 2021, while R-515B has been used since 2022 and R-454B has been used since 2023.

The following refrigerant model is applied to chillers (Warncke & Gschrey, 2024):

- Chillers are divided into four categories. The number of new systems in each of the following categories is determined each year by surveying experts and drawing on international sales statistics: chillers <100 kW cooling capacity; chillers >100 kW cooling capacity; chillers >900 kW cooling capacity; and turbo compressor systems in the performance range above 1,500 kW.
- For each category, the average charge, and the percentage shares for the various types of refrigerants used, are determined. The charges are 10 kg for chillers <100 kW, 95 kg for chillers >100 kW, 300 kg for chillers >900 kW, and 630 kg for turbo compressor systems.
- Data on annual HFC additions to domestic stocks are obtained from the numbers of new systems, in connection with the above assumptions. In this regard, consumption for CFC replacements in old turbo compressor systems also has to be taken into account.
- The year-end refrigerant stocks can be calculated from the previous-year stocks, the new additions and the removals.
- Production emissions are calculated by multiplying the quantities consumed in charging by the $EF_{production}$, pursuant to Equation 8.
- Emissions from units in service are calculated pursuant to Equation 9.

- Disposal emissions occurred for the first time in 2003 (converted HFC systems). They are calculated with Equation 11.
- Emissions of HFO-1234ze and HCFC-1233zd, which are not subject to reporting obligations, from use as individual substances, and of HFO-1234yf and HFO-1234ze from use of the refrigerant mixtures R-454B, R-513A and R-515B, are voluntarily reported as "additional greenhouse gases" pursuant to the recommendations of the 2014 UNFCCC Reporting Guidelines ((UNFCCC, 2014), FCCC/CP/2013/10/Add.3, Decision 24/CP.19). These emissions are aggregated with other emissions not subject to reporting obligations and listed in Chapter 4.9.3. The CRT tables do not contain any data on emissions that are voluntarily reported.

Emission factors

The emission factors used were obtained by surveying experts. They are listed in Table 193.

The loss from charging of 0.5% is within the 0.2 to 1% range in the 2006 IPCC Guidelines ((IPCC, 2006a): Vol. 3, Table 7.9). To take account of the fact that large numbers of chillers are imported as pre-filled units, the actual $EF_{production}$ of 1% is not used.

Ongoing HFC emissions until 2000 are estimated at 6% for all cooling-capacity classes/compressor models, age classes and refrigerant types. Thereafter, the EF_{use} decreases continuously to 2.8% (as of 2020). All of the values used are therefore within the lower band of the 2 to 15% range proposed by the 2006 IPCC Guidelines (IPCC (2006a): Vol. 3, Table 7.9).

The 2006 IPCC Guidelines, in Vol. 3, Table 7.9, specify a service life of 15 to 30 years for liquid chiller systems. The values used in the present case lie within this range: 15 years for chillers and 25 years for turbo compressor systems.

The residual charge upon disposal is 90% for all chiller types. The 2006 IPCC Guidelines, in Vol. 3, Table 7.9 recommend values ranging from 80 to 100%. The residual-charge figures used are thus default values.

The recovery factors have continuously increased as a result of technical progress and greater care taken in handling refrigerants, in turn leading to a constant decrease in losses occurring upon disposal with respect to initial charge/residual charge. The recovery factor for chillers is 65.8% in 2003 and 80% as of 2020, while the factor for turbo compressor systems is 69.5% in 2003 and 80% as of 2020. The recovery factor figures used are therefore within the 0 to 95% range specified in Vol. 3, Table 7.9 of the 2006 IPCC Guidelines.

Activity data

The numbers of new systems are determined annually by experts surveying manufacturers and drawing on international sales statistics (e.g. BSRIA Limited (Versch. Jahrgänge)).

The average charges and the percentage shares for the various types of refrigerants used were determined with the help of an external research contractor in meetings with experts and personal consultations with industry representatives.

4.7.1.2.6.3 Heat-pump systems

Heat pumps use a refrigeration cycle to draw heat from the air, ground or groundwater and make it available for heating or cooling indoor areas or for heating water. Heat pumps that directly use heat from the outdoor environment to warm indoor air fall within the category of room air conditioners.

Since 1995, HFC-134a and the HFC mixtures R-404A and R-407C have been used as refrigerants in heat pumps. R-410A has also been used since 2002, while HFC-32 has also been used since 2011 and the mixture R-454C has been used since 2022. Since 1995, propane (R-290) has been used as a halogen-free alternative in heat pumps for heating, and CO_2 (R-744) has been used since 2018 as a halogen-free alternative in heat pumps for hot process water.

Methodologically, the refrigerant model for heat pumps is structured like the model for room air conditioners (Warncke & Gschrey, 2024):

- Four categories of heat pumps for heating are differentiated: Air – water monobloc; air – water split; ground (groundwater) – water; ground (brine) – water. Heat pumps for pumping hot process water are treated as a fifth category.
- The starting and reference point for calculations consists of the annual numbers of newly installed heat pump units in each of the five categories. These data are published annually by the German heat pump association (BWP). The numbers of newly installed heat pumps for hot process water are also used as production quantities. Up to and including 2021, the quantities of heat pumps produced for heating systems were larger by a factor of 2 than the numbers of newly installed units. As of 2022, the numbers of domestically produced heat pumps for heating systems have been identical with the numbers of newly installed units. On the basis of the data for new additions, the various heat pump types are assigned average HFC charges and percentage shares of the various types of HFCs. The model also includes service life and emissions rate figures.
- Production emissions are calculated by multiplying the quantities consumed in charging by the $EF_{production}$ pursuant to Equation 8, with emissions from units in service calculated pursuant to Equation 9.
- Heat pumps with HFCs have been produced and sold since 1995. Since the units have an average service life of 15 years, emissions from disposal began occurring in 2010. Emissions from units in service are calculated with Equation 11.
- Emissions of HFO-1234yf from use of the refrigerant mixture R-454C, which are not subject to reporting obligations, are voluntarily reported as “additional greenhouse gases” pursuant to the recommendations of the 2014 UNFCCC Reporting Guidelines (FCCC/CP/2013/10/Add.3, Decision 24/CP.19). These emissions are aggregated with other emissions not subject to reporting obligations and listed in Chapter 4.9.3. The CRT tables do not contain any data on emissions that are voluntarily reported.

Emission factors

The emission factors on which the emissions data are based are listed in Table 193.

The emission factors used were obtained by surveying experts.

The charging loss is 0.5%. Consequently, the $EF_{production}$ is within the 0.2 to 1% range specified in Vol. 3, Table 7.9 of the 2006 IPCC Guidelines IPCC (2006a)).

Until and including 2017, the annual HFC emissions for heating system heat pumps are estimated at 2.5%, while the emissions for process water heating heat pumps are estimated at 2%. From 2018, they are only 2% for heating system heat pumps of the following types: air – water split; ground (groundwater) – water; ground (brine) – water; and 1% for air – water monobloc heat pumps. The emission factor for process water heating heat pumps drops to 1.5% The reason is that, according to industry experts, national and European laws have led to more careful handling of HFC refrigerants and thus to lower leakage rates. The EF_{use} used is therefore

within the 1 to 10% range proposed by the 2006 IPCC Guidelines (IPCC (2006a):Vol. 3, Table 7.9).

The average service life prior to disposal is 15 years. The service life used is therefore within the range of 10 to 20 years specified in the 2006 IPCC Guidelines (Vol. 3, Table 7.9).

The residual charges in heat pumps with respect to initial charge average 75%. The relevant values specified in the 2006 IPCC Guidelines (IPCC (2006a): Vol. 3, Table 7.9) range from 0 to 80%. The value used is thus a default value.

The recovery factor for heat pumps has been increasing continuously, also as a result of the greater care taken in handling refrigerants, and thus the losses during disposal, with respect to initial charge/residual charge, have decreased over the years. The recovery factor is 50% in 2010, 65% as of 2020 and 75% as of 2025. All recovery factors used are therefore within the range of 0 to 80% specified in Vol. 3, Table 7.9 of the 2006 IPCC Guidelines (IPCC (2006a)).

Activity data

Each year, the German heat pump association (BWP) publishes the numbers of new heat pumps installed domestically, which serve as the basis for the emissions calculation.

The production/installation ratio used is based on information provided by heat pump producers.

4.7.1.2.6.4 Heat pump clothes dryers

Heat pump clothes dryers with HFC refrigerants have been sold on the German market since 2008. The dryers use HFC-134a as a refrigerant in the heat pump unit. From 2008 to 2021, they were also charged with the refrigerant mixture R-407C. The charges in the units, which are hermetically sealed, range from 220 g to 485 g. In heat pump clothes dryers, use of propane (R-290), a halogen-free alternative, has been increasing sharply since 2015.

From 2008 to 2012, one domestic company produced heat pump clothes dryers charged with the refrigerant HFC-134a. At the end of 2012, that company transferred its production abroad.

The refrigerant model for heat pump clothes dryers is structured similarly to the models for room air conditioners:

- The most important starting values are a) the unit-number figures for domestic sales and domestic production, and b) the split applied to the refrigerants used (the refrigerant-use figures are tied to the domestic sales figures). The total numbers of devices are calculated from the sums of new additions.
- Production emissions are calculated by multiplying the quantities consumed in charging by the $EF_{production}$ pursuant to Equation 8, with emissions from units in service calculated pursuant to Equation 9.
- Heat pump clothes dryers with HFCs have been produced and sold since 2008. Since the units have an average service life of 15 years, emissions from disposal began occurring in 2023. Emissions from units in service are calculated with Equation 11.

Emission factors

The emission factors used are based on information from experts. They are listed in Table 193.

The charging loss is 0.5%. The $EF_{production}$ is country-specific since the 2006 IPCC Guidelines do not cover these appliances.

The ongoing HFC emissions of these hermetically sealed units are estimated at 0.3%. The 2006 IPCC Guidelines provide no specifications in this regard.

The average service life prior to disposal is 15 years. The 2006 IPCC Guidelines provide no information on this.

The residual charges in heat pump clothes dryers with respect to initial charge average 95.5%. The 2006 IPCC Guidelines ((IPCC, 2006a)) provide no values in this regard. The value used is thus also a country-specific value.

The recovery factor was 65% in 2023. It is not possible to compare these figures with those in the 2006 IPCC Guidelines (IPCC, 2006a).

Activity data

Heat pump clothes dryers are a relatively new product for which little statistical data and technical information are available. The refrigerant model is thus based almost exclusively on information provided by manufacturers (Schwarz et al., 2012).

4.7.1.2.6.5 Dishwashers with heat pump systems

In order to use the waste heat from commercial dishwashers in large kitchens, individual models with heat pump functionality have been available on the German market since 2005. The refrigerant HFC-134a has been used since 2005, the refrigerant mixture R-513A since 2020, the refrigerant mixture R-450A since 2021 and HFO-1234yf since 2024. The average charges in refrigerated containers depend on the refrigerants used and range from 0.8 kg (R-450A) to 3 kg (R-513A). Since 2017, carbon dioxide has increasingly been used as a halogen-free alternative refrigerant.

In Germany, there are two producers of commercial dishwashers with heat pump systems. Production of the dishwashers began in 2005 and now serves nearly the entire national market. While the dishwashers themselves are built in Germany, their heat-pump systems are imported, pre-charged, from external suppliers located abroad. When the heat pump systems are fitted to the dishwashers located in Germany, additional charges of between 64 g (R-450A) and 240 g (R-513A) per unit are added.

The national market for commercial dishwashers is quite stable. It has remained at a relatively constant level for a number of years now.

The refrigerant model for dishwashers with heat pumps is structured similarly to the models for room air conditioners (Warncke et al., 2018):

- The most important outset values are the unit-number figures for domestic sales and domestic production. The stocks (pool of relevant devices) are calculated from the sum of new additions, less the removals during disposal.
- Production emissions are calculated by multiplying the quantities consumed in charging by the $EF_{production}$ pursuant to Equation 8, with emissions from units in service calculated pursuant to Equation 9.
- Commercial dishwashers with heat-pump systems have been produced and sold since 2005. Since the units have an average service life of 12 years, emissions from disposal began occurring in 2017. Emissions from units in service are calculated with Equation 11.

Emission factors

The emission factors used are based on information from experts. They are listed in Table 193.

The charging loss is 1%. The $EF_{production}$ is country-specific since the 2006 IPCC Guidelines do not cover these appliances.

The ongoing HFC emissions of dishwashers with a heat pump are estimated to be 0.3%. The 2006 IPCC Guidelines provide no specifications in this regard.

The average service life prior to disposal is 12 years. The 2006 IPCC Guidelines provide no information on this.

The residual charges in dishwashers with respect to initial charge average 95.5%. The 2006 IPCC Guidelines ((IPCC, 2006a)) do not provide any values. The value used is thus also a country-specific value.

As is the case with heat pumps and room air-conditioners, the recovery factor has been increasing continually. In 2017, it was 82% and, as of 2020, it is 25%. It is not possible to compare these figures with those specified in the 2006 IPCC Guidelines (IPCC, 2006a).

Activity data

Very little statistical data and technical information are available for the area of commercial dishwashers with heat-pump systems. The refrigerant model is thus based almost exclusively on information provided by manufacturers (Warncke et al., 2018).

4.7.1.3 Uncertainties and time series consistency (2.F.1 all)

The emission factors are subject to considerable uncertainties. The broad range of emission factors found in the literature (see the refrigerant models) for identical applications is only partly a consequence of technical modifications, of how well systems are sealed or of national differences. To a large extent, it also results from real uncertainties since there are few reliable empirical studies available for such factors (Schwarz, 2007).

As a result of the aforementioned uncertainty in terms of emission factors and given the large number of individual applications (systems) involved, the emissions data are considered to be too imprecise. In order to improve the quality of the data, the data were compared with manufacturers' (substance-oriented) sales data.

Until the 2001 report year, Germany reported only aggregated emissions, covering all sub-source categories. As part of emissions surveys for the years 1999 to 2001 and the emissions survey for report year 2002, the emissions for the report years 1995 to 1998 were reviewed and updated on the basis of new findings on input quantities and emission factors. All data are thus being improved on an ongoing basis. A comprehensive review of the currentness of the refrigerant models, outset data and emission factors used was carried out in 2012. Additional areas of HFC-refrigerant use continue to be added on an ongoing basis. Most recently, in 2018, the categories of ice cream machines and commercial dishwashers were added to the national inventory.

The quality of the data on emissions from mobile air conditioning systems is good. The reason for this is that annual HFC consumption can be determined accurately by statistics on registered vehicles, new registrations, production, imports and exports of passenger cars, which account for the largest part of this sector, as well as annual model-specific figures on air conditioner installation rates and the corresponding charges. Only the data for commercial vehicles are subject to major uncertainties.

The emission factors have been updated on the basis of the results of a study of the German Environment Agency (UBA) (Schwarz et al., 2012). In many application areas, the factors show a continuous development within the time series. Overall, the EFs are considered to be accurate.

In the study, the residual charges and recovery factors were determined for all uses of refrigeration and air conditioning systems in order to comply with the 2006 IPCC Guidelines.

The uncertainties for the entire subcategory of refrigeration and air conditioning systems were quantified for the 2015 report.

4.7.1.4 Category-specific recalculations (2.F.1 all)

For plug-in units and condensing units used for commercial refrigeration applications (subcategory 2.F.1.a), the number of hospitals, care homes and specialist retail food outlets was updated for 2023 based on new publications by the Federal Statistical Office. Moreover, the number of filling station shops for the years 1999-2023 was based on data published by the German National Association of Independent Filling Stations (Bundesverband freier Tankstellen e.V. - bft). For condensing units used for commercial refrigeration applications (subcategory 2.F.1.a), the number of flower shops for the years 2022 and 2023 was updated based on recently published statistics by the Federal Statistical Office. This led to changes in emissions from the production, use and disposal of HFC-125, HFC-134a, HFC-143a and HFC-32 in the years 1999 to 2023.

The average service life of central commercial refrigeration systems in discount stores (subcategory 2.F.1.a) was increased from 10 to 12 years. This increase is due to the results of an ongoing research project in which the data sets collected by the Association of German Refrigeration and Air Conditioning Companies (Verband Deutscher Kälte-Klima-Fachbetriebe e.V. (VDKF)) were evaluated. This led to changes in emissions from the production, use and disposal of HFC-125, HFC-134a, HFC-143a and HFC-32 in the years 2001 to 2023.

For low-temperature applications in commercial refrigeration and systems converted from HCFC-22 (subcategory 2.F.1.a), data collected by the Federal Statistical Office pursuant to the Environmental Statistics Act (UStatG, 2005) are used with regard to initial charges of new systems and initial charges of systems converted to R-413A, R-508A, R-508B, Isceon 89 , HFKW-152a and HFC-23. The UStatG data on HFC for each year in question do not become available until December of the following year. As a result, the figures for the relevant previous year have to be recalculated annually. This leads to changes in emissions from production and use of PFC-116, PFC-218, HFC-125, HFC-152a and HFC-23 for the relevant previous year. In addition, the value for initial charges of HFC-152a were updated for the year 2022.

In industrial refrigeration (subcategory 2.F.1.c), data collected by the Federal Statistical Office under the Environmental Statistics Act (UStatG, 2005) is used for the initial charges of new systems and initial charges of systems converted to HFC-23 and HFC-227ea. The numbers of new additions in the previous year have to be recalculated annually since the relevant UStatG data for each year do not become available until December of the following year. This leads to changes in emissions from production and use of HFC-227ea and HFC-23 for the given previous year.

For plug-in units used in industrial refrigeration, the share of new units filled with HFC-134a were corrected as of 2014. This led to changes in emissions from the production and use of HFC-134a in the years 2014 to 2023.

For dairy farms and dairies belonging to large industrial refrigeration systems, the nationally produced volume of milk for the years 2022 to 2023 was recalculated on the basis of statistics by the Federal Ministry of Agriculture, Food and Regional Identity (BMLEH), (production of milk, milk fat and milk protein, supply at producer site: series 406004001_01). A review of the model led to a reduction in the number of newly installed units and units in use which are filled with R-404A and R-407C as the review showed that refrigeration units were increasingly being

installed with halogen-free refrigerants. Recalculations were made for beer breweries, abattoirs and production of frozen foods for the years 2021 to 2023, for chocolate production for the years 2019 to 2023, and for cold storage systems for the years 2016 to 2023. Changes were made for the refrigerants HFC-134a, R-404A and R-407C used at skating rinks for the years 2021 to 2023. This led to changes in emissions from the production and use of HFC-125, HFC-134a, HFC-143a and HFC-32 used in industrial refrigeration (subcategory 2.F.1.c) as of the year 2016.

With refrigerated vehicles (subcategory 2.F.1.d), the refrigerant shares of HFC-134a and R-452A for the year 2023 was updated for all size classes. Due to the vehicle registration figures published by the Federal Motor Transport Authority (KBA) (registrations of brand-new passenger buses, trucks, tractors, other motor vehicles and motor vehicle trailers for the conveyance of loads according to their permissible total weight; series FZ 26), the number of new registrations in the years 2022 and 2023 were recalculated. This led to changes in emissions from the production and use of HFC-125, HFC-134a, HFC-143a and HFC-32 used in transport refrigeration (subcategory 2.F.1.d) in the years 2022 and 2023.

Based on publications from the German Federal Aviation Office (LBA), the number of aircraft (subcategory 2.F.1.e) operated in Germany under registration class H (helicopter) for the year 2022 has been updated. This led to changes in emissions from the use of HFC-134a in 2022.

With passenger cars and commercial vehicles (subcategory 2.F.1.e), the number of vehicles disposed of (both passenger cars and N1 commercial vehicles) annually has been taken from the waste statistics of the Federal Statistical Office. Since the data are published with a two-year time lag, the previous year's value has to be recalculated each year. This regularly leads to changes in emissions from disposal of HFC-134a for the relevant previous year.

For passenger cars (subcategory 2.F.1.e), the number of domestically produced units that use HFC-134a as a refrigerant has been corrected to zero as of 2020. From then on, only HFO-1234yf was used as a refrigerant in new air conditioning systems. This led to a change in HFC-134a emissions from car air conditioning systems as of 2020.

For commercial vehicles (subcategory 2.F.1.e), the climate quotas of newly registered vehicles for the years 2016 to 2023 were corrected. This led to changes in emissions from the use of HFC-134a in commercial vehicles from 2016.

For ships (subcategory 2.F.1.e), the number of domestically produced inland cabin vessels in 2023 and the number of cruise ships for the years 1997-2000, 2003-2005, 2010, 2012, 2019 and 2021 had to be corrected on the basis of figures from the Association of Shipbuilding and Marine Technology (Verband für Schiffbau und Meerestechnik e.V. - VSM) and data supplied by shipyard Meyer Werft Papenburg. The number of operating cruise ships also had to be adjusted; the sole cruise ship under German flag (MS Deutschland, 1998-2014) was equipped with an air conditioning system using the ozone-depleting substance HFC-22, which is not subject to reporting obligations. For naval vessels, the fill quantity in 2002 was corrected from 500 kg to 1,250 kg. Corrections were also required for ship disposal as new research showed that up to and including 2024, no ship disposal took place in Germany; instead, decommissioned ships were exported abroad for dismantling. As a result, no disposal emissions have been generated in Germany to date and the previously reported emissions of HFC-134a from disposal in the years 2022 and 2023 have been corrected to zero. Overall, there have been changes to the emissions of HFC-134a from air conditioning systems on ships as of the year 1997.

For room air conditioners (subcategory 2.F.1.f), the number of newly produced mobile room air conditioners was updated to reflect new statistics from JARN and BSRIA. Based on the findings of an ongoing research project in which the datasets collected by the German trade association

for the refrigeration, air conditioning and heat pump industry (Verband Deutscher Kälte-Klima-Fachbetriebe e.V. - VDKF) were evaluated, the average service life of multi-split and VRF-multi-split air conditioning units was reduced from 13 to 10 years. This led to changes in emissions from the production, use and disposal of HFC-125, HFC-134a and HFC-32 as of 2008.

For heat-pump clothes dryers (subcategory 2.F.1.f), adjustments were required to the refrigerant shares of large dryers using HFC-134a from 2018 due to an early market shift caused by the EU F-Gas Regulation (EU, 2024b) banning the placing of such equipment on the market from 2027. This led to changes in emissions from the production and use of HFC-134a dryers as of 2018.

For dishwashers with a heat pump (subcategory 2.F.1.f), the average fill volumes of units using R-450A were revised from 2,500 g to 800 g per appliance, and those using R-513A from 2,500 g to 3,000 g per appliance. Likewise, the fill quantities for the production of machines using R-450A were adjusted from 200 g to 64 g per unit, and those using R-513A from 200 g to 240 g per unit. This led to changes in emissions from the production and use of HFC-134a as of 2020.

The changes in the emissions of PFC-116, PFC-218, HFC-125, HFC-134a, HFC-143a, HFC-152a, HFC-227ea, HFC-23 and HFC-32 in the subcategory refrigeration and air conditioning systems (2.F.1), in the years 1995 (the base year for fluorinated greenhouse gases) to 2023 are shown in Table 195.

Table 195: Recalculated emissions of HFC-23, HFC-32, HFC-125, HFC-134a, HFC-143a, HFC-152a, HFC-227ea, PFC-116 and PFC-218 in the subcategory refrigeration and air conditioning systems (2.F.1) in the years 1995-2023, in t CO_2-eq

	Units	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
EM HFC-23															
2026 submission	t CO_2-eq														
2025 submission	t CO_2-eq														
Difference	t CO_2-eq														
EM HFC-32															
2026 submission	t CO_2-eq					9,718	12,754	14,733	17,402	21,063	25,822	31,587	38,314	46,436	54,946
2025 submission	t CO_2-eq					9,715	12,751	14,727	17,395	21,055	25,814	31,580	38,307	46,430	54,939
Difference	t CO_2-eq					+3	+3	+6	+7	+8	+8	+7	+7	+6	+7
EM HFC-125															
2026 submission	t CO_2-eq	135,681	284,635	428,611	570,811	682,107	822,656	913,183	1,001,137	1,097,938	1,231,044	1,321,258	1,369,809	1,441,325	1,504,032
2025 submission	t CO_2-eq	135,741	284,744	428,722	570,926	682,114	825,323	915,753	1,003,476	1.100286	1,234,463	1,334,052	1,378,214	1,442,597	1,507,007
Difference	t CO_2-eq	-60	-109	-111	-116	-7	-2,667	-2,569	-2,339	-2,348	-3,419	-12,794	-8,405	-1,273	-2,974
EM HFC-134a															
2026 submission	t CO_2-eq	318,601	590,546	906,976	1,289,629	1,680,837	2,065,082	2,343,701	2,614,535	2,888,637	3,152,749	3,443,513	3,722,244	3,678,278	3,854,565
2025 submission	t CO_2-eq	318,642	590,634	907,077	1,289,734	1,680,832	2,067,204	2,345,724	2,616,168	2,890,907	3,156,601	3,451,580	3,727,774	3,680,141	3,856,728
Difference	t CO_2-eq	-41	-87	-101	-105	+5	-2,122	-2,023	-1,633	-2,270	-3,852	-8,066	-5,530	-1,863	-2,162
EM HFC-143a															
2026 submission	t CO_2-eq	76,480	238,028	394,002	562,870	730,108	954,692	1,104,237	1,242,634	1,376,567	1,487,826	1,599,104	1,713,486	1,854,551	1,970,250
2025 submission	t CO_2-eq	76,587	238,222	394,200	563,077	730,152	959,492	1,108,893	1,246,884	1,380,842	1,494,022	1,622,067	1,728,588	1,856,887	1,975,635
Difference	t CO_2-eq	-107	-194	-198	-207	-44	-4,800	-4,656	-4,250	-4,275	-6,195	-22,963	-15,103	-2,336	-5,385
EM HFC-152a															
2026 submission	t CO_2-eq														
2025 submission	t CO_2-eq														

	Units	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Difference	t CO_2-eq														
EM HFC-227ea															
2026 submission	t CO_2-eq														
2025 submission	t CO_2-eq														
Difference	t CO_2-eq														
EM PFC-116															
2026 submission	t CO_2-eq														
2025 submission	t CO_2-eq														
Difference	t CO_2-eq														
EM PFC-218															
2026 submission	t CO_2-eq														
2025 submission	t CO_2-eq														
Difference	t CO_2-eq														

	Units	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
EM HFC-23																
2026 submission	t CO_2-eq															33,828
2025 submission	t CO_2-eq															34,433
Difference	t CO_2-eq															-605
EM HFC-32																
2026 submission	t CO_2-eq	62,686	71,547	81,818	93,905	107,196	119,981	132,120	146,248	159,996	164,940	170,177	187,482	208,563	225,221	245,381
2025 submission	t CO_2-eq	62,456	71,285	81,466	93,084	104,351	116,540	130,331	146,343	160,466	166,755	174,828	193,235	213,074	229,187	250,724
Difference	t CO_2-eq	+230	+262	+352	+821	+2,845	+3,441	+1,789	-95	-470	-1,815	-4,651	-5,753	-4,511	-3,966	-5,343
EM HFC-125																
2026 submission	t CO_2-eq	1,569,633	1,702,910	1,839,303	1,967,132	1,976,642	2,006,485	2,006,884	2,024,422	1,996,999	1,935,326	1,786,131	1,690,514	1,669,187	1,633,696	1,625,925
2025 submission	t CO_2-eq	1,571,571	1,712,062	1,847,824	1,966,904	1,966,136	1,993,688	2,002,584	2,029,707	2,004,312	1,949,623	1,814,063	1,722,365	1,696,396	1,658,811	1,657,089
Difference	t CO_2-eq	-1,937	-9,152	-8,522	+227	+10,506	+12,797	+4,299	-5,285	-7,313	-14,296	-27,932	-31,851	-27,210	-25,116	-31,163

	Units	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
EM HFC-134a																
2026 submission	t CO_2-eq	4,242,979	4,241,796	4,414,177	4,559,687	4,653,672	4,726,454	4,784,221	4,732,993	4,550,962	4,369,587	4,119,743	3,926,718	3,796,869	3,655,753	3,524,832
2025 submission	t CO_2-eq	4,244,136	4,248,728	4,420,608	4,559,019	4,646,905	4,721,411	4,787,192	4,742,425	4,561,910	4,383,233	4,144,680	3,962,076	3,841,286	3,709,085	3,592,932
Difference	t CO_2-eq	-1,157	-6,932	-6,431	+669	+6,767	+5,043	-2,971	-9,431	-10,947	-13,646	-24,937	-35,358	-44,417	-53,331	-68,100
EM HFC-143a																
2026 submission	t CO_2-eq	2,075,390	2,153,275	2,236,265	2,290,382	2,250,659	2,247,023	2,180,451	2,067,303	1,903,078	1,710,953	1,486,432	1,297,487	1,188,448	1,091,841	1,028,297
2025 submission	t CO_2-eq	2,080,949	2,172,042	2,254,722	2,297,450	2,257,334	2,254,415	2,187,957	2,075,128	1,911,319	1,720,257	1,495,398	1,303,934	1,197,243	1,101,944	1,039,423
Difference	t CO_2-eq	-5,559	-18,767	-18,458	-7,068	-6,675	-7,393	-7,506	-7,825	-8,241	-9,304	-8,967	-6,448	-8,795	-10,104	-11,126
EM HFC-152a																
2026 submission	t CO_2-eq														1	0.619
2025 submission	t CO_2-eq														0	0.635
Difference	t CO_2-eq														+1	-0.02
EM HFC-227ea																
2026 submission	t CO_2-eq															3,773
2025 submission	t CO_2-eq															3,795
Difference	t CO_2-eq															-23
EM PFC-116																
2026 submission	t CO_2-eq															3,057
2025 submission	t CO_2-eq															3,092
Difference	t CO_2-eq															-34
EM PFC-218																
2026 submission	t CO_2-eq															522
2025 submission	t CO_2-eq															533
Difference	t CO_2-eq															-11

4.7.1.5 Category-specific planned improvements (2.F.1 all)

No improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.7.2 Foam blowing (2.F.2)

Since 1992, hydrofluorocarbons (HFCs) have also been used in foam blowing, as blowing agents substituting for ozone-depleting, climate-damaging CFCs and HCFCs.

A useful distinction can be made between open-cell and closed-cell foam products. In the case of open-cell foam products, the blowing-agent emissions occur only during the production process or immediately after it. The open-cell foam products that are produced and used in Germany include polyurethane integral foam, one-component polyurethane foam (OCF) and extruded polystyrene hard foam (XPS) blown with HFC-152a. In the case of closed-cell foam products, emissions occur throughout products' entire lifetimes: in production, during use and upon disposal. The products in this category include rigid polyurethane foam, as well as extruded polystyrene hard foam (XPS) blown with HFC-134a or HFO-1234ze. Both types of closed-cell foam products are produced and used in Germany.

The activity data for production (new domestic consumption) of open-cell foam products (polyurethane integral foam, one-component polyurethane foam (OCF) and polystyrene hard foam (XPS) blown with HFC-152a) and closed-cell foam products (rigid polyurethane foam, and polystyrene hard foam (XPS) blown with HFC-134a) are confidential, since each of these products is made by fewer than three producers in Germany. In the inventory tables, the relevant cells for activity data for production in category 2.F.2 show "C" (confidential).

Since the emission factor for production of open-cell foam products is 100% in all cases, meaning that the activity data for production can be directly derived from it, the production emissions are also confidential. They are aggregated with emissions from the production of closed-cell foam products in category 2.F.2.b in the inventory tables. Also in the inventory tables, emissions from production of closed-cell foam products are listed as "I.E." (included elsewhere).

4.7.2.1 Closed-cell polyurethane hard foam products (2.F.2 PU hard foam)

4.7.2.1.1 Category description (2.F.2 PU hard foam)

Closed-cell polyurethane (PU) hard foam products are used in many different kinds of products, including household appliances, refrigerated vehicles, insulating boards with flexible laminates and sandwich elements with rigid laminates. HFC-134a was used as a blowing agent from 1998 to 2003. Since 2002, HFC-365mfc (with small quantities of added HFC-227ea) has also been used as a blowing agent, and HFC-245fa has also been used as such an agent from 2004 to 2020. Small quantities of HFC-41 were used for test purposes between 2014 and 2019. Use of HFC has been decreasing; it is being supplanted by hydrocarbons such as pentane, and by CO_2 (in small amounts).

The time series, which does not begin until 1998, shows a small increase in emissions until 2003. A larger increase occurred in 2004. These results agree with the historical development of HFC use in this application area, an area which emerged only slowly as a result of the long period in which HCFCs were used. Emissions from PUR hard foam products decreased again from 2020 through 2030. A slight increase occurred in 2010, and since then the emissions have remained at a relatively constant level.

4.7.2.1.2 Methodological issues (2.F.2 PU hard foam)

The production emissions are calculated using Equation 8 by multiplying the quantity of HFC that is emitted no later than one year after the time of production (the first year loss) by the $EF_{production}$. The emissions from units in service are calculated with Equation 9.

For an average service life of up to 50 years (sandwich elements), disposal of PU hard foam products will not begin until a few years from now.

Emission factors

The emission factors used are shown in Table 194.

The emission factor for production with HFC-134a is 10% and corresponds to the standard value provided in the 2006 IPCC Guidelines (IPCC (2006a): Vol. 3, Table 7.6) for "polyurethane continuous panels".

The emission factors for all other HFCs have been approved by national experts and adjusted where necessary. For example, the emission factor for production of PU hard foam using HFC-365mfc/HFC-227ea as of 2004 was increased from 10 to 15% because that HFC mixture has been used increasingly in open on-site applications, especially in spray foams. The emission factor for production with HFC-245fa and HFC-41 is also 15%. Those values lie within the standard-value range proposed in the 2006 IPCC Guidelines (IPCC (2006a): Vol. 3, Table 7.7) for the "first year loss" for the various PU hard-foam applications.

For PU hard foam blown with HFC-134a, the annual HFC emissions from the "stock" are estimated at 0.5%. This figure corresponds to the default value provided in the 2006 IPCC Guidelines (IPCC (2006a): Vol. 3, Table 7.6) for "polyurethane continuous panels". The products blown with HFC-365mfc/HFC-227ea, HFC-245fa and HFC-41 emit 1% annually and are therefore within the default value ranges specified in the 2006 IPCC Guidelines (IPCC (2006a): Vol. 3, Table 7.7) for various PU hard-foam applications. The emission factor used for HFC-365mfc/HFC-227ea emissions from units in service was taken from an estimate based on test products.

Activity data

The figures for new domestic consumption for each blowing agent and each product group are based on the amounts of foam products produced in Germany. The data for products in service are based on the amounts of foam products used in Germany (sales in Germany) since the introduction of HFCs. With a service life of up to 50 years, disposals that reduce stock do not yet play any significant role.

New domestic consumption and domestic sales of foam products are determined annually by surveying manufacturers, users and blowing-agent suppliers, by gathering information from the relevant industry association (IVPU[70]), and from the annual quantities used pursuant to the Environmental Statistics Act (UStatG, 2005). The data on new domestic consumption of HFC-41 are obtained from data collected in surveys pursuant to the Environmental Statistics Act (Umweltstatistikgesetz (UStatG, 2005)).

4.7.2.2 Closed-cell and open-cell XPS hard foam (2.F.2 XPS)

4.7.2.2.1 Category description (2.F.2 XPS)

Extruded polystyrene hard foam (XPS) is used in insulating boards that need to be highly moisture-resistant. HFC consumption and emissions from production of XPS insulation boards

[70] IVPU - Industrieverband Polyurethan-Hartschaum e. V.

have occurred only since 2001 since HCFCs or $CO_{2/ethanol}$ were used prior to that. HFC-134a has been used as a blowing agent from 2001 to 2018, while HFC-152a has been used from 2001 to 2022, either individually or as a mixture. Since 2012, HFO-1234ze has also been used as a blowing agent. The emissions behaviour of XPS insulating boards varies depending on the blowing agents used to produce them. When HFC-152a is used, HFC emissions occur only during production, and thus the resulting XPS insulating boards can be considered "open-cell" products. When HFC-134a or HFO-1234ze are used, closed-cell XPS hard foam products result that also release HFC emissions during use and disposal.

The relevant time series begins in 2001 and exhibits a slight initial emissions increase until 2002. As of 2003, the emissions decrease continuously; this is related to the increasing use of non-halogenated blowing agents in production of XPS hard foam products in Germany. In the years 2018 and 2019, a marked emissions reduction occurred. After those years, emissions remained nearly constant at a low level.

4.7.2.2.2 Methodological issues (2.F.2 XPS)

Production emissions are calculated by multiplying the new HFC consumption from production of XPS insulating boards by the $EF_{production}$ as shown in Equation 8.

The use emissions are calculated from the domestic final HFC stocks in XPS insulating materials as shown in Equation 9. These stocks increase annually solely through new additions of insulating boards containing HFC-134a and HFO-1234ze. Given a service life of 50 years, removals from products in service do not yet play any significant role. The new HFC additions does not correspond to annual new consumption, minus production emissions. With foreign trade, especially exports of XPS products with HFC-134a or HFO-1234ze, only 25% (the complementary value for the export rate) of the HFC-134a or HFO-1234ze contained in products is a new addition to domestic HFC stocks.

Given that XPS insulating boards have an average service life of 50 years, disposal will not begin until 2051 at the earliest. Disposal emissions thus play no significant role to date.

HFO-1234ze is not subject to reporting obligations. Germany voluntarily reports emissions of this substance as "additional greenhouse gas" pursuant to the recommendations of the 2014 UNFCCC Reporting Guidelines ((UNFCCC, 2014), FCCC/CP/2013/10/Add.3, Decision 24/CP.19). For reasons of confidentiality, the HFO-1234ze emissions are aggregated with other emissions not subject to reporting obligations and reported in Chapter 4.9.3 under CRF 2.H.3.

Emission factors

The emission factors used are shown in Table 194.

The production emissions (HFC first year losses) for HFC-152a are practically 100% ($EF_{production}$ = 1) since the substance is used solely as a blowing agent in production. With HFC-134a, only part of consumption is emitted upon blowing, meaning that most of the substance enters into the product. The $EF_{production}$ for HFC-134a is determined empirically and communicated by the CEFIC association[71] or by its EXIBA industry association[72]. It is subject to confidentiality requirements. Until experimental measurements become available, the same $EF_{production}$ will be used for XPS insulating boards blown with HFO-1234ze as the one used for insulating boards blown with HFC-134a.

[71] CEFIC - The European Chemical Industry Council

[72] EXIBA - European Extruded Polystyrene Insulation Board Association

Trials with HFC collection and recovery in the production process have been conducted, but no relevant systems have been implemented to date for technical and economic reasons.

The 2006 IPCC Guidelines (IPCC, 2006a) specify the following default values in Vol. 3, Table 7.6 for insulating boards blown with HFC-134a and HFC-152a: the "first year loss" is 25% for HFC-134a and 50% for HFC-152a. The corresponding values used in Germany, especially that for HFC-152a, differ widely from these figures. At the same time, they are considered to be representative, since they are based on information provided by industry experts.

A representative of the FPX extruded-polystyrene-foam association estimated the annual releases from enclosed HFC-134a cell gas as being less than 1% in 2002. That figure is based on aspects including an internal study by BASF regarding the half-lives of various cell gases, such as HFC-134a (Weilbacher, 1987). The EF_{use} from that laboratory study has been used for HFC-134a. Fugitive emissions from boards depend on board thickness and can only be given as average values or values for specific board thicknesses. The value used, EF_{use} = 0.66%, is based on average board thickness and is lower than the value of 0.75% proposed in the 2006 IPCC Guidelines (IPCC (2006a): Vol. 3, Table 7.6). The 2006 IPCC Guidelines do not provide any default values for insulating boards blown with HFO-1234ze. The same EF_{use} is used for such boards as is used for boards blown with HFC-134a.

Activity data

The data on new domestic consumption of HFC-134a and HFC-152a are obtained from data collected pursuant to the Environmental Statistics Act (UStatG, 2005) and from surveys of manufacturers.

The data on new domestic consumption of HFO-1234ze are obtained from data collected in surveys pursuant to the Environmental Statistics Act (UStatG, 2005) and from information provided by the propellant manufacturer.

All of the data required for emissions calculation, including new domestic consumption, loss rate in production and the foreign trade balance for insulation boards containing HFC-134a, are provided by the relevant European industry association (CEFIC or EXIBA).

4.7.2.3 Open-cell polyurethane integral foam (2.F.2 PU integral foam)

4.7.2.3.1 Category description (2.F.2 PU integral foam)

Open-cell polyurethane (PU) integral foams are foams with a porous core and a compact, tough skin. They are produced by way of reaction injection moulding. In that process, the reaction mixture, including the blowing agent, is injected in liquid form into a cold injection mould. All of the blowing agent is emitted during the foaming action that ensues. PU integral foams are used in the soles of athletic and leisure shoes, in car-body parts and in window profiles. HFCs have been used as blowing agents for production of PU integral foams since 1996.

The blowing agents used in Germany are HFC-134a from 1996 to 2021, and HFC-245fa from 2004 to 2022. HFC-365mfc (with minor additions of HFC-227ea) has been used since 2022. HFO-1336mzz (Z) has also been used since 2019, and HCFC-1233zd (E) since 2022.

The time series begins in 1996. From then until 2001, the emissions remained relatively constant. As of 2002, the emissions increase continuously. HCFCs were long used in production of PU integral foams in Germany, and this delayed the phasing-in of HFCs. An emissions reduction occurred in 2012. This was due to the increased use of hydrocarbons (such as pentane) as blowing agents instead of HFCs. Until 2017, the emissions increased again, however. Then, as of 2019, and following a sharp reduction in 2018, they remained at a relatively constant low level. Another sharp decrease occurred in 2023.

4.7.2.3.2 Methodological issues (2.F.2 PU integral foam)

As per the 2006 IPCC Guidelines (IPCC (2006a): page 7.34, Equation 7.8), the emissions in this open application are considered to be the same as the HFC quantity used in production (new HFC consumption).

Production emissions are calculated by multiplying the new HFC consumption from production by the $EF_{production}$ as shown in Equation 8.

No use emissions or disposal emissions occur since all of the blowing agent is emitted during production.

HFO-1336mzz (Z) and HCFC-1233zd (E) are not subject to reporting obligations. Germany voluntarily reports emissions of these substances as "additional greenhouse gas" pursuant to the recommendations of the 2014 UNFCCC Reporting Guidelines ((UNFCCC, 2014), FCCC/CP/2013/10/Add.3, Decision 24/CP.19). For reasons of confidentiality, the emissions are aggregated with other emissions not subject to reporting obligations and reported in Chapter 4.9.3 under CRF 2.H.3.

Emission factors

The emission factors used are shown in Table 194.

For PU integral foams blown with HFC-134a, HFC-245fa or HFC-365mfc (with additions of HFC-227ea), the 2006 IPCC Guidelines specify a default value of 95% for the *first year loss*. The annual loss is given as 2.5%, resulting in emissions that occur over three years.

According to the in-country experts consulted, all of the blowing agent – except for small residual quantities – escapes during the blowing process. The small residual quantities are then emitted over a period of no longer than two years. For this reason, in a departure from the 2006 IPCC Guidelines, Germany considers an emission factor of 100% to be appropriate for production.

Activity data

The figures for new domestic consumption, for each blowing agent and each product group, are based on the amounts of integral foam products produced in Germany.

New domestic consumption and domestic sales of foam products are determined annually by surveying manufacturers, users and blowing-agent suppliers, by gathering information from the relevant industry association (IVPU), and from the annual quantities used pursuant to the Environmental Statistics Act (UStatG, 2005).

The data on new domestic consumption of HFO-1336mzz und HCFC-1233zd are obtained from data collected in surveys pursuant to the Environmental Statistics Act (UStatG, 2005).

4.7.2.4 Open-cell one-component polyurethane foam (2.F.2 one-component PU foam)

4.7.2.4.1 Category description (2.F.2 one-component PU foam)

The term "one-component foam" refers to open-cell polyurethane foam (PU foam) that is sprayed on site from pressurised containers (cans). Such foam is used, for example, when installing windows and doorframes. Following the ban on HCFCs, the blowing agents now used for such foam include mixtures of HFCs and propane, butane or dimethyl ether (DME). At the same time, the HFC quantities in such cans have been continually reduced since 1996 and were zero from 2025.

HFC-134a was used in Germany between 1992 and 2022 to produce PU one-component foam (in cans). HFC-152a was used in domestic production from 2002 to 2004. Imported cans of one-

component foam used in Germany contained HFC-134a between 1992 and 2024, and HFC-152a between 1995 and 2023.

The emissions of PU one-component foam increased sharply from 1992 to 1994; thereafter, they decreased considerably and continuously. Since 4 July 2008, a ban has been in force in the EU, with a few permitted exceptions on the sale of one-component foam products filled with fluorinated greenhouse gases with a global warming potential (GWP) greater than 150. Due to this ban, emissions decreased continually from 2008 and were zero as of 2025.

4.7.2.4.2 Methodological issues (2.F.2 one-component PU foam)

The production emissions are calculated from the number of cans filled per year in Germany and the blowing-agent loss per can.

As per the 2006 IPCC Guidelines (IPCC (2006a): page 7.34, Equation 7.8), the emissions in this open application are considered to be the same as the HFC quantity sold in cans. Emissions from use are calculated with Equation 9 based on the HFC quantities sold in cans.

No disposal emissions occur since all of the HFCs in cans of one-component foam are emitted when the cans are used.

Emission factors

The emission factors used are shown in Table 194.

The $EF_{production}$ was determined by surveying experts and manufacturers. From 1992 to 2002, it amounted to 1.5 g/can, while from 2003 it has been only 0.5 g/can since the total fill quantities in cans decreased.

Vol. 3, Table 7.6 of the 2006 IPCC Guidelines (IPCC, 2006a) specify a first year loss of 95% and an annual loss of 2.5% for one-component foams, resulting in the relevant emissions being distributed over a total of three years. In contrast to the IPCC method, it is assumed that all emissions occur in the year of sale (EF_{use} = 100%) for the German inventory since use and disposal take place in close succession. At the same time, used cans are not completely empty when they go to waste management; they still contain about 8% of their original foam contents, including the relevant blowing agent. The majority of that blowing agent eventually also enters the atmosphere after a certain delay.

Activity data

The data required to determine the losses from charging (production emissions), the number of cans filled with HFC-134a or HFC-152a each year in Germany, the quantity of HFC per can in grams, and the specific loss from charging are obtained by surveying experts and from information provided by manufacturers.

The data required to determine the emissions from use, i.e. the number of cans sold annually in Germany with the propellants HFC-134a or HFC-152a and the HFC quantity per can in grams, are obtained from the manufacturers of spray cans with one-component-foam.

The pre-1995 data for foam sealants were obtained during a discussion in 2006 with leading foreign sellers of one-component foam products, and from older publications.

4.7.2.5 Uncertainties and time series consistency (2.F.2 all)

The uncertainties for the “foams” subcategory have been systematically quantified.

The emissions data for PU foam products for preceding years are considered fairly accurate since the quantities of HFCs used are rather small.

The XPS market in Germany is relatively small as there are only a few such manufacturers. Since the EFs and AD were prepared with manufacturers, they are deemed sufficiently accurate.

Since 2001, the relevant industry association has determined through research the input quantities of HFC-152a and HFC-134a in production of XPS hard foams. Since 2006, data collected pursuant to the Environmental Statistics Act (UStatG, 2005) have also been available. Since only three manufacturers use HFC for XPS blowing, there is little reason to doubt the reliability of the activity data. This also applies to the export rate and the HFC production emissions determined for use of HFC-134a.

The 100% production emissions in the use of HFC-152a do not align with the existing IPCC estimates. Nonetheless, the industry association considers them to be realistic.

The value for the emissions rate from current stocks, as determined by a laboratory study, will be used as long as no reliable measurements with insulation boards in actual service have been carried out; such measurements would be considered more conclusive than laboratory values.

4.7.2.6 Category-specific recalculations (2.F.2 all)

The values for the domestic consumption of HFC-134a, HFC-152a and HFO-1234ze, for the production of XPS hard foam were taken from surveys pursuant to the Environmental Statistics Act (UStatG, 2005). The domestic consumption of the previous year has to be recalculated annually since the relevant data collected pursuant to UStatG for each year in question do not become available until December of the following year. This regularly leads to changes in emissions from production and use for the relevant previous year.

With polyurethane hard-foam products and polyurethane integral foams, the domestic-consumption figures for production with HFC-245fa and HFC-365mfc are updated for the previous year to reflect the propellants' applicable shares surveyed pursuant to the Environmental Statistics Act (UStatG, 2005). Such updating changes the emissions from production.

For polyurethane integral foams, data on domestic consumption for production with HFC-134a are taken from surveys pursuant to the Environmental Statistics Act (UStatG, 2005). The domestic consumption of the previous year has to be recalculated annually since the relevant data collected pursuant to UStatG for each year in question do not become available until December of the following year. This regularly leads to changes in emissions from production.

For polyurethane hard-foam products and polyurethane integral foams, the domestic consumption figures for production using HFC-245fa were recalculated for the years 2017 to 2020 as new information became available regarding the quantities used.

The changes in the emissions of HFC-152a and HFC-245fa in the subcategory foam blowing (2.F.2), for the years 2017 to 2023 are shown in Table 196.

Table 196: Recalculated emissions of HFC-152a and HFC-245fa from 2017 to 2023, in [t CO_2-eq]

	2017	2018	2019	2020	2021	2022	2023
HFC-152a							
2025 submission							1,717
2026 submission							889
Difference	-						-828
HFC-245fa							

	2017	2018	2019	2020	2021	2022	2023
2025 submission	157,497	108,702	107,998	172,802	178,432	178,432	178,432
2026 submission	157,276	92,483	75,910	92,442	67,658	40,059	12,460
Difference	-220	-16,219	-32,089	-80,360	-110,774	-138,373	-165,972

4.7.2.7 Category-specific planned improvements (2.F.2 all)

No improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.7.3 Fire extinguishers (2.F.3)

4.7.3.1 Category description (2.F.3)

Halons, which were permitted as fire extinguishing agents until 1991, have since been largely supplanted by ecologically safe substances. Such substances include, above all, inert gases such as nitrogen and argon for systems used to flood rooms, and powders, CO_2 and foams used in handheld fire extinguishers.

In 1998, HFC-227ea was certified in Germany as a halon substitute. In 2001, HFC 236fa also received such certification. That substance is used solely in the military sector, however. HFC-23, while certified since 2002, was not used until 2005. While certification of fire extinguishing agents is no longer required, the list of fire extinguishing agents in use has nonetheless not grown since all application areas can be covered with halogen-free agents and with the aforementioned HFCs (especially 227ea and 236fa).

HFC-based fire extinguishing agents are imported and filled into fire extinguishing systems in Germany. Virtually no foreign trade with charged systems takes place. The time series do not begin until 1998.

4.7.3.2 Methodological issues (2.F.3)

The annual new HFC additions in domestic systems are identical to the amounts added to new systems within the country (new HFC consumption).

Since activity data are available in Germany for HFC-227ea and HFC-236fa until the year 2017, a bottom-up approach is used for the period 1995 to 2017. Unlike the top-down approach of the 2006 IPCC Guidelines (IPCC (2006a): Vol. 3, Chapter 7.6), the bottom-up approach includes emissions from charging. As of 2021, no further initial charges of HFC-227ea occur.

As of report year 2018, the top-down approach given by the 2006 IPCC Guidelines ((IPCC, 2006a): Vol. 3, Chapter 7.6) is used.

Due to a lack of data, the German Environment Agency estimates the installed quantities of HFC-23. As of report year 2016, it has been assumed that no further new systems have been installed due to the provisions of the EU F Gas Regulation (EU, 2024b).

The average service life of fire extinguishing systems is estimated to be 20 years, which largely aligns with the range of 15 to 20 years proposed in the 2006 IPCC Guidelines (IPCC (2006a): Vol. 3, Chapter 7.6.2.2).

Disposal emissions occurred for the first time in 2018 after the 20-year average service life.

Emission factors

The emission factors used are shown in Table 194.

The $EF_{production}$ are based on estimates by experts.

The EF_{use} ranges between 1 and 0.4% for HFC-236fa. The emission factor includes the major uncertainty for stock estimates and is based on recharge quantities for the years 2001/2002 and 2019-2023. A detailed recalculation is not possible here on confidentiality grounds.

For HFC-23, 4% is also assumed to account for the uncertainties in the activity data.

Specific installation and recharge quantities are available for HFC-227ea until report year 2007. Those quantities are extrapolated for the German market as a whole on the basis of the market share estimated by the company. In the report years 2008 to 2017, the emissions from use are calculated with an emission factor of 2.5%. That EF_{use} is slightly higher than the 2% EF recommended by the Guidelines for stationary fire extinguishing systems.

For all HFCs, the emission factor for disposal is 1% until report year 2021. Experts from the environmental research institution Öko-Recherche recommended this value, which differs from the value specified by the 2006 IPCC Guidelines (IPCC (2006a): Vol. 3, Chapter 7.6.2.2) because, in practice, the gas cylinders used in such systems are normally separated and then shipped abroad for reuse. From report year 2022, it is raised to 9% as there were new findings from the report on the data collection for the inventory.

Activity data

The figures for HFC 227ea emissions are based on statistical surveys of one company on input quantities, recharge quantities, accidental releases, releases in cases of fire, and flooding tests in Germany (as per Tier 2). Upscaling was carried out on the basis of the market shares estimated by the company. These data are available at this level of detail until report year 2007. As of report year 2008, two companies have been reporting the quantities they use. The two companies together have a market share of 90% and the relevant input quantities are extrapolated to 100% of the market. As of report year 2018, the trend is simply carried forward due to a lack of data and the fact that one of the two firms has announced that it plans to discontinue use of HFC-227ea. From report year 2021, no further growth is assumed since there were no discussions about a ban at EU level.

Until report year 2017, the data for HFC-236fa are based on company information provided on a voluntary basis. As of report year 2018, the figures for additions to quantities in service are simply carried forward in accordance with the figures for report year 2017. From report year 2021, no further growth is assumed since the Bundeswehr (armed forces) obtained service equipment and it can be assumed that there was no significant increase in demand.

The figures for HFC-23 are based on estimates of the German Environment Agency. As of 2016 it is assumed that no further additions to quantities in service occur due to the provisions of EU Regulation (EU) 517/2014 (F-GasV, 2014).

4.7.3.3 Uncertainties and time series consistency (2.F.3)

The uncertainties for the “fire extinguishing agents” subcategory have been systematically quantified.

4.7.3.4 Category-specific recalculations (2.F.3)

Recalculations were needed for the emissions of HFC-236fa from units in service for the report years 2004 to 2023. However, these recalculations cannot be provided here for reasons of confidentiality.

4.7.3.5 Category-specific planned improvements (2.F.3)

No further improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.7.4 Aerosols (2.F.4)

This area includes metered-dose inhalers (MDI), which are used in medical applications, as well as general purpose aerosols and "novelty aerosols".

4.7.4.1 Metered-dose inhalers (2.F.4.a)

4.7.4.1.1 Category description (2.F.4.a)

Metered-dose inhalers are used in the medical sector, primarily for treatment of asthma, as well as COPD. Metered-dose inhalers with an HFC propellant first reached the German market in 1996. They contained the propellant HFC-134a. Beginning 1999, metered dose inhalers with the propellant HFC-227ea were also sold. Since then, the number of available preparations has grown continually. Charging of inhalers with HFC-134a has taken place in Germany since 2001.

From 1996 through 2002, the time series shows a sharp emissions increase that correlates with increasing use of HFCs as CFC substitutes. A large change occurred in 2001. As of that year, CFCs were prohibited for the largest group of active ingredients, the short-acting betamimetics. Since 2003, the emissions have remained at a relatively constant high level. Since 2015, a slightly increasing trend has been occurring.

4.7.4.1.2 Methodological issues (2.F.4.a)

Since 98% of the contents of metered dose inhalers consist of propellant, their contents are considered to consist solely of HFCs.

The production emissions are calculated from the number of metered dose inhalers charged per year in Germany and the propellant loss per can. Some of the propellant emissions are collected with cold traps and then combusted. Without such collection, the emissions would be higher.

Emissions from use are calculated with Equation 9 based on the HFC quantities sold in metered dose inhalers. The vast majority of metered dose inhalers used in Germany are sold in pharmacies. An estimated 10% are used by hospitals for their own needs, while 3% are free, "not-for-sale" medical samples for doctors and pharmaceutical representatives. These two shares are taken into account by adding 13% to sales by pharmacies.

The time period between pharmacy sales and use is short. In contrast to the proposal in the 2006 IPCC Guidelines (IPCC (2006a): Vol. 3, Equation 7.6), the reference figure for the emissions from use is not the sum of half the purchases (sales) of the previous year and half the purchases (sales) of the current year, but all purchases/sales for the current year. The approach in the 2006 IPCC Guidelines would be a useful choice if the available data covered produced rather than sold inhalers since because a considerable amount of time can elapse between production and use for transport and storage.

No disposal emissions occur since all of the HFCs in metered dose inhalers are emitted when the cans are used.

Emission factors

The emission factors used are shown in Table 194.

The $EF_{production}$ on which emissions data for production are based is itself based on a highly accurate determination of charging emissions in actual operations by the only German company that charges such inhalers. These amount to about 1.5% of new consumption for charging. This translates to about 0.2 g per 10 ml inhaler.

In agreement with IPCC specifications ((IPCC, 2006a), Vol. 3, p. 7.28), a 100% emissions level in use (EF_{use} = 1) is assumed. Inhaled HFCs are not broken down in bronchial passages; they are released into the atmosphere, without undergoing any changes, upon exhalation. In a departure from the Guidelines, Germany uses a service life of only one year for metered dose inhalers. The emission factor has thus been classified as "country-specific".

Activity data

The emissions data for the period until report years 2005 (production) and 2006 (use) are based on sales figures (sales in pharmacies) for metered-dose inhalers in Germany as obtained by surveying producers. The total unit numbers, the average fill quantity in ml and the propellant used have all entered into relevant calculations. As of report year 2006, the activity data for production are based on data provided by annual Drug Prescription Reports (Arzneiverordnungs-Reporte) (Ludwig et al., 2022). As of report year 2007, the activity data for use are also based on such data. As of report year 2008, the activity data for production are taken from annual surveys, focussing on certain climate-relevant substances, carried out by the Federal Statistical Office (UStatG, 2005) (industrial sector/Wirtschaftszweig 21). The data are confidential since there are fewer than three producers in Germany.

4.7.4.2 Other aerosols (2.F.4.b)

4.7.4.2.1 Category description (2.F.4.b)

In Germany, six types of general-purpose aerosols (includes neither medical metered dose inhalers nor novelties) containing HFC are sold:

- compressed-air sprays,
- cooling sprays,
- drain-opener sprays,
- lubricating sprays,
- insecticides, and
- self-defence sprays.

Production and use of general-purpose aerosols with HFC-134a began in 1992; use of HFC-152a occurred between 1995 and 2017. Since 2013, HFO-1234ze has also been used as a propellant in cooling sprays and cleaning sprays. From 1992 to 1996, the time series shows a sharp emissions increase that correlates with increasing use of HFCs as CFC substitutes. The emissions remained at a constant level between 1996 and 2005. They made a large downward jump in 2009, and then increased again slightly. Since 2018, they have fallen to very low values.

Other aerosols include “novelty” aerosols (artificial snow, “silly string”, etc.). Such products are not produced in Germany, however. Novelties containing HFC-134a were used from 1995 to 2016, while HFC-152a was also used between 2000 and 2008. HFO-1234ze has been used as a propellant since 2014. The time series shows a relatively constant high level from 1995 to 2003. As of 2004, the emissions from such sprays decreased sharply and have remained at a constant low level since 2010. Another sharp decrease in emissions is seen from 2017 as HFC-134a was no longer used after that time. This is attributable to an EU ban on the sale of novelty aerosols filled with hydrofluorocarbons (HFCs) with a Global Warming Potential (GWP) greater than 150 that came into force on 4 July 2009. Producers were quick to respond by choosing other propellants for their products.

As of 1 January 2018, sales of technical aerosols that use HFC with a GWP of more than 150 are prohibited in the EU (a few exceptions apply). From 2030, there will be a blanket ban on the use of HFC in aerosols.

4.7.4.2.2 Methodological issues (2.F.4.b)

In the case of general-purpose aerosols, imports and exports are roughly in balance, meaning that the domestic market can be considered equivalent to consumption for domestic filling. Domestic consumption refers to spray cans filled in Germany, regardless of where the cans are ultimately used. The production emissions are calculated pursuant to Equation 8 from the HFC consumption for in-country filling of general-purpose aerosols and the propellant loss in production.

No novelty aerosols are produced in Germany. The basis for calculating the HFC quantities sold in novelty-aerosol cans consists of the German market’s share of the EU market.

Emissions from use are calculated using Equation 9 based on the HFC quantities sold in other aerosols.

Since the calculations are oriented to the numbers of aerosol cans sold and not to the numbers produced, the average time period between the sale and use of such cans may be assumed to be very short. In contrast to the recommendation in the 2006 IPCC Guidelines ((IPCC, 2006a); Vol. 3, Equation 7.6), the reference figure for calculating the emissions from use is not the sum of half the purchases (sales) of the previous year and half the purchases (sales) of the current year, but all purchases (sales) for the current year.

Since the HFCs contained in such aerosols are emitted in full when the aerosols are used, there are no disposal emissions to be reported.

HFO-1234ze is not subject to reporting obligations. Germany voluntarily reports emissions of this substance as “additional greenhouse gas” pursuant to the recommendations of the 2014 UNFCCC Reporting Guidelines ((UNFCCC, 2014), FCCC/CP/2013/10/Add.3, Decision 24/CP.19). For reasons of confidentiality, the HFO-1234ze emissions are aggregated with other emissions not subject to reporting obligations and reported in Chapter 4.9.3 under CRF 2.H.3.

Emission factors

The emission factors used are shown in Table 194.

The $EF_{production}$ = 1.5 % on which production emissions data for other aerosols are based is itself based on estimates by experts.

As laid down in the IPCC specifications (IPCC (2006a), Vol. 3, p. 7.28), a 100% emissions level in use of other aerosols (EF_{use} = 1) is assumed. In a departure from the Guidelines’ relevant

proposal, it is assumed that all of the cans sold in Germany are used in full in the same year in which they are sold. The emission factor has thus been classified as "country-specific".

Activity data

The data for the period prior to 1995 are based on estimates by experts. In line with a bottom-up approach, all quantity data as of 1995 are provided directly by producers, fillers and operators, propellant manufacturers and the relevant industry association. Emissions data for general-purpose aerosols also include filling emissions (= production emissions). Estimates are based on EU-wide data.

4.7.4.3 Uncertainties and time series consistency (2.F.4 all)

The uncertainties for the "aerosols" subcategory have been systematically quantified.

In the case of metered dose inhalers, the surcharge factor for hospitals and doctors' samples can vary by ±3% from the 13% cited above.

In comparison to the emissions data for metered dose inhalers, the data for other aerosols are considered not as good, since the large number of products involved makes it difficult to obtain an overview of the market. Large quantities of imports, especially "novelties", also complicate the situation. The uncertainties are thus considerably higher (more than 20%).

Since the shift from CFCs to chlorine-free propellants had already been completed by the beginning of the 1990s, the time series for the period 1995 to 2005 showed virtually no changes. Slight emissions decreases have been seen since 2006.

4.7.4.3.1 Category-specific recalculations (2.F.4 all)

The data on domestic consumption of HFC-134a for the production of metered dose inhalers are taken directly from surveys pursuant to the Environmental Statistics Act (UStatG, 2005). An annual recalculation is necessary since the data collected pursuant to UStatG for each year in question do not become available until December of the following year. This regularly leads to changes in emissions from production. The activity data for use of HFC-134a and HFC-227ea in metered dose inhalers were updated based on data recently published in the Drug Prescription Reports (Arzneiverordnungs-Reporte) (Ludwig et al., 2022). This led to recalculations for the emissions from the use of HFC-134a and HFC-227a in the years 2022 and 2023.

For novelty aerosols, the activity data for use of HFC-134a in the years 2014 to 2023 was recalculated. This was to account for the increasing use of HFO-1234ze from 2014, which was the only propellant containing halogen used in novelty aerosols from 2017.

The changes in the emissions of HFC-134a and HFC-227ea in the subcategory aerosols (2.F.4) for the years 2014 to 2023 are shown in Table 197.

Table 197: Recalculated emissions of HFC-134a and HFC-227ea from 2014 to 2023, in [t CO_2-eq]

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
HFC-134a										
2025 submission	493,844	534,921	562,481	516,103	322,970	324,467	319,614	331,983	321,037	321,513
2026 submission	492,999	533,231	559,946	512,723	319,590	321,087	316,234	328,603	368,313	414,099
Difference	-845	-1,690	-2,535	-3,380	-3,380	-3,380	-3,380	-3,380	+47,276	+92,586
HFC-227ea										
2025 submission									51,654	51,654
2026 submission									46,846	43,278
Difference									-4,809	-8,376

4.7.4.3.2 Category-specific planned improvements (2.F.4 all)

No improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.7.5 Solvents (2.F.5)

4.7.5.1 Category description (2.F.5)

Use of HFCs as solvents was banned in Germany until the year 2001 (2nd Ordinance on the Implementation of the Federal Immission Control Act – 2. BImSchV) and remains heavily restricted to this day. A separate permit has to be applied for every surface treatment facility that uses HFCs either in a pure form or in mixtures with trans-1,2-dichloroethene, and such permits are granted only in special cases. In addition to HFC-43-10mee, which has already been reported, the following substances are now also used in very small quantities: HFC-365mfc (since 2013), HFC-245fa (since 2010) and C_6F_{14} (since 2006).

4.7.5.2 Methodological issues (2.F.5)

Emissions are calculated as per Tier 2a in the 2006 IPCC Guidelines (IPCC (2006a): Vol. 3, Chapter 7.2). Emissions occur only during use.

Emission factors

As laid down in the IPCC specifications (IPCC (2006a), Vol. 3, Equation 7.5), a 100% emissions level in use of solvents (EF_{use} = 1) is assumed.

Activity data

The consumption figures for HFC-43-10mee are based on sales data provided by an authorised dealer. The quantities of HFC-245fa and of HFC-365mfc used are based on information provided by industry experts. The data on domestic consumption of C_6F_{14} were obtained from data collected pursuant to the Environmental Statistics Act (UStatG, 2005).

Since the data are confidential, they are reported under CRF 2.H.3.

4.7.5.3 Uncertainties and time series consistency (2.F.5)

The uncertainties for the solvents subcategory have been systematically quantified. The figures on solvents consumption are obtained directly from the individual companies concerned. The uncertainties for the emissions (U_{min}/U_{max}) are thus very low and assumed to be 2%. C_6F_{14} is an exception. According to an estimate by experts, the uncertainties for the emissions (U_{min}/U_{max}) of that substance amount to 20%.

Prior to 2006, the emissions stayed at a constantly low level. Between 2006 and 2008, a sudden sharp emissions increase occurred, triggered in part by the onset of use of C_6F_{14}. Since 2009, the quantities used – and thus the emissions – have remained at a relatively constant low level.

4.7.5.4 Category-specific recalculations (2.F.5)

No recalculations were required.

4.7.5.5 Category-specific planned improvements (2.F.5)

No further improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.7.6 Other applications that use ODS substitutes (2.F.6)

Germany reports no emissions in this category.

4.7.7 Category-specific QA/QC and verification (2.F all)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

The data for the current report year, like the data for most of the previous years, were collected by an external expert working on a research project commissioned by the German Environment Agency.

For the most part, quality assurance was carried out by the external expert. In addition, the data are checked by the relevant German Environment Agency specialists upon receipt.

In 2011, the entire sector of F gas emissions was subjected to voluntary trilateral review. Experts from the UK, Germany and Austria reviewed "each other's" F gas inventories. The aims of the review were to exchange information regarding country-specific methods for preparing F gas inventories; to learn about the institutional and legal regulations for F gas inventories in each country; to identify obstacles for the preparation of complete, precise inventories; and to discuss differences and similarities between the various methods used to prepare F gas inventories. The meeting helped all three countries to review their methods for relevant emission calculation. In addition, the transparency, completeness and precision of the various inventories were assessed. That review had a positive outcome, namely that Germany has a good F gas inventory. As a result, no recommendations were issued to improve on the German F gas inventory.

No data sources are available to review the F gas quantities gathered for emissions reporting as a basis for verification other than the data provided by the Federal Statistical Office, the data collected by the research contractor and the data reported by the companies. Comparisons with other countries do not show any need for improvements. The emission factors either correspond to the default emission factors provided in the 2006 IPCC Guidelines or are of the same order of magnitude as the values used by other countries.

4.8 Other product manufacture and use (2.G)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
-/-	2 G, Other Product Manufacture and Use		CH_4	5.07	5.07	16.73	5.07	5.07
-/2	2 G, Other Product Manufacture and Use		N_2O	C	C	C	C	C
L/T	2 G, Other Product Manufacture and Use		SF_6	C	C	C	C	C
-/-	2 G, Other Product Manufacture and Use		HFC-134a	0.00	0.00	0.18	0.01	0.00

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
-/-	2 G, Other Product Manufacture and Use		HFC-245fa	0.00	0.00	21.54	0.01	0.00
-/-	2 G, Other Product Manufacture and Use		HFC-365mfc	0.00	0.00	0.71	0.00	0.00
-/-	2 G, Other Product Manufacture and Use		$C_{10}F_{18}$	C	C	C	C	C

Gas	Method used	Source for the activity data	Emission factors used
CO_2, CH_4, N_2O, SF_6, PFC, HFC	cf. Table 198	cf. Table 198	cf. Table 198

The category "Other product manufacture and use" is a key category for SF_6 emissions in terms of level and trend. For N_2O emissions, it is a key category based on the method 2 analysis.

The category 2.G includes SF6 from electrical equipment (2.G.1), SF6 and PFCs from other product use (2.G.2), use of N_2O (2.G.3), use of F gases in ORC systems (2.G.4 ORC systems) and container fumigation (2.G.4 Container fumigation), and CO_2, CH_4, N_2O and particulate emissions from use of charcoal (2.G.4 Charcoal). With regard to use of cigarettes (2.G.4) and fireworks (2.G.4), emissions of dust, precursor substances and heavy metals are reported. In the interest of more accurate data collection, these subcategories are further divided, to some extent, in the following section.

The methods, emission factors and service lives on which the emission calculation is based are listed in Table 198.

Table 198: Overview of the methods and emission factors used for the current report year in the categories 2.G.1 (Electrical equipment), 2.G.2 (SF_6 and PFCs from other product use) and 2.G.4 (ORC systems, container fumigation and charcoal use)

	SC	Method	Gas			Service life	Emission factor (dimensionless)		
			SF_6	HFC	PFC	[years]	Production	Use	Disposal
Electrical equipment	**2.G.1**								
Switchgear and control gear	**2.G.1a**	Tier 3	SF_6			40	0.02 (CS)	0.001-0.01 (CS)	0.015 (CS)
SF_6 and PFC from other product use	**2.G.2**								
AWACS	**2.G.2a**	CS	SF_6				NO	1 (CS)	NO
Particle accelerators	**2.G.2b**	CS					0.15-1 (CS)	0.006-0.003 (CS)	NO
Sound-proof glazing	**2.G.2c**	Equ. 3.24 ff					0.33 (D)	0.01 (D)	1 (D)
Adiabatic behaviour	**2.G.2d**								
- Car tyres		Equ. 3.23	SF_6				NO	NO	1 (D)
- Athletic shoes		Equ. 3.23	SF_6		PFC		NO	NO	1 (D)
Other	**2.G.2e**								
- Trace gases		Equ. 3.22	SF_6				NO	1 (D)	NO
- Welding		CS	SF_6				NO	1 (CS)	NO
- Optical glass fibre		CS	SF_6				C	NO	NO

	SC	Method	Gas	Service life	Emission factor (dimensionless)		
- Medicines and cosmetics		CS	PFC	-	NO	1 (D) 0.95-0.998 (CS)	NO
N_2O use	**2.G.3**						
Semiconductor manufacturing		D	N_2O		C		
Narcotic applications		D				1	
Explosives		D				0.1036 kg/t	
Spray cans		D				1	
Other	**2.G.4**						
ORC systems	**2.G.4a**	CS	HFC PFC	20-30 (CS)	0.02 (CS)	0.04 (CS)	0.2 (CS)
Container fumigation	**2.G.4a**	CS	SO_2F_2	-	NO	1 (CS)	NO
Charcoal use	**2.G.4b**	Tier 1	CO_2, CH_4, N_2O and dust		C	C	

4.8.1 Electrical equipment (2.G.1)

This category consists primarily of use of electrical equipment (2.G.1), which is further subdivided into high-voltage (HV), medium-voltage (MV) and other electrical equipment.

4.8.1.1 Category description (2.G.1)

In electricity transmission and distribution, SF_6 is used primarily as an arc-extinguishing and insulation gas in switchgear and control gear and equipment in high-voltage (52-380 kV) and, increasingly, medium-voltage (10-52 kV) networks. In addition, it is used in production of components installed in gas-insulated indoor switchgear and control gear (instrument transformers, bushings) or supplied directly to operators (high-voltage instrument transformers for outdoor installations).

As a result of including additional SF_6 applications for the first time in report year 2002, the time series shows a marked increase in emissions in 2002. In report year 2005, new companies were included in reporting, especially in the new category "Other electrical equipment". Due to the economy as a whole, more systems were sold in 2005 and 2006. Absolute emissions have decreased in general, which is primarily the result of reduced emissions from the high-voltage sector until 2020. Emissions from medium-voltage systems and other equipment have been increasing, partly as a result of the continually growing numbers of systems in service. The total emissions remained constant in 2022. The industry, represented by producers' and operators' associations and the SF_6 producer, has agreed to report annually on a voluntary basis.

4.8.1.2 Methodological issues (2.G.1)

The emission factors used are shown in Table 198.

The emissions figures are based largely on a mass balance, in combination with emission factors for sub-areas in which the technical measurement limits for mass-balancing have been reached or in which mass-balancing would necessitate unreasonably high costs.

The method used is based on the "Tier 3 Hybrid Life-Cycle Approach" described in the 2006 IPCC Guidelines (IPCC (2006a): Vol. 3, Chapter 8.2.2).

Usage emissions

The stocks of SF_6 in all electrical equipment for a given year n change annually by the balance of new additions and removals. Some removals (high voltage) have been recorded since 1997; with an estimated service life of at least 40 years, the increased retirement of first-generation high-voltage switchgear and equipment has only taken place in recent years.

Three specific aspects must be taken into account in reporting when it comes to switchgear:

- Calculation of the final stocks for a given year n is based on the final stocks for the previous year (n-1); this does not extend back to the first year of service, however. This backward extension, an otherwise customary procedure, is not used for switchgear because operators/manufacturers estimated the SF_6 stocks in service for 1995, broken down into high-voltage and medium-voltage categories.
- In the area of high-voltage switchgear and control gear, stocks and emissions are determined by directly surveying around 100 operators. In such surveys, the operators are asked to provide data on their current stocks of SF_6 in electrical equipment (gas-insulated HV switchgear (GIS), circuit breakers, outdoor instrument transformers). Emission factors determined on the basis of reference systems are then applied to such stocks data.
- The group of operators of medium-voltage switchgear is very numerous and highly diverse. It is thus not feasible to conduct direct surveys. Manufacturers of medium-voltage switchgear have themselves taken responsibility for updating their domestic stocks data on the basis of their sales data. The emissions can be determined in that the systems are practically maintenance-free and, by definition (IEC 62271-1; they are “sealed for life” as hermetically sealed pressurised systems pursuant to IEC), require no refilling throughout their entire service life. The emissions are minimal (usually occurring only as the result of external influences). The stocks are calculated on the basis of the previous year’s stocks, plus new deliveries and less decommissioned systems.

Disposal emissions

As switchgear and control gear have long service live (> 40 years), and because the first use of SF_6 dates back to the late 1960s, disposal emissions were very low until 2004. For the period until 2004, therefore, the quantities of SF_6 in old (high-voltage and medium-voltage) switchgear and control gear that were scheduled for disposal have only been roughly estimated (at a constant 3 t/a). As of the 2005 report year, amounts for disposal from systems removal were determined precisely for the first time by the relevant associations. This also applies to emissions from disposal, which prior to 2005 were estimated at 0.06 t.

Activity data

As part of manufacturer’s voluntary commitment, their annual consumption of electrical equipment and stocks of medium-voltage switchgear and control gear are reported to the German Environment Agency by the German Electrical and Electronic Manufacturers’ Association (ZVEI), while stocks of high-voltage switchgear and control gear, outdoor instrument transformers, gas-insulated lines and transformers are reported by the Forum network technology/network operation (FNN) in the Association for Electrical, Electronic & Information Technologies (VDE) and, since 2004, by the Association of the Energy and Power Generation Industry (VIK). Participants in the voluntary commitment jointly determine quantities of decommissioned units.

Table 198 shows the inventory data for the current year, broken down by subcategory. The sum total for electrical equipment for energy transmission and distribution aligns with the data in Table 2 (II)F, Sheet 2, category 2.G.1 in the CRF.

Table 199: 2024 inventory data for category 2.G.1, including subcategories

Category 2.G.1: Electrical equipment for energy transmission and distribution	Activity data			Emissions	
	Annual consumption, production	Stocks	Decommissioned (tonnes of SF_6)	Production	Operation
Electrical equipment for energy transmission and distribution 2.G.1 (total), including:	632	3,549	10.7	2.4	6.7
MV switchgear and control gear *	216	1,654	1.6	0.1	1.6
HV switchgear and control gear **	290	1,416	9.0	0.8	3.7
Other electrical equipment ***	126	480	0	1.8	1.3

IE = Included in "HV switchgear and control gear"; marginal

Explanatory remarks:

* Hermetically sealed pressurised systems pursuant to IEC 62271-1 for the range 1kV to 52 kV; also known as "sealed for life" systems

** Sealed pressurised systems pursuant to IEC 62271-1 for the range above 52 kV

*** Gas-insulated transformers: marginal residual stocks in the network; (no production emissions) + high-voltage instrument transformers for outdoor installation (all emissions categories) + gas-insulated lines (GIL) (all emissions categories) + high-voltage bushings (only production emissions) + medium-voltage cast-resin instrument transformers (only production emissions) + testing of medium-voltage components (only production emissions) + 1,000V capacitors (only production emissions)

4.8.1.3 Uncertainties and time series consistency (2.G.1)

Since there is only a small number of manufacturers of electrical equipment (including bushings and instrument transformers), the consumption data, and the new-additions and decommissioned-units figures, are highly reliable. This holds all the more in that such data and figures are based on internal accounting, and that fill amounts are determined with great precision and then noted on device name plates. The uncertainty here is around ±5%.

Determination of emissions is more difficult, since the plants typically concerned have several different emissions sources, each quite small. Gas losses occur in filling of devices, in testing, in opening of products that fail to pass quality inspections, in product development, etc. On the other hand, all domestic plants proceed in accordance with a standardised questionnaire that lists all possible emissions sources and that is checked for correctness during surveys. For this reason, and because there are only a few manufacturers, the precision of data collection ultimately depends on the precision of the relevant measurements. The resulting figures lie within ±10% of the estimates.

Emissions from operations in the high-voltage sector are determined by selected operators by monitoring of annual refilling of reference systems (refills are carried out when levels fall below 90% of the desired charge, and the devices themselves normally display these fill requirements as soon as they occur). This method can be considered very reliable, i.e. the deviations from the actual value are about ±5%. All surveys to date have produced similar results for emissions rates; all results are within a range of 0.55 to 0.88%. The one-time peak in emissions rate for high-voltage switchgear and control gear that occurred in 2004 is the result of specific circumstances, mainly the simultaneous refilling of old, older-model systems that were less well-sealed.

In the year 2000, a decrease with respect to the previous year occurred in high-voltage in-service stocks and, thus, in emissions, both of which had been increasing since 1995. For in-service stocks, the decrease amounted to over 25 t, while for emissions it amounted to 0.85 t. That decrease, which was due to trends in gas-insulated HV switchgear (GIS) (600 to 567 t), cannot be explained as the result of decommissioning removals since the role of such removals is still insignificant. According to the association of network operators (VDN), which carried out the surveys at the time, the underlying problem is both statistical and organisational in nature. At the end of the 1990s, electricity market liberalisation led to profound operator regrouping (through mergers and changes in ownership of various parts of companies). Along with those changes, personnel assignments related to electrical equipment in service were repeatedly changed. As a result, it is possible that double-counting occurred in 1999 and that some operating equipment was not counted in 2000. In light of experience gained in recent years, the uncertainty today is assumed to be in the order of ±5% for high-voltage stocks.

4.8.1.4 Category-specific recalculations (2.G.1)

No recalculations were required.

4.8.1.5 Category-specific QA/QC and verification (2.G.1)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

As in previous years, the data for the current report year were reported to the German Environment Agency as part of a voluntary agreement by the relevant producer and operator associations and the SF_6 producer.

For the most part, quality assurance was carried out by the associations. In addition, the data are checked by the relevant German Environment Agency specialists upon receipt.

In 2011, the entire sector of F gas emissions was subjected to voluntary trilateral review. Experts from the UK, Germany and Austria reviewed “each other’s” F gas inventories. The aims of the review were to exchange information regarding country-specific methods for preparing F gas inventories; to learn about the institutional and legal regulations for F gas inventories in each country; to identify obstacles for the preparation of complete, precise inventories; and to discuss differences and similarities between the various methods used to prepare F gas inventories. The meeting helped all three countries to review their methods for relevant emission calculation. In addition, the transparency, completeness and precision of the various inventories were assessed. That review had a positive outcome, namely that Germany has a good F gas inventory. As a result, no recommendations were issued to improve on the German F gas inventory.

No data sources are available to review the F gas quantities gathered for emissions reporting as a basis for verification other than the data provided by the associations. Comparisons with other countries do not show any need for improvements. The emission factors are of the same order of magnitude as the factors used in other countries.

4.8.1.6 Category-specific planned improvements (2.G.1)

No improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.8.2 SF_6 and PFC from other product use (2.G.2)

This category comprises the applications Military AWACS (2.G.2.a), Particle accelerators (2.G.2.b), Sound-proof glazing (2.G.2.c), Adiabatic properties: car tyres and athletic shoes (2.G.2.d), Other: trace gas, welding, optical glass fibres and medical and cosmetic applications (2.G.2.e).

4.8.2.1 Military AWACS maintenance (2.G.2.a)

4.8.2.1.1 Category description (2.G.2.a)

SF_6 is used as an insulating medium for radar in Boeing E-3A (NAEWF; formerly, AWACS) aircraft, which are large military surveillance aircraft. It is used to prevent electrical arcing to the antenna in waveguides with high voltages exceeding 135 kV. Ongoing emissions are relatively high since SF_6 is released to equalise pressure as aircraft climb.

4.8.2.1.2 Methodological issues (2.G.2.a)

The emissions data for report years until 2001 are based on estimates that are themselves based on a survey from the year 1996. For this reason, the accuracy of the emissions data for the years 1997 to 2001 is lower than in subsequent years. For report year 2002, a new survey of consumed quantities was carried out. This showed a significant increase over relevant quantities in report year 2001. As of report year 2006, the quantities used are determined by surveys conducted by the Federal Statistical Office (UStatG, 2005).

For the SF_6 emissions of AWACS, an emission factor of 100% of the purchase is initially assumed. According to the Federal Ministry of Defence, service equipment for SF_6 was purchased in 2006, making it possible to reduce the emission factor as of that year. It was agreed that this reduction should be reviewed every 5 years.

The emissions decreased until 2016. Since then, they have been subject to slight fluctuations, but are relatively constant. Data on AWACS maintenance are reported under CRF 2.H.3 since the data are confidential.

4.8.2.2 Particle accelerators (2.G.2.b)

4.8.2.2.1 Category description (2.G.2.b)

The insulating gas SF_6 is used to protect human safety and to safeguard parts of equipment (to guard against burning of insulators). In relevant applications, high-voltage parts are insulated by being enveloped with the gas (which guards against electrical arc flashes between high-voltage parts and equipment walls).

In some cases, such protection can also be achieved by using other gases (such as nitrogen, nitrogen/CO_2 mixtures), by providing adequate physical distance (air insulation) or by enclosing equipment in concrete walls. The criteria entering into decisions for or against SF_6 as an insulating gas for equipment (either by itself or as an additive) include technical circumstances, design considerations and voltage levels. For this reason, the quantities of SF_6 that non-standardised equipment and components require will vary. The SF_6 charge in any given unit or system thus depends on the unit's or system's setup, and not on its size class (measured in MV, for example).

The SF_6-insulated particle accelerators in use differ in terms of size, design and function. High-voltage accelerator systems (0.3 to more than 23 MV) are used by university institutes, research groups and industry. In these high-voltage systems, the accelerator and the high-voltage source (Van de Graaff generator or a more compact high-voltage generator with cascaded diodes) are located in a tank that is insulated with SF* or a mixture containing SF_6, which may be

pressurised. These tanks must be opened when equipment requires adjustment or repair. In these cases, the insulating gas is pumped into reserve tanks. SF_6 losses occur during such pumping, and they occur whenever overpressure valves of accelerator or reserve tanks are activated. Research accelerators, which are operated under varying conditions, have to be opened more frequently than industrially used electron accelerators do.

In industry, low-voltage devices with less than 0.3 MV are also used. In low-voltage systems, the depth to which electrons penetrate materials being processed is considerably lower than the depths occurring in connection with high-voltage systems. In industry, "electron-beam tools" are used for cross-linking of polymers, primarily polymers in cable and wire insulation. Low-voltage systems with lower accelerator voltages require less shielding (= smaller quantities of SF_6) than high-voltage systems do.

Yet another relevant category consists of radiation therapy devices in medical facilities. In cancer treatment with electron or photon radiation, industrially preset particle accelerators are used. These accelerators accelerate particles in waveguides that are filled with the insulating gas SF_6 to prevent electrical flashovers. Prior to 1996, CFCs were used in such equipment.

SF_6 is also used as an insulating gas in large electron microscopes (with accelerator voltages >100 kV) and in electron-beam lithography systems. These devices, which are merged in the category "other equipment", have now been covered for the first time for the year 2010.

In general, the following applies: the SF_6 consumption tied to initial charging and recharging of equipment, and to replacements of emissions, depends on equipment size, pressure conditions and operating conditions.

4.8.2.2.2 Methodological issues (2.G.2.b)

In early 2004, Öko-Recherche was commissioned by the German Environment Agency to carry out a full survey of particle accelerators in the country to update the data, some of which were last updated in 1996. In the process, both users and producers of the devices/systems were queried. The questions posed had to do with the quantities of SF_6 in their devices and with refills of SF_6 carried out during the last seven years.

The CSE assumes responsibility for structuring the survey. For all five relevant categories, it contains annual data on SF_6 stocks and replacements to compensate for emissions. The emissions in question include both ongoing emissions and filling and disposal losses.

For the 2011 report year, another exhaustive survey was carried out. For the first time, data on electron microscopes were gathered (Schwarz et al., 2012). Only very small numbers of equipment changes – additions or removals, depending on the application – were seen. For this reason, constant levels of usage are assumed. Radiation therapy is an exception. In this area, the quantities used have been increasing slightly.

In the years 2023/2024, another review of the system stocks was carried out. This review showed that some larger particle accelerators had been taken out of service, e.g. at the University of Heidelberg in 2012 and 2020 at the University of Munich in 2020). The resulting changes to the stocks and emissions are provided in a table in the recalculations section.

Table 200: SF_6 stocks in particle accelerators in five application sectors as of 1995, in [t]

User category	1995	2005	2015	2024
(1) University institutes	30.70	26.897	26.89	8.210
(2) Research institutions	19.55	19.30	6.30	6.28

User category	1995	2005	2015	2024
(3) Industry (high-voltage)	11.61	19.04	16.54	16.54
(4) Industry (low-voltage)	1.6	1.55	1.42	1.58
(5) Institutions for radiation therapy	0.16	0.18	0.21	0.24
Total (1-5)	63.63	66.95	51.38	32.87

When tanks of high-volume high-voltage systems are opened, the SF_6 in the tanks is pumped out and then later returned to the tanks. This can entail considerable gas losses. Other particle accelerators (particularly the radiotherapy devices) are also serviced multiple times each year, with the gas being completely removed. In recent years, a number of devices have been retrofitted so that opening the SF_6 tanks is no longer required, or extraction equipment has been used more frequently so as to reduce emissions.

The reported recharges also include compensations for emissions due to accidents.

Table 201: SF_6 emissions from particle accelerators broken down by five areas of application as of 1995, in [t]

User category	1995	2005	2015	2024
(1) University institutes	1.859	1.514	1.309	0.304
(2) Research institutions	1.259	1.196	0.796	0.617
(3) Industry (high-voltage)	0.958	1.593	1.543	0.538
(4) Industry (low-voltage)	0.020	0.020	0.017	0.018
(5) Institutions for radiation therapy	0.245	0.422	0.494	0.516
Total	4.441	4.746	4.16	1.995

4.8.2.3 Sound-proof glazing (2.G.2.c)

4.8.2.3.1 Category description (2.G.2.c)

Since 1975, SF_6 has been used to enhance the soundproofing properties of multi-pane windows. In such use, the gas is inserted into the spaces between the panes. The disadvantages of such use are that it reduces windows' thermal insulation performance and that SF_6 is a potent greenhouse gas. The higher priority given to thermal insulation, e.g. by the Thermal Insulation Ordinance (Wärmeschutzverordnung), along with improved SF_6-free window technologies have led to a reduction in use of SF_6 in this application since the mid-1990s.

In Germany, soundproof windows filled with gas have been produced by numerous companies. Exports of assembled windows play no significant role.

Since 4 July 2007, a ban has been in force in the EU on sale of windows for residential use that are filled with fluorinated greenhouse gases. As of 4 July 2008, that ban also applies to other windows. Current and future emissions in this category therefore come primarily from open waste management of old windows, which is assumed to occur an average of 20 years (10% of windows) and 25 years (90% of windows) after the windows were filled. For this reason, total emissions are expected to continue growing until the year 2019.

4.8.2.3.2 Methodological issues (2.G.2.c)

Emissions occur during filling of spaces between panes as a result of overfilling (production emissions), during use (use emissions) and during disposal (disposal emissions). Emissions are calculated using Equations 3.24 to 3.26 of IPCC-GPG (Penman et al., 2000) based on new domestic consumption, average annual stocks and remaining stocks 25 years ago.

The time series for soundproof glazing begin in 1975 since the filling quantities of the year 1975 are of relevance for emissions from units in service in 1995. These data, which were reconstructed with the help of industry experts in 1996, were published in 2004 for the first time.

Due to an error in the calculation method, a recalculation had to be made in that year for the entire time series as of 1995.

Emission factors

According to expert information from window pane and gas-filling equipment manufacturers, industry experts and a scientific institute, one-third of the SF_6 used in the process of pumping SF_6 into spaces between window panes escapes. Consequently, the $EF_{production}$ is 33% with respect to new annual consumption.

This emission factor is obtained in the following manner: in use of both manual filling devices and automatic gas-filling presses, gas-swirling in the space between the panes cannot be avoided. As a result, the escaping gas consists not only of the air originally between the panes, it also includes an air-SF_6 mixture. More and more mixed gases escape as the filling process progresses. The gas loss, known as overfill, ranges from 20 to 60% of the amount filled. The smaller the window concerned, the greater the overfill's relative importance. On average, i.e. throughout the entire spectrum of filled windows of all shapes and sizes, the overfill amounts to 50% of the amount actually contained between the panes. This corresponds to one-third (33%) of the relevant consumed amounts. This emission factor continues to be used since neither filling technologies nor the range of window geometries have changed.

A DIN standard (DIN EN 1279-3, DIN 2003) specifies an upper limit of 10 per mil for annual losses of filled gas from panes' peripheral seals. This value also takes account of gas losses resulting from glass breakage in transport, installation and use, as well as from age-related increasing leakage from peripheral seals. The result is an emission factor EF_{use} of 1% for the average SF_6 stocks that have accumulated since 1975 and that are in place in year n.

Finally, disposal losses are incurred at the end of a window's service life, or an average of 25 years after the window was filled. For this reason, emissions from disposal do not have to be taken into account until the year 2000.

Since a window loses 1% of its gas year on year, only part of a window's original quantity of gas is emitted during disposal. However, as there is no gas collection during disposal, the emissions level is 100% ($EF_{disposal} = 1$).

Activity data

The new annual consumption was determined by a top-down survey (domestic sales by the gas industry).

Since the 2006 report year, the data have been obtained by the Federal Statistical Office by surveying gas sellers with regard to SF_6 sales figures (UStatG, 2005).

4.8.2.4 Adiabatic behaviour - car tyres (2.G.2.d)

4.8.2.4.1 Category description (2.G.2.d)

Beginning in 1984, car tyres were filled with SF_6 for image reasons (the resulting improved pressure constancy is not relevant in practice). The peak consumption year was 1995. In that year, over 500 of the some 3,500 sales outlets in Germany had equipment for filling tyres with SF_6 gas. Since SF_6 is a powerfully acting greenhouse gas, many tyre dealers began filling tyres with nitrogen instead. This practice led to a considerable reduction in use of SF_6. Sales of new car tyres filled with fluorinated greenhouse gases have been banned in the EU since 4 July 2007. No further emissions occur.

4.8.2.4.2 Methodological issues (2.G.2.d)

For the sake of simplicity, gas emissions during a tyre's service life are not taken into account; as a result, emissions occur only when tyres are removed. Based on a planned service life of about 3 years and the fact that there is no foreign trade with filled tyres, emissions follow domestic consumption for filling, with a three-year time lag (Schwarz & Leisewitz, 1996). The emissions are calculated using Equation 8.19 of the 2006 IPCC Guidelines (Vol. 3).

Emission factors

The very small losses incurred in the filling of tyres are not taken into account. Since all of the SF_6 escapes when tyres are removed, $EF_{disposal} = 1$.

Activity data

To determine annual consumption quantities, the Federal Statistical Office (UStatG, 2005) surveyed gas suppliers to ascertain their domestic sales to tyre dealers and car service centres.

4.8.2.5 Adiabatic behaviour - Athletic shoes (2.G.2.d)

4.8.2.5.1 Category description (2.G.2.d)

SF_6 was used in the soles of sport shoes to enhance cushioning. As of 2004, SF_6 was replaced by PFC-218 (C_3F_8) whose use was in turn discontinued in 2006. Today, nitrogen is usually used for this purpose. The sale of footwear produced with fluorinated greenhouse gases has been prohibited in the EU since 4 July 2006. No further emissions occur.

4.8.2.5.2 Methodological issues (2.G.2.d)

The emissions were calculated using Equation 8.9 of the IPCC Guidelines (IPCC, 2006a). Production emissions occurred only in foreign countries. Current emissions were not determined. Due to a commitment to uphold confidentiality, data on athletic shoe soles are reported under CRF 2.H.3.

Emission factors

Manufacturers have not reported production emissions.

It is assumed that no emissions occur during use.

During disposal, emissions may be equated with input quantities ($EF_{disposal} = 1$). In addition, in a procedure similar to the IPCC method for car tyres, a time lag of three years is assumed (IPCC (2006a): Vol. 3, Equation 8.19).

Activity data

The filled quantities are based on manufacturers' European sales figures. These figures are broken down by Germany's population to obtain figures for Germany. While such data have been

available to the German Environment Agency since the 2001 report year, for reasons of confidentiality they are reported only in aggregate form under CRF 2.H.3.

4.8.2.6 Other: Trace gas (2.G.2.e)

4.8.2.6.1 Category description (2.G.2.e)

SF_6 is a stable and readily detectable trace gas, even at extremely low concentrations. It is used by research institutions to investigate ground-level and atmospheric airflows and gas dispersions along with water currents. It is also used for the purpose of testing laboratory fume hoods.

As of report year 2007, use of SF_6 as a trace gas was reduced considerably with respect to earlier years.

4.8.2.6.2 Methodological issues (2.G.2.e)

The quantities used have been estimated by experts.

Emission factors

An "open use" is assumed, i.e. annual new inputs are emitted in full in the same year and treated as consumption for production ($EF_{production}$ = 1). No recovery takes place.

Activity data

In 1996, total domestic use was estimated by experts of all relevant research institutions. Since then, use levels have been estimated by one expert at three-year intervals. These assessments indicate that the quantities used vary only slightly. The figures on use of SF_6 in the years 2007 to 2015 were upwardly corrected in 2017 to take account of its first-time inclusion in the inventory for testing of laboratory fume hoods.

4.8.2.7 Other: Welding (2.G.2.e)

4.8.2.7.1 Category description (2.G.2.e)

According to gas suppliers, use of SF_6 in welding began in 2001. SF_6 is used as a protective gas when welding metal. Since there is only one user in Germany, the data are subject to strict confidentiality.

4.8.2.7.2 Methodological issues (2.G.2.e)

Emissions occur only during use. Because they are confidential, data on consumption and emissions in connection with welding are reported under CRF 2.H.3.

Emission factors

No reliable data are available on SF_6 decomposition during use. Experts estimate that the entire relevant input quantities of SF_6 are emitted completely into the atmosphere in full during use. For this reason, consumption and emissions are considered equal for welding applications. The emission factor for welding is specified as EF_{use} = 1.

Activity data

The annual amounts consumed are determined by querying the company that uses SF_6 for welding purposes.

4.8.2.8 Other: Optical glass fibre (2.G.2.e)

4.8.2.8.1 Category description (2.G.2.e)

Use of SF_6 in the production of optical glass fibre began in 2002. In such production, SF_6 is used for fluorine doping. There are only a few such manufacturers in Germany.

4.8.2.8.2 Methodological issues (2.G.2.e)

As the emission factor is based on confidential data, the emissions related to the production of optical glass fibres are reported confidentially under CRF 2.H.3.

Emission factors

The 2006 IPCC Guidelines (IPCC (2006a): Vol. 3) do not contain any information on the use of SF_6 in the production of optical glass fibre. To date, experts have estimated the emission factor to be 70% ($EF_{production}$ = 0.7). Measurements have yielded a considerably lower emission factor, however. For this reason, the emission factor has been reduced considerably. It is confidential, however. In 2018, the time series for the emissions was recalculated retroactively for all years.

Activity data

To determine annual consumption quantities, the Federal Statistical Office (UStatG, 2005) surveyed gas suppliers to ascertain their domestic sales. They have been increasing since 2001, with slight fluctuations.

4.8.2.9 Other: Medical and cosmetic applications (2.G.2.e)

4.8.2.9.1 Category description (2.G.2.e)

In Germany, fluorinated greenhouse gases are used in medical metered dose inhalers (category 2.F.4) and in various medical and cosmetic applications.

Since 2000, perfluorodecalin ($C_{10}F_{18}$, PFC-9-1-18) has been used in pure form in ophthalmology and in research. In ophthalmology, perfluorodecalin is used in retinal surgery within the eye, especially in treatment of retinal detachments, retinal tears, proliferative vitreoretinopathy, etc. Perfluorodecalin is also used in considerably smaller quantities for research into organ preservation during transplants, as a contrast agent in diagnostic imaging techniques (magnetic resonance tomography, ultrasound) and as an oxygen carrier in cell cultivation.

Since 2012, perfluorodecalin has also been used as an ingredient in cosmetic products (skin care; nail care). In such products, it serves as a carrier or storage medium for oxygen. According to manufacturers the perfluorodecalin concentrations used in such products amount to 0.1%.

In Germany, hydrofluoroethers (HFEs) are the standard anaesthetic gases used for inhalative anaesthesia in human medicine. They are used in some 9 million operations annually. Isoflurane, a halogenated ether (HCFE-235da2, CHF_2-O-CHCl-CF_3), has been used since 1985. Desflurane (HFE-236ea2, CHF_2-O-CHF-CF_3) and sevoflurane (HFE-347mmz1, CH_2F-O-CH(CF_3)$_2$), which have been used since 1996, currently have a combined market share of about 90%. In relevant uses, the hydrofluoroethers are vaporised in special equipment. They are administered in concentrations of 1 to 6% in a carrier gas consisting of oxygen and nitrous oxide (N_2O). On average, 8.2 g of isoflurane, 32.6 g of desflurane or 11.4 g of sevoflurane are used per operation. The quantities of the various hydrofluoroethers that are used per operation vary because the concentrations of narcotic gases provided through respirators with carrier gases differ wildly in terms of achieving the necessary anaesthetic effect.

As recommended by the 2006 IPCC Guidelines, medical and cosmetic applications of PFCs are placed in category 2.G.2.

4.8.2.9.2 Methodological issues (2.G.2.e)

In ophthalmological and research applications in which it is used in pure form, all of the perfluorodecalin used is emitted. The perfluorodecalin in cosmetic products is also emitted completely when the products are used (EF_{use} = 1).

Hydrofluoroethers used as inhalation anaesthetics are collected during operations and then vented into the atmosphere from central points. During operations, the various hydrofluoroethers that patients inhale are not exhaled in unchanged form; to some extent, and to varying degrees, they are metabolised in patients' bodies. In each case, the gas-specific emission factors amount to 100% minus the metabolisation rate.

No production emissions occur in the case of medical and cosmetic applications, since no products are produced in Germany.

In the case of perfluorodecalin, the emissions from use are calculated using Equation 9 based on the quantities of perfluorodecalin sold in bulk and in cosmetic products. In a departure from the method proposed by the 2006 IPCC Guidelines for calculation of "prompt emissions" (Equation 8.23), it is assumed that all of the quantities sold in a given year are emitted in full in the same year, i.e. the emissions are not calculated as the sum of half the purchases (sales) of the previous year and half the purchases (sales) of the current year. This approach is justified in that the time between sale and use tends to be very short.

Emissions from use of hydrofluoroethers used as anaesthetic gases are calculated with Equation 9 based on the quantities used in Germany. The 2006 IPCC Guidelines provide no instructions for calculating such emissions.

Since the perfluorodecalin and the hydrofluoroethers are emitted in full when used, no disposal emissions have to be reported.

As they are confidential, data on consumption and emissions in connection with perfluorodecalin are reported under CRF 2.H.3.

Emissions of hydrofluoroethers are not subject to reporting obligations. Germany voluntarily reports HFE emissions "additional greenhouse gases" pursuant to the recommendations of the 2014 UNFCCC Reporting Guidelines ((UNFCCC, 2014), FCCC/CP/2013/10/Add.3, Decision 24/CP.19). These emissions are aggregated with other emissions not subject to reporting obligations and listed in Chapter 4.9.3. The CRT tables do not contain any data on emissions that are voluntarily reported.

Emission factors

The emission factors used are the result of consulting experts and listed in Table 198. The EF_{use} for all medical and cosmetic applications of perfluorodecalin is 100%. With regard to the hydrofluoroethers used as inhalation anaesthetics, the EF_{use} is 99.8% for isoflurane and desflurane, and 95% for sevoflurane.

In agreement with IPCC specifications ((IPCC, 2006a), p. 8.32), a 100% emissions level in the use of perfluorodecalin (EF_{use} = 100%) is assumed. In a departure from the Guidelines, Germany applies a service life of only one year in this area.

The 2006 IPCC Guidelines do not provide any instructions for the use of hydrofluoroethers as inhalation anaesthetics.

Activity data

The annual imports of $C_{10}F_{18}$ to Germany for use in ophthalmology and research were disclosed by the manufacturer F2 Chemicals, UK, on a confidential basis.

The quantities of cosmetic products containing $C_{10}F_{18}$ that are imported to Germany were disclosed on a confidential basis by the trading enterprise P2 cosmetics, which sells the products in Germany.

The quantities of hydrofluoroethers that are used as inhalation anaesthetics were determined by surveying industry experts (hospitals, manufacturers of anaesthesia equipment) and by way of a research project into the corresponding literature (Gschrey et al., 2015). For subsequent years, the relevant quantities are estimated on the basis of the annual numbers of operations carried out in Germany.

4.8.2.10 Uncertainties and time series consistency (2.G.2 all)

The uncertainties for this category have been systematically quantified.

In the case of sound-proof glazing, since 2006 the annual new consumption data from the top-down survey on commercial sales data have been compared with data from the Federal Statistical Office's annual surveys (UStatG, 2005). This procedure, which may be considered reliable and complete, has increased data reliability. Due to the wide range of influencing factors, the $EF_{production}$ cannot be measured reliably. Estimates from surveying ten industry experts (window manufacturers, suppliers of filling devices and one scientific institute) in 1996 and 1999 indicate that the mean filling loss ranges between 30 and 40%. A 1% rate is considered realistic for ongoing gas losses.

With regard to athletic shoes, the filled quantities broken down by Member State is subject to considerable uncertainties in spite of the good quality of data available for the EU .

In the case of medical applications, the data on the quantities of perfluorodecalin used are considered to be of good quality since they were obtained directly from the manufacturer (F2 Chemicals Ltd, UK) and sole exporter of perfluorodecalin to Germany. The uncertainties for cosmetic products are larger, since Germany's market for cosmetics is extremely dynamic, with the result that no reliable statistics for this purpose are available.

4.8.2.11 Category-specific QA/QC and verification (2.G.2 all)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

The data for the current report year, like the data for most of the previous years, were collected by an external expert working on a research project commissioned by the German Environment Agency or come from data collected in a survey by the Federal Statistical Office (UStatG, 2005).

For the most part, quality assurance was carried out by the external expert and by the Federal Statistical Office. In addition, the data are checked by the relevant German Environment Agency specialists upon receipt.

In 2011, the entire sector of F gas emissions was subjected to voluntary trilateral review. Experts from the UK, Germany and Austria reviewed "each other's" F gas inventories. The aims of the review were to exchange information regarding country-specific methods for preparing F gas inventories; to learn about the institutional and legal regulations for F gas inventories in each country; to identify obstacles for the preparation of complete, precise inventories; and to discuss differences and similarities between the various methods used to prepare F gas inventories. The meeting helped all three countries to review their methods for relevant emission calculation. In addition, the transparency, completeness and precision of the various inventories were assessed. That review had a positive outcome, namely that Germany has a good

F gas inventory. As a result, no recommendations were issued to improve on the German F gas inventory.

No data sources are available to review the F gas quantities gathered for emissions reporting as a basis for verification other than the data provided by the Federal Statistical Office, the data collected by the research contractor and the data reported by the companies. Comparisons with other countries do not show any need for improvements. The emission factors either correspond to the default emission factors provided in the 2006 IPCC Guidelines or are of the same order of magnitude as the values used by other countries.

The methods and data in connection with medical and cosmetic applications (subcategory 2.G.2.e) cannot be verified since no countries other than Germany report emissions in this area.

4.8.2.12 Category-specific recalculations (2.G.2 all)

The data on domestic consumption of hydrofluoroethers used as anaesthetic gases are determined on the basis of national data on operations on people. Recalculations are required annually since the corresponding national statistics are only available after data collection for the inventory has concluded. This regularly leads to changes in emissions from use for the relevant previous year. New research findings gave rise to the need to update the proportions of anaesthetic gases used in anaesthesia for the years 2013 to 2023. This resulted in changes to the usage amounts and emissions of isoflurane, desflurane and sevoflurane during those years. Since hydrofluoroethers are among the substances that are reported on a voluntary basis, no further quantification is carried out.

In 2.G.2.b Particle accelerators, a review of the system inventory and emissions resulted in the following recalculations:

Table 202: Recalculated SF_6 emissions from particle accelerators, in tonnes [t]

	2026 submission	2025 submission	Difference
1995	4.44	4.44	0.01
1996	4.65	4.65	0.01
1997	4.79	4.78	0.01
1998	4.90	4.90	0.01
1999	4.85	4.84	0.01
2000	4.85	4.98	-0.12
2001	4.71	4.83	-0.12
2002	4.76	4.89	-0.12
2003	4.77	4.88	-0.11
2004	4.73	4.89	-0.16
2005	4.75	4.91	-0.16
2006	4.76	4.92	-0.16
2007	4.77	4.93	-0.12
2008	4.79	4.95	-0.16
2009	4.61	4.96	-0.35
2010	4.61	4.13	0.48
2011	4.62	4.13	0.48

	2026 submission	2025 submission	Difference
2012	4.22	4.13	0.08
2013	4.17	4.14	0.03
2014	4.16	4.17	0.02
2015	4.16	4.14	0.02
2016	4.00	4.15	-0.14
2017	4.01	4.15	-0.14
2018	4.01	4.15	-0.14
2019	2.98	4.16	-1.17
2020	1.99	4.16	-2.17
2021	1.99	4.16	-2.17
2022	1.99	4.17	-2.17
2023	1.99	4.17	-2.18

Note: Due to rounding differences, minor discrepancies may arise in the presentation of the figures.

In 2.G.2.c Sound-proof glazing, a calculation error required a recalculation as of report year 1995:

Table 203: Recalculated SF_6 emissions from sound-proof glazing, in tonnes [t]

	2026 submission	2025 submission	Difference
1995	107.9	107.8	0.1
1996	85.9	85.6	0.4
1997	75.6	75.0	0.6
1998	57.6	56.4	1.2
1999	53.8	51.9	1.8
2000	53.8	54.5	-0.7
2001	59.7	57.0	2.7
2002	55.1	52.3	2.8
2003	57.3	54.4	2.9
2004	63.0	60.0	3.0
2005	65.9	62.8	3.1
2006	71.0	67.8	3.2
2007	76.6	73.5	3.1
2008	82.6	79.7	2.9
2009	88.0	85.5	2.5
2010	94.9	93.0	1.9
2011	99.3	96.9	2.3
2012	105.0	102.0	3.1
2013	108.3	104.3	4.0
2014	110.3	105.8	4.5

	2026 submission	2025 submission	Difference
2015	118.7	114.7	4.0
2016	125.8	126.7	-0.9
2017	134.6	138.6	-4.0
2018	136.7	144.4	-7.7
2019	140.0	149.0	-9.0
2020	105.0	110.7	-5.7
2021	86.9	91.5	-4.6
2022	57.1	60.4	-3.3
2023	48.9	52.2	-3.3

Note: Due to rounding differences, minor discrepancies may arise in the presentation of the figures.

4.8.2.13 Category-specific planned improvements (2.G.2 all)

No improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.8.3 N_2O use (2.G.3)

4.8.3.1 Category description (2.G.3)

The German nitrous oxide market is dominated by just a few companies, e.g. Air Liquide, Linde AG and Westfalen AG, who are leading producers and importers. No nitrous oxide emissions occur in nitrous oxide production and in filling of the gas into gas bottles. Emissions occur solely when using the gas. Medical applications represent the most important N_2O emissions source. Other emissions sources include use of nitrous oxide as a propellant in whipped-cream aerosol cans and use in the semiconductor industry, which is covered in 2.E.1. N_2O is also released in small amounts in blasting.

Medicine - anaesthesia

In medicine, nitrous oxide is a gas with analgesic properties and used for anaesthetic purposes. In such applications, nitrous oxide is mixed with pure oxygen to produce an active gas mixture consisting of 70% nitrous oxide and 30% oxygen. In modern anaesthesia, the effects of nitrous oxide are enhanced through addition of other anaesthetics. While medical use of N_2O is not prohibited, the German medical sector has strongly opposed its use in general. In the years 1990 to 2005 in particular, nitrous oxide emissions from anaesthesia dropped sharply as a dominant emission source as nitrous oxide was increasingly replaced by alternative fluorine-containing anaesthetics. This trend has since continued, albeit at a slower pace.

Food industry - whipped-cream aerosol cans

Nitrous oxide is used in various food industry applications under the label E 942. For example, it is a propelling gas to foam up foods, mainly cream and ice-cream. It is also used to extract and conserve foodstuffs.

Explosives

Explosives are used in both military and industrial contexts. Civil and commercial explosives are used in mining, construction in rocky terrain, demolition, geology and fireworks.

Nitrous oxide emissions occur primarily upon detonation of explosives containing ammonium nitrate, such as ANFO (ammonium nitrate/fuel oil) and emulsion explosives. In general, ammonium nitrate (AN) makes up 60 to 80% of commercial/civil explosives. By contrast, Andex, an ANFO explosive, contains up to 94% ammonium nitrate.

In Germany, two companies produce explosives for civil use: Orica Mining (formerly Dynamit Nobel) and Westpreng GmbH (Wasag Chemie).

While no nitrous oxide emissions occur in the manufacturing of explosives, nitrous oxide can form during thermal decomposition of explosives. This is because ammonium nitrate (AN) forms nitrous oxide and water during thermal decomposition.

Under careful warming to a temperature above the melting temperature, the reaction is as follows:

$$NH_4NO_3 \longrightarrow N_2O + 2H_2O$$

But in a fast, detonative reaction of an explosive containing AN, the reaction occurs as follows:

$$NH_4NO_3 \longrightarrow 2H_2O + N_2 + 0{,}5O_2$$

This means that under high pressure and temperature, AN primarily forms nitrogen, oxygen and water as it reacts. Only a small concentration of primarily formed N_2O remains intact during the detonation process. For example, detonation clouds of amatols[73], which contain some 80% AN, have only 0.1 mole N_2O per mole of ammonium nitrate. From this figure, a theoretical maximum for nitrous-oxide formation of about 68 g (this figure was provided by an explosives expert; the stoichiometric value would be 44 g/mole amatol (80% AN)) per kilogramme AN can be calculated ((Ornellas, 1982); Volk (1986): p. 74). According to experts, this AN content can be used as a basis for assumptions regarding N_2O emissions for other explosives.

N_2O in car tuning

In automotive technology, nitrous oxide is used to improve combustion in gasoline engines, called “nitrous oxide injection”. In the process, nitrous oxide is broken down into nitrogen and oxygen. The nitrogen cools the combustion process, and the oxygen increases the combustion power. This “tuning” tactic can quickly increase engine performance. To date, one company in Germany offers such tuning measures. Research has shown that the equipment used for such tuning is designed to consume the input nitrous oxide completely, without producing significant emissions.

4.8.3.2 Methodological issues (2.G.3)

In cases in which the calculation method is not explicitly mentioned in connection with individual product uses, the N_2O emissions have been calculated using a Tier 1 method.

Anaesthesia

The 1990 figure for N_2O emissions from medical applications is based on an extrapolation of a statistical plant survey conducted in 1990 in the former GDR. At the time, it was ascertained that there was one plant producing N_2O for anaesthetic purposes in the former GDR. At that time, the plant had not been operational for long (it was constructed in 1988) and its annual production capacity was approximately 1,200 t. Research indicated that there were no exports or imports of this substance, and thus it was assumed that all of the substance was intended for

[73] Amatol x/y: military explosives. Pourable mixtures, generally consisting of x% TNT and y% ammonium nitrate

domestic consumption. Based on the per-capita emissions calculated from this for the former GDR, and assuming identical conditions, N_2O emissions of 6,200 t were estimated for Germany in 1990. The N_2O figure for 2001 was obtained by way of a written memorandum in 2002 by the Industriegaseverband e.V. (IGV) industrial-gas association. That figure was tied to a range of 3,000 to 3,500 t/a. The mean value (3,250 t/a) was then used for generation of an N_2O emissions time series.

Since 2005, the IGV has carried out surveys of N_2O sales for all applications in Germany. In addition, the IGV has made these overall sales volumes available, without differentiation by application, to the German Environment Agency for reporting purposes. In 2010, the IGV entered into a voluntary agreement with the Federal Ministry of Economics and Technology (BMWi) regarding annual provision of N_2O sales data for purposes of emissions reporting. It is still not possible to break down these sales volumes into different applications. For this reason, the N_2O emissions from medical applications need to be calculated from the association's data.

The gaps in the data for anaesthesia are closed by way of interpolation and extrapolation. The emission factor is 100%.

Whipped cream aerosol cans

The use of N_2O in aerosol cans for whipped cream in Germany has to be carefully differentiated. In Germany, there is one maker of aerosol cans for whipped cream. That maker also fills the cans in Germany. In emissions calculations, it is assumed, on the basis of the research described above, that that company accounts for a share of about 3% of nitrous-oxide sales of the IGV industrial-gas association. Most of the companies who deal with such aerosol cans have them filled abroad and then import them into Germany. The relevant sales of such companies are thus not included in the data of the IGV industrial-gas association. The MIV dairy-industry association has reported to the German Environment Agency the results of a one-time survey which showed that 50.2 million whipped cream aerosol cans were sold in 2008. At the same time, the MIV association reported that the units involved vary in size, and that it is not possible to break the figures down by can sizes. Internet research showed that pressurised cartridges are sold in Germany: cartridges with 8g of N_2O for 0.5l (whipped cream) cans, and cartridges with 16g of N_2O for 1.0l cans. Comparison calculations have shown that 8g of N_2O is a safe approximation, for purposes of calculation, for the amount of nitrous oxide contained in each whipped cream aerosol can. That, in turn, leads to an input figure of 401.6 t N_2O for whipped cream aerosol cans in 2008 in Germany. As there are no data available for the years prior to 2008, that value is assumed to be constant.

The emission factor for whipped cream aerosol cans is assumed to be 100%.

Explosives

In 2003, a total of 59 kt of explosives was produced in Germany. 13 kt was exported abroad, and 5.8 kt was imported into Germany[74]. Those figures, in turn, yield a figure of 51.8 kt for the amount of explosives used in Germany. Of that amount, ANFO accounts for a share of 60%, emulsion explosives account for 25% and dynamite explosives account for 15%. ANFO explosives consist of 94% ammonium nitrate and 6% fuels. The corresponding relationship for emulsion explosives is 80 to 20%; for dynamite explosives, it is 50 to 50%.

At present, the quantities of nitrous oxide present in detonation clouds are not determined, while the quantities of NO and NO_2 are determined.

[74] Personal communication: Federal Office for Material Research and Testing (BAM).

In general, N_2O formation plays a significant role only in explosives that contain ammonium nitrate (AN). That said, no precise analyses of detonation clouds of ANFO explosives have been carried out. For this reason, it must be assumed that the N_2O concentrations formed upon detonation of ANFO are similar in terms of AN content to those formed upon detonation of amatols and ammonites[75] for which analyses have been carried out that support relevant estimates. The following result has been obtained: upon detonation, amatols and ammonites form about 0.1 mole N_2O per mole of ammonium nitrate (AN).

According to the Federal Institute for Materials Research and Testing (BAM), levels of explosives use in Germany remained constant from 1990 to 2005.

The emission factor for use of explosives is 0.1036 kg N_2O/t explosives. That emission factor was determined by a measurement taken by BAM in February 2010. As a result, the emission factor has been downwardly corrected, considerably, with respect to the 2010 submission.

4.8.3.3 Uncertainties and time series consistency (2.G.3)

Since 2005, activity data for anaesthetic uses have been obtained from association information. For that reason, the uncertainty is estimated at 20%. The data on consumption for whipped cream aerosol cans and explosives are subject to a very high level of uncertainty (75%) since the relevant calculations are based on several assumptions and a definite figure is only available for one year.

The uncertainty in the emission factors for anaesthesia and whipped cream aerosol cans is set as 0% because, at present, it is assumed that N_2O undergoes no transformation in use and the gas thus escapes completely into the atmosphere following its use. The emission factor for explosives is estimated to have an uncertainty of 5% as the emission factor has been determined by an official measurement.

With these results, the time series can be considered to show a normal type of distribution.

4.8.3.4 Category-specific QA/QC and verification (2.G.3)

General and category specific quality control and quality assurance, have been carried out in conformance with the requirements of the QSE-manual and its associated applicable documents, by the Single National Entity.

With regard to use in anaesthesia, a comparison with other countries shows that most other countries use an emission factor of 1.0, as Germany does. This figure corresponds to the default value in the 2006 IPCC Guidelines (IPCC (2006a): Vol. 3, p. 8.36).

With regard to nitrous oxide emissions from use of explosives, no comparisons with other comparison or data sources are possible since Germany is the only country that reports such emissions.

The quantities of nitrous oxide used cannot be verified with other data sources since there are no other data available to support such verification. A special survey was carried out in order to obtain the data for the present report.

4.8.3.5 Category-specific recalculations (2.G.3)

No recalculations are required.

[75] Ammonite: Composition: 70-88% ammonium nitrate, with 5-20% nitroaromates, 1-6 % vegetable flour and, in some cases, 4% nitroglycerine, aluminium powder and potassium perchlorate

4.8.3.6 Category-specific planned improvements (2.G.3)

No further improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.8.4 Other product manufacture and use: Other - ORC systems (2.G.4 ORC systems)

4.8.4.1 Category description (2.G.4 ORC systems)

Fluorinated greenhouse gases have been used in ORC systems in Germany since 2003 and are reported under category 2.G.4.

The *Organic Rankine Cycle* (ORC) is used to generate electricity from heat sources with temperatures and pressures that are too low for steam-powered generation. ORC systems are used especially in geothermal power generation and in harnessing of waste heat from combined heat and power (CHP) stations and biogas plants.

The working media used in the ORC cycle are certain organic substances, such as HFCs, PFCs, hydrocarbons and silicone oils, that evaporate at lower temperatures than water does. In ORC systems, such working media evaporate and drive turbines, just as steam drives turbines in conventional power stations. Geothermal applications constitute by far the largest fill quantities, using up to 75 tonnes of fluorinated working media. Considerably smaller fill quantities (0.2 to 0.6 tonnes) are used in systems that harness waste heat from biogas plants and in compact combined heat-and-power (CHP) generating systems.

In Germany, C_5F_{12} was first used as a working medium in an ORC pilot system in 2003. That system was decommissioned in 2010. HFC-134a was used for the first time in an ORC system in 2008. Use of HFC-245fa as a working medium began in 2010. From 2011, several systems were commissioned that operate with HFC-245fa and the working medium “Solkatherm”, which consists of HFC-365mfc (65%) and a perfluorinated polyether (PFPE) with the trade name “Galden” (35%). The unsaturated fluorinated substances HCFO-1224yd, HCFC-1233zd and HFO-1234ze, which are not subject to reporting obligations, came into use from 2020 onwards.

4.8.4.2 Methodological issues (2.G.4 ORC systems)

Emissions from ORC systems occur during filling, operation and disposal.

Production emissions are determined using new domestic consumption as the activity data and calculated pursuant to Equation 8.

Emissions from use are determined using Equation 9 based on the final quantities (i.e. in systems) of working media – the activity data – and by multiplication with the EF_{use}.

Disposal emissions refer to new additions for the year that is x years (based on product service life) prior to the current report year n. They are calculated pursuant to Equation 10.

With one exception, disposal emissions have not begun playing a role yet since most systems are new. Large ORC systems in geothermal applications are expected to have a service life of 30 years, while smaller systems are expected to have a service life of 20 years.

Emissions of the perfluorinated polyether “Galden” and HCFO-1224yd, HCFC-1233zd and HFO-1234ze are not subject to reporting obligations. Germany voluntarily reports such emissions as “*additional greenhouse gas*” pursuant to the recommendations of the *2014 UNFCCC Reporting Guidelines* ((UNFCCC, 2014), FCCC/CP/2013/10/Add.3, Decision 24/CP.19). These emissions are

aggregated with other emissions not subject to reporting obligations and listed in Chapter 4.9.3. The CRT tables do not contain any data on emissions which are voluntarily reported.

Emission factors

The emission factors used are the result of consulting experts and listed in Table 198.

The filling loss is 2%. It is country-specific since ORC systems are not covered by the 2006 IPCC Guidelines, meaning that there are no default factors available yet.

The emissions from use are estimated to be 4%. The 2006 IPCC Guidelines provide no specifications in this regard.

Based on the latest technology, the emission factor for disposal is 20%. That value is also country-specific.

Activity data

ORC systems are a new area of application for fluorinated greenhouse gases, an area for which little data and technical information has been gathered to date. Almost all of the data used, therefore, are based on information provided by producers and operators of ORC systems. The data were determined through expert-level discussions (Gschrey et al., 2015).

4.8.4.3 Uncertainties and time series consistency (2.G.4 ORC systems)

The uncertainties for the "ORC systems" subcategory have been systematically quantified.

The data on the quantities used are considered to be of good quality overall. Germany has fewer than 10 manufacturers and sellers of ORC systems with fluorinated working media, and the country's market is relatively small. The data on the quantities of HFC-245fa and Solkatherm (HFC-365mfc and PFPE) used annually are of good quality since the data come directly from the manufacturers of these working media (Honeywell und Solvay Solexis), and these companies are the only sellers who export to Germany. For the period as of 2018, these figures have been provided by the leading systems maker (Orcan Energy), which also provides the quantities of HCFO-1224yd, HCFC-1233zd and HFO-1234ze used.

The emission factors are subject to considerable uncertainties. Since sales of ORC systems in Germany began only a few years ago, no reliable empirical studies have been carried out to date. The values are therefore based on estimates provided by operators of such systems.

4.8.4.4 Category-specific QA/QC and verification (2.G.4 ORC systems)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

The data for the current report year, like the data for most of the previous years, were collected by an external expert working on a research project commissioned by the German Environment Agency.

For the most part, quality assurance was carried out by the external expert. In addition, the data are checked by the relevant German Environment Agency specialists upon receipt.

No data sources are available to review the F gas quantities gathered for emissions reporting as a basis for verification other than the data provided by the research contractor. No comparisons with other countries are possible, since no other countries report emissions from ORC systems. Neither can the emission factors be compared. The 2006 IPCC Guidelines provide no default emission factors, and thus no comparability is available in this area as well.

4.8.4.5 Category-specific recalculations (2.G.4 ORC systems)

The domestic consumption of HFC-245fa in the years 2018 to 2023 has been updated on the basis of new research findings, which also resulted in changes to the stock as well as to the filling and stock emissions.

The working substances HCFO-1224yd, HCFC-1233zd and HFO-1234ze were added to the inventory. They have not been quantified as they are fluorinated greenhouse gases which are not subject to reporting obligations.

The changes in the emissions of HFC-245fa in the subcategory ORC systems (2.G.4) for the years 2018 to 2023 are shown in Table 204.

Table 204: Recalculated emissions of HFC-245fa from 2018 to 2023, in [t CO_2-eq]

	2018	2019	2020	2021	2022	2023
HFC-245fa						
2025 submission	8,641	9,011	11,033	13,288	14,603	24,445
2026 submission	8,331	8,588	9,598	10,770	11,451	16,670
Difference	-309	-424	-1,435	-2,517	-3,152	-7,775

4.8.4.6 Category-specific planned improvements (2.G.4 ORC systems)

No improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.8.5 Other product manufacture and use: Other - Container fumigation (2.G.4 Container fumigation)

4.8.5.1 Category description (2.G.4 Container fumigation)

Since 2004, the fluorinated greenhouse gas sulphuryl difluoride (SO_2F_2) has been used in Germany for pest-control fumigation of containers with roundwood exports, and as a substitute for the ozone-depleting substance methyl bromide, the use of which has been prohibited for many years. In such applications, wood in containers is fumigated with the pesticide *ProFume*®, which contains sulphuryl difluoride as an active ingredient. All of the pesticide used is released as an emission.

For many years, the utilised quantities and emissions of SO_2F_2 remained at a constant, high level. Recently, they have increased sharply, however, due to growing roundwood exports linked to the droughts and heavy bark-beetle infestation in spruce forests that occurred in Germany between 2018 and 2020.

As a powerful greenhouse gas, sulphuryl difluoride has a high degree of environmental relevance. Because of this relevance, and since use of this substance has increased sharply, both domestically and globally, Germany is now reporting this substance voluntarily as of report year 2020 in category 2.G.4.

4.8.5.2 Methodological issues (2.G.4 Container fumigation)

Emissions occur only during use of the substance, i.e. during fumigation of roundwoods in containers. They are determined by multiplying the new domestic consumption, the activity data, by the EF_{use} as per Equation 9.

Emissions of sulphuryl difluoride, which is not subject to reporting obligations, are reported voluntarily as "*additional greenhouse gas*" pursuant to the recommendations of the 2014 UNFCCC Reporting Guidelines ((UNFCCC, 2014), FCCC/CP/2013/10/Add.3, Decision 24/CP.19). These emissions are aggregated with other emissions not subject to reporting obligations and listed in Chapter 4.9.3. The CRT tables do not contain any data on emissions that are voluntarily reported.

Emission factors

The emission factor used is the result of consulting experts and listed in Table 198.

Based on the latest technology, the emission factor for use is 100% since no waste-gas scrubbing has been carried out to date in connection with this substance. This value is country-specific, since container fumigation is not listed in the 2006 IPCC Guidelines, meaning that no default factor is available.

Activity data

The data on the quantities used are taken from annual statistics of the Federal Office of Consumer Protection and Food Safety (BVL) on sales of sulphuryl difluoride as an active ingredient for pesticides in Germany (BVL, 2022).

4.8.5.3 Uncertainties and time series consistency (2.G.4 Container fumigation)

The uncertainties for the "container fumigation" subcategory have been systematically quantified.

The quality of the data on the quantities used are considered to be of good quality overall since they are taken from official BVL statistics.

The emission factor is subject to considerable uncertainty. Since SO_2F_2 only started to be used a few years ago, there are no reliable empirical studies available yet. For this reason, a conservative approach is used whereby emission of the substance is assumed to be complete.

4.8.5.4 Category-specific QA/QC and verification (2.G.4 Container fumigation)

For the most part, quality assurance was carried out by experts from the German Environment Agency.

No other data sources are available to review the F gas quantities gathered for emissions reporting as a basis for verification. It is not possible to compare data with other countries since no other countries report emissions from container fumigation. The emission factors also cannot be compared. The 2006 IPCC Guidelines provide no default emission factors, and thus no comparability is available in this area either.

4.8.5.5 Category-specific recalculations (2.G.4 Container fumigation)

The sales figures for sulphuryl fluoride as an active ingredient for pesticides collated in the annual statistics of the Federal Office of Consumer Protection and Food Safety (BVL) are not available in time for the compilation of the inventory. This makes it necessary to recalculate the previous year's emissions each year. Since sulphuryl fluoride is among the substances that are reported on a voluntary basis, no further quantification is carried out.

4.8.5.6 Category-specific planned improvements (2.G.4 Container fumigation)

No improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.8.6 Other product manufacture and use: Other, charcoal use (2.G.4 Charcoal)

4.8.6.1 Category description (2.G.4 Charcoal)

In this category, CO_2, CH_4, N_2O and particulate emissions from use of charcoal for barbecuing are reported.

Only small quantities of charcoal are produced in Germany by one major charcoal factory operator and several regional charcoal kilns. The respective quantities are determined by the Federal Statistical Office and subject to confidentiality requirements. Use of charcoal is reported under 1.A.1.a.

Apart from a downturn in 2008 in connection with an economic slowdown, charcoal consumption increased continuously in the years 1990 to 2012 before levelling off by 2019. Since then, charcoal consumption has been decreasing. In 2020, it decreased by about 30% in comparison with the previous year; in 2024, the decline was 12%. The great majority of the charcoal used is imported.

4.8.6.2 Methodological issues (2.G.4 Charcoal)

The calculation model is based on the assumption that all calculation method is consumed within a year of its purchase and is burned completely.

The CO_2, CH_4 and N_2O emissions are calculated using a Tier 1 method.

Activity data

The production quantity data and the data on imported and exported quantities of charcoal for the years as of 1996 were obtained from the Federal Statistical Office ((Statistisches Bundesamt, FS 4, R 3.1), manufacturing industry; production in the manufacturing industry and foreign trade statistics (Produzierendes Gewerbe, Produktion im Produzierenden Gewerbe sowie Außenhandelsstatistik).

The quantities consumed are calculated with the formula Production + Imports – Exports.

For the years 1990 to 1995, the quantities consumed are calculated from the per-capita consumption, which has been derived from the data for the years 1996 to 2013. In the process, it is assumed that consumption also grew on a linear basis in these years.

Emission factors

Since import and export data are published, no exact emission factors for CO_2, CH_4 and N_2O may be specified for reasons of confidentiality. However, the emission factors can be compared with the emission factors that can be derived from the 2006 IPCC Guidelines.

Each emission factor is applied to the entire time series.

4.8.6.3 Uncertainties and time series consistency (2.G.4 Charcoal)

A Tier 1 method with emission factors similar to those provided by the 2006 IPCC Guidelines has been used, meaning that the relevant uncertainties for the activity data and emission factors apply (IPCC (2006a): Vol. 3, Chapter 5).

4.8.6.4 Category-specific QA/QC and verification (2.G.4 Charcoal)

General and category specific quality control and quality assurance, have been carried out in conformance with the requirements of the QSE-manual and its associated applicable documents, by the Single National Entity.

No data sources are available to review the import, export and production quantities gathered as a basis for verification other than the data provided by the Federal Statistical Office. The import and export figures were compared with the corresponding data of EUROSTAT. The figures are consistent with the figures the Federal Statistical Office has provided to EUROSTAT. It was not possible to compare production quantities because EUROSTAT also lists them as confidential.

The emission factors were compared with the corresponding emission factors of other countries. For reasons of confidentiality, the result of that comparison can be documented only internally. The emission factors are comparable.

4.8.6.5 Category-specific recalculations (2.G.4 Charcoal)

The emissions had to be corrected for the year 2023 as a result of adjustments to foreign trade statistics. The usage quantities and, consequently, the emissions, increased by 1.9% as a result.

4.8.6.6 Category-specific planned improvements (2.G.4 Charcoal)

No further improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.9 Other production (2.H)

The category “Other production” is not a key category.

In the CSE, process-related emissions from production of particle board and from pulp production are reported under 2.H.1 Pulp and paper.

Process-related emissions from production of alcoholic beverages, bread and other foods are listed under 2.H.2 Food and drink.

Confidential data on emissions of fluorinated greenhouse gases are reported under 2.H.3. Data on F gases subject to voluntary reporting are also reported in that section in aggregated form.

4.9.1 Other production: Pulp and paper (2.H.1)

4.9.1.1 Category description (2.H.1)

Gas	Method used	Source for the activity data	Emission factors used
NO_X, SO_2, NMVOC			CS

The category “Other production - pulp and paper” is not a source of greenhouse gas emissions and is thus not a key category.

All emissions of climate-relevant gases from the pulp and paper industry and from particle board production in Germany are the result of fuel combustion; for this reason, they are reported in Chapter 3.2 as energy-related emissions. The pulp and paper industry does not produce any process-related emissions of climate-relevant gases as defined in the 2006 IPCC *Guidelines*.

Two of the five pulp plants in Germany use caustification in sulphate pulp production. For these plants, fuel-related CO_2 emissions in lime ovens are already accounted for as energy-related emissions in the corresponding fuel statistics. The remaining three plants use the sulphite process.

Both the sulphate and sulphite pulp-production processes can be sources of SO_2 emissions. In sulphate pulp production, NO_X, CO and NMVOC emissions are also released from recovery boilers, lime ovens, bark boilers and auxiliary boilers.

Particle board is produced from wood chips with added binders in a process that applies heat and pressure. The main source of NMVOC emissions in such production are the wood chips used, which release NMVOC when heated to dry. NMVOC can also be emitted from wood and binders during the pressing process.

Particle board is produced in a total of around 20 plants in Germany. The particle board industry tends to be dominated by larger companies.

4.9.1.2 Methodological issues (2.H.1)

The pulp and paper industry produces no process-related emissions of climate-relevant gases as defined in the *IPCC Good Practice Guidance* (Penman et al., 2000). Plant operators reported emission factors for the precursor substances nitrogen oxides, sulphur oxides and NMVOC.

Table 205: Emission factors for the production of pulp, in [kg/t]

	NO_X	NMVOC	SO_2	CO
Sulphate pulp	1.071	C	0.017	0.474
Sulphite pulp	1.66		1.54	0.1

Origin: German contribution to revision of the BAT reference (BREF) document for the pulp and paper industry (Spörl, 2009) and review of the emission factors on the basis of actual plant measurements from 2021

According to the most recent figures, the following quantities were produced at a total of 140 plants:

Table 206: Pulp and paper production, produced quantities in 2024

Product	2024 quantities
Production of paper, paperboard and carton (PPC): Raw-material production:	19.19 million t
Paper pulp	1.396 kt
Wood pulp	361 kt
Recycled paper	12.399 kt
Quantity of recycled paper used for this purpose	(16.075 kt)

Source: (Papierindustrie, 2025)

These figures, which the German Pulp and Paper Association (Die Papierindustrie e.V.; DPI) collects annually and publishes in a production report, are available back to 1990.

Particle board

The emission factors, amounting to 0.9 kg/t for NMVOC and 0.3 kg/t for dust, were determined by estimates from experts.

For use, the activity data, which were obtained from national statistics (Statistisches Bundesamt, 2025c), have to be converted from volume-based units to mass-based units. The time series from 1995 was recalculated using a completed dataset from the Federal Statistical Office.

Table 207: Converted activity data for the particle board industry, in [t]

Year	Particle board production	Year	Particle board production	Year	Particle board production
1995	5,302,304	2005	6,107,625	2015	4,401,951
1996	5,083,453	2006	6,038,427	2016	4,584,715
1997	5,424,305	2007	5,998,782	2017	4,708,521
1998	5,618,847	2008	5,592,744	2018	4,562,401
1999	5,596,004	2009	4,962,749	2019	4,489,681
2000	5,859,367	2010	4,991,234	2020	4,430,611
2001	5,574,354	2011	4,488,544	2021	4,775,500
2002	5,081,481	2012	4,430,381	2022	4,365,817
2003	5,528,671	2013	4,489,213	2023	4,041,418
2004	6,000,147	2014	4,446,688	2024	4,005,586

Source: Statistisches Bundesamt, Melde-Nrn. (reporting numbers) through 2018: 1621 13 131; 1621 13 133; 1621 13 163; 1621 13 500; Meldenummern (reporting numbers) as of 2019: 162112001, 162112002, 162112003, 162113160, 162114190, 162114500, converted and summed in tonnes

4.9.1.3 Uncertainties and time series consistency (2.H.1)

Pulp and paper

Germany's country-specific emission factors reflect the considerable modernisations carried out at German sulphate pulp plants which have significantly reduced their emissions. In sulphite pulp plants, continual improvements led to considerable reductions in SO_2 emissions when compared with corresponding emissions levels in 1990.

The uncertainties in the activity data are estimated at 5%. The uncertainties for the emission factors are estimated at 20%.

Particle board

The uncertainties for the activity data for the particle board industry are ±3% (estimate by experts due to conversion of statistical data).

4.9.1.4 Category-specific QA/QC and verification (2.H.1)

Due to resource limitations and the area's minimal relevance, no QC/QA is carried out for reporting precursors.

4.9.1.5 Category-specific recalculations (2.H.1)

The recalculations had no effect on greenhouse gas emissions; i.e. there were no changes in greenhouse gas emissions.

4.9.1.6 Category-specific planned improvements (2.H.1)

No inventory improvements are currently planned for this category.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.9.2 Other production: Food and drink (2.H.2)

4.9.2.1 Category description (2.H.2)

Gas	Method used	Source for the activity data	Emission factors used
CO_2	NA	NA	NA
NMVOC	CS	NS	CS/D

The category "Other production - food and drink" is not a source of greenhouse gas emissions and is thus not a key category.

The food and beverage industry's emissions of direct climate gases in Germany result from fuel combustion; for this reason, they are reported in CRF 1.A.2. The food and beverage industry's important process-related emissions include non-methane volatile organic compounds (NMVOC) (IPCC (2006a): Vol. 1 p. 7.13). Carbon dioxide emissions from food inputs that occur during certain production processes are not reported in CRF 2.H.2. since they result from use of biological carbon and do not contribute to net CO_2 emissions. The solvent emissions that occur from the extraction of oils & fats (soy, rapeseed, sunflower seeds, etc.), i.e. from solvent use during raw material production, are reported in category 2.D.3. The CO_2 used in sugar production and obtained from burning of limestone is bound during the production process. For this reason, this process is not emissions-relevant (cf. Lechtenböhmer, Nanning and Buttermann (2006); Lechtenböhmer, Nanning, et al. (2006a).

Emissions of the food and drink industry are reported, in summary form, in the inventory in "Table2(I)s2" of the sectoral report for industrial processes.

Pursuant to the IPCC Guidelines, emissions reporting for the category food and drink covers the following products:

Alcoholic beverages

- Vineyards
- Beer
- Spirits

Bread and other foods

- Meat, fish and poultry
- Sugar
- Margarine and solid and hardened fats
- Cake, cookies and breakfast cereals
- Bread

- Animal feedstuffs
- Coffee roasting
- The 2019 EMEP/EEA air pollutant emission inventory guidebook lists default emission factors for NMVOC emissions for these products (EMEP/EEA (2023), Chapter 2.H.2).

4.9.2.2 Methodological issues (2.H.2)

For emissions calculations, national emission factors were used where available. Otherwise, the emission factors recommended by EMEP/EEA were used. The emission factors selected are based on the research report "Emissions from the food industry" (Emissionen aus der Nahrungsmittelindustrie) ((Anderl et al., 2008; Theloke et al., 2008). This procedure is consistent with the one described in the NIR (UBA et al., 2013).

With a few exceptions, the activity data is provided directly by the Federal Statistical Office. Also, queries can be submitted on the Federal Statistical Office's "Genesis-Online" website. Additional data have been used as follows: for feed production, data from the Federal Ministry of Food and Agriculture's (BMEL's) Statistical yearbook on food, agriculture and forestry (Statistisches Jahrbuch über Ernährung, Landwirtschaft und Forsten); for the wine and spirits industry, surveys by the Federal association of the German wine and spirits industry (Bundesverband der Deutschen Spirituosen-Industrie und Importeure - BSI). For international comparability, the Single National Entity aggregates all products in kilotonnes. These overall figures can be viewed in the CRF tables as activity data, but they are based on an estimation method.

For category 2.H.2, a total of 16.4 kt of NMVOC emissions result for 2024. Of those, 4.1 kt NMVOC are from bread production, 4.1 kt NMVOC are from sugar production and 3.7 kt NMVOC are from production of spirits. The changes with respect to the previous year are within the typical fluctuation range. Considerable decreases occurred only in smoked products and the production of spirits and wine. There was an increase in terms of the production of sugar, bread and animal fat In the case of wine and sugar, the changes were mainly harvest-related.

4.9.2.3 Uncertainties and time series consistency (2.H.2)

The uncertainties in the activity data are estimated at 5-20%. Further information about uncertainties is provided in the NIR (UBA et al., 2013).

4.9.2.4 Category-specific QA/QC and verification (2.H.2)

Due to resource limitations and the area's minimal relevance, no QC/QA is carried out for reporting precursors.

Other countries' reports contain very little information about 2.H.2, hence no comparisons are possible at present. No comparison with ETS data is possible, since no emissions subject to emissions trading occur in 2.H.2.

4.9.2.5 Category-specific recalculations (2.H.2)

No category-specific recalculations were carried out.

4.9.2.6 Category-specific planned improvements (2.H.2)

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

4.9.3 Other sectors (2.H.3)

Gas	Method used	Source for the activity data	Emission factors used
HFC, PFC, SF_6	cf. Chapter 4.6.4: Table 194/Table 198	cf. Chapter 4.6.4/4.7.5/4.8.2	cf. Table 194/Table 198

SF_6 emissions from use in connection with AWACS Maintenance (2.G.2.a Military uses), with Athletic shoes (2.G.2.d. Adiabatic properties - athletic shoes), with Welding (2.G.2.e Other - welding) and with production of Optical glass fibres (2.G.2.e Other - optical glass fibres) are reported in 2.H.3 for reasons of confidentiality.

HFC emissions from use of the solvents HFC-43-10mee, HFC-245fa and HFC-365mfc (2.F.5 Solvents) are also reported under 2.H.3. The same applies to the emissions of HFC-23, HFC-134a and HFC-227ea from production (2.B.9 Production of halocarbons and SF_6).

The PFC emissions from the production of CF_4 (2.B.9 Production of halocarbons and SF_6), from the manufacture of solar cells (2.E.3 Photovoltaics), from uses as heat transfer fluids (2.E.4), as solvents (2.F.5), in athletic shoes (2.G.2.d Adiabatic properties - athletic shoes) and from use of perfluorodecalin in medical and cosmetic applications (2.G.2.e Other - medical and cosmetic applications) are also reported under 2.H.3. In accordance with the recommendation of the Expert Review Team, it should be noted that all information concerning the emissions reported under 2.H.3 with respect to source category description, methodological issues, uncertainties & time series consistency and category-specific recalculations & verification, and to planned improvements, is provided in the relevant category chapters.

In addition to reporting on greenhouse gases subject to reporting obligations, Germany has decided to report on the greenhouses gases shown in Table 208, which are not subject to reporting obligations. This reporting covers the applications relevant for Germany, which are also listed in the table. For reasons of confidentiality, Table 209 shows the emissions of these greenhouse gases, which are not subject to reporting obligations, in aggregated form.

Table 208: Overview of voluntarily reported fluorinated greenhouse gases, their global warming potentials and their areas of application

Greenhouse gas	Formula	GWP	Scope	SC
HCFO-1224yd	$CHCl=CF-CF_3$ (Z)	1	ORC systems	2.G.4
HCFC-1233zd	$CHCl=CH-CF_3$ (E)	1	Stationary air conditioning systems PUR integral foams ORC systems	2.F.1.f 2.F.2.b 2.G.4
HFO-1234yf	$CF_3-CF=CH_2$	1	Commercial refrigeration Refrigerated transports Mobile air conditioning systems Stationary air conditioning systems	2.F.1.a 2.F.1.d 2.F.1.e 2.F.1.f
HFO-1234ze	$CF_3-CH=CHF$ (E)	1	Commercial refrigeration Stationary air conditioning systems XPS foams General-purpose aerosols ORC systems	2.F.1.a 2.F.1.f 2.F.2.a 2.F.4.b 2.G.4
HFO-1336mzz	$CF_3-CH=CH-CF_3$ (Z)	2	PUR integral foam	2.F.2.b
HCFE-235da2 (isoflurane)	$CHF_2OCHClCF_3$	491	Inhaled anaesthetic	2.G.2.e
HFE-236ea2 (desflurane)	$CHF_2OCHFCF_3$	1,790	Inhaled anaesthetic	2.G.2.e

Greenhouse gas	Formula	GWP	Scope	SC
HFE-347mmz1 (sevoflurane)	$CH_2FOCH(CF_3)_2$	216	Inhaled anaesthetic	2.G.2.e
PFPE/PFPMIE	$CF_3(OCF(CF_3)\,CF_2)_n\,(OCF_2)_mOCF_3$	9,710	ORC systems	2.G.4
Sulphuryl difluoride	SO_2F_2	4,090	Container fumigation	2.G.4

Source: 5th IPCC Assessment Report, Chapter 8, p. 731, Appendix 8. A (Stocker et al., 2014).

Table 209: Aggregated emissions of the fluorinated greenhouse gases which are not subject to reporting obligations – HCFO-1224yd, HCFC-1233zd, HFO-1234yf, HFO-1234ze, HFO-1336mzz, HCFE-235da2, HFE-236ea2, HFE-347mmz1, PFPE/PFPMIE and SO_2F_2, in [t CO_2-eq]

Year	Emissions	Year	Emissions	Year	Emissions	Year	Emissions	Year	Emissions
1990	4,262	1997	32,320	2004	118,336	2011	310,949	2018	431,686
1991	5,323	1998	43,855	2005	130,831	2012	348,969	2019	820,063
1992	6,480	1999	56,254	2006	379,351	2013	424,875	2020	984,072
1993	7,733	2000	69,519	2007	416,911	2014	388,703	2021	554,427
1994	9,082	2001	80,526	2008	368,045	2015	402,409	2022	712,611
1995	10,527	2002	92,161	2009	417,697	2016	376,018	2023	443,024
1996	21,650	2003	104,423	2010	394,191	2017	338,785	2024	432,074

5 Agriculture (CRF Sector 3)

5.1 Overview (CRF Sector 3)

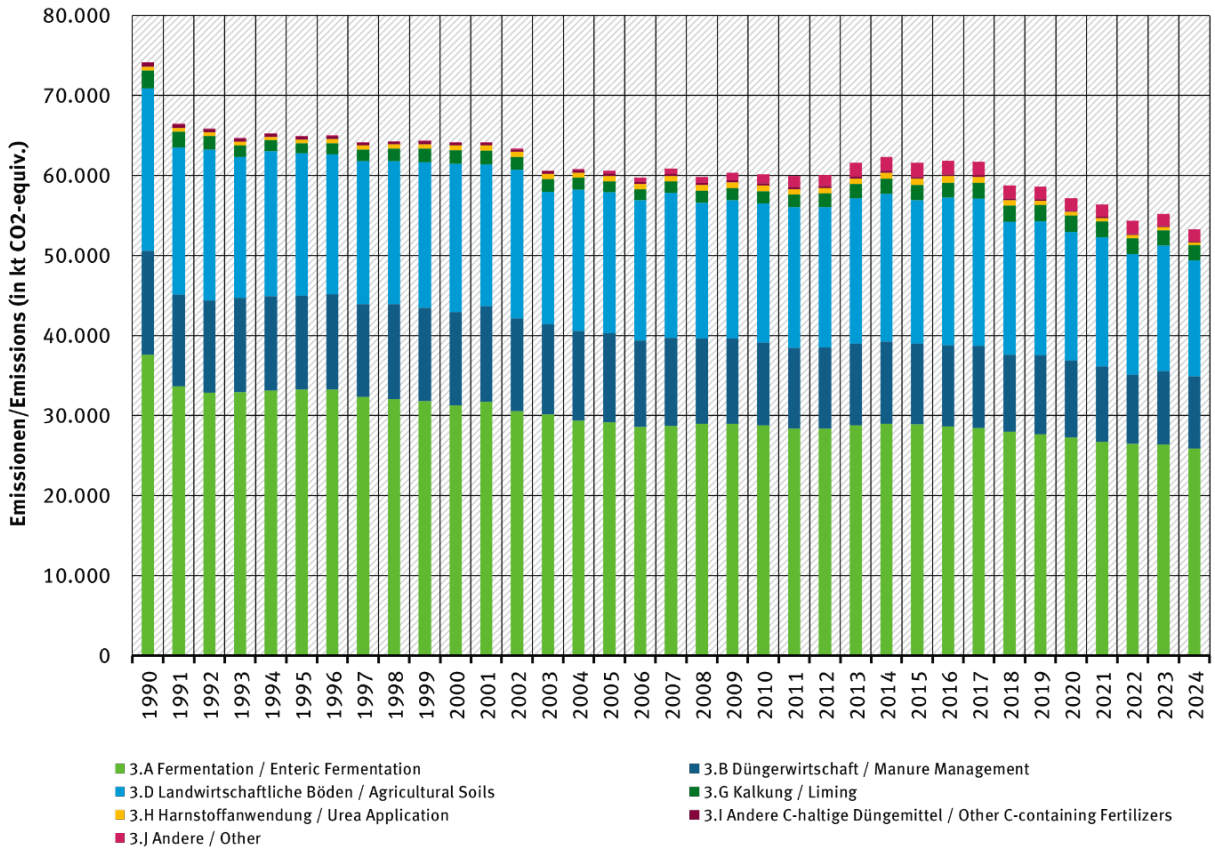
5.1.1 Categories and total emissions 1990-2024

In category 3, Agriculture, Germany reports on emissions from enteric fermentation (3.A), manure management (including manure digestion and storage of digestates of manure) (3.B) and agricultural soils (3.D), liming (3.G), the use of urea (3.H) and the use of other lime-containing fertilisers (3.I). The NID also reports on emissions occurring in connection with the digestion of energy crops (3.J: Emissions from digestion of energy crops and from storage of digestates). Emissions from the application of digested and composted other substances, such as from food waste and green waste, are reported in waste sector 5.B.2 (cf. Chapter 7.3.2). However, emissions from the spreading of digestates of waste and the spreading of compost of biowaste and green waste are reported under 3.D.

Emissions from rice cultivation (3.C) do not occur in Germany, while clearance of land by prescribed burning (3.E) is not practised in Germany (NO). Field burning of agricultural residues (3.F) is prohibited in Germany by law (Federal Law Gazette (BGBl), 2004 and by preceding federal and federal state provisions; cf. Vos et al. (2026), Chapter 2.9) (NO).

For the present 2026 NID, Figure 46 provides an overview of the development of greenhouse gas emissions since 1990 in the areas 3.A, 3.B, 3.D, 3.G, 3.H and 3.J. The data were calculated with the Py-GAS-EM inventory model (cf. 5.1.2).

Figure 46: Overview of greenhouse gas emissions in CRF Sector 3



Source: own illustration, German Environment Agency

5.1.2 The Py-GAS-EM emissions inventory model

5.1.2.1 Guidelines applied and detailed report

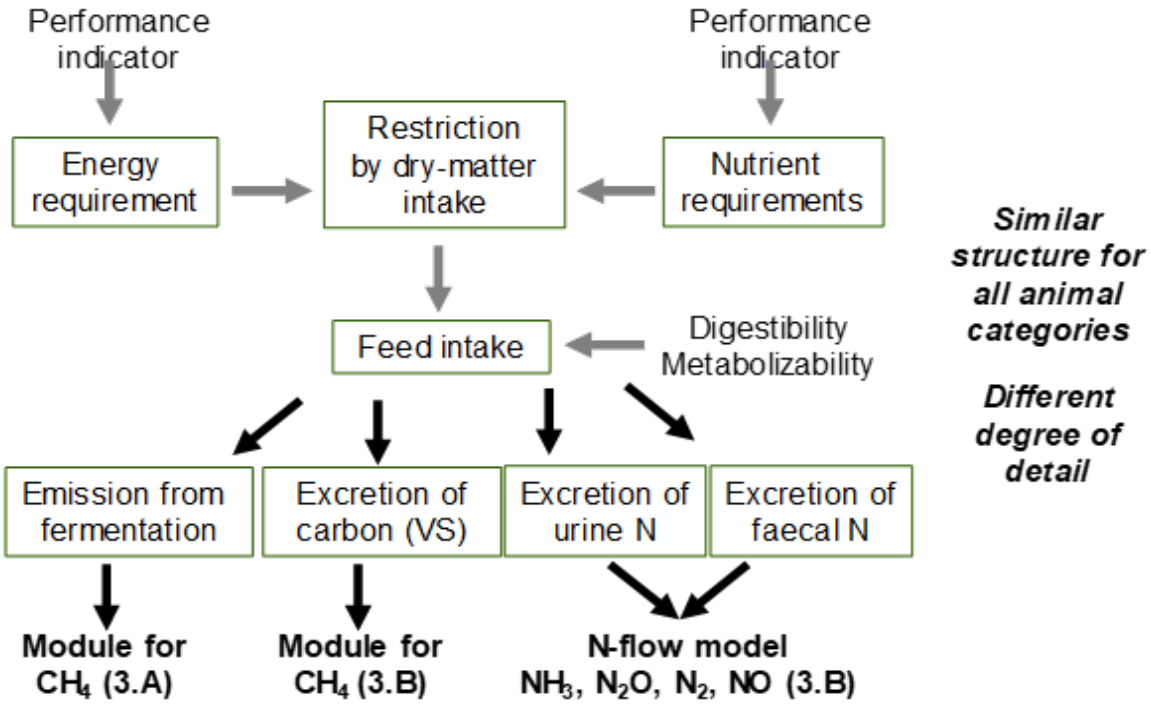
The Py-GAS-EM emissions inventory model is based primarily on the relevant sets of guidelines (greenhouse gases: IPCC (2006b, Vol. 1 & 4); (IPCC, 2019); pollutants, especially NH_3: EMEP (2023)).

Over the past few years, many of the methods described in the guidelines have been further developed for the Py-GAS-EM model and a national method has been developed for the calculation of emissions from digestion of energy crops. A comprehensive description of the Py-GAS-EM inventory model, including listings of relevant additional sources, is presented in the detailed report (Vos et al., 2026). The following remarks summarise the detailed report.

5.1.2.2 Basic structure of the Py-GAS-EM emissions inventory model

Feed intake serves as the basis for emissions calculations in the animal husbandry sector. It is calculated as a function of basic and performance-related energy requirements, as Figure 47 shows with the example of suckling cows. That approach provides the CH_4 emissions from enteric fermentation (3.A), as well as the carbon and nitrogen excretions data needed to calculate emissions from management of manure and digested slurry (3.B). The latter are also used when calculating nitrogen discharges into agricultural soils (3.D).

Figure 47: Logical structure behind national methods for calculating emissions from animal husbandry using the example of suckler cows

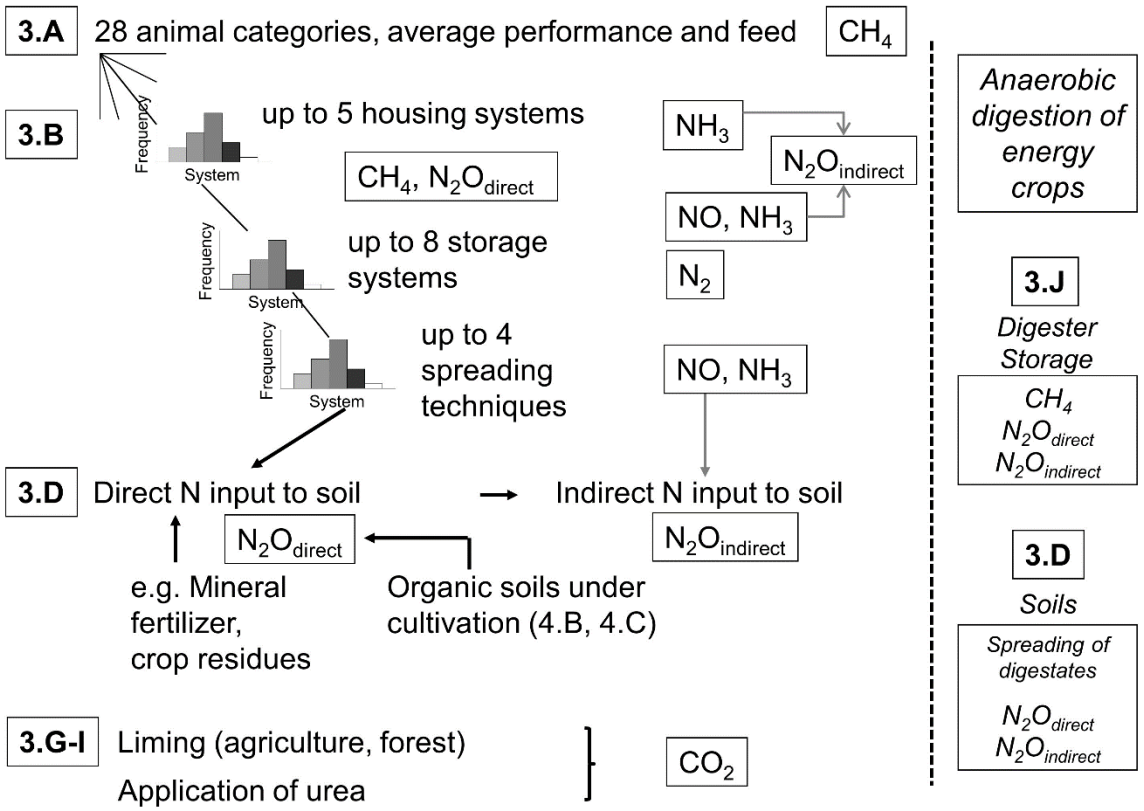


Source: own illustration, Thünen-Institut
Performance indicator stands for the sum of basic and performance-related requirements

Figure 48 shows how the Py-GAS-EM model, for the purpose of calculations in categories 3.A and 3.B, first differentiates between animal categories and subcategories and then further subdivides

those categories into housing systems, storage systems (with digestion as a separate storage system) and procedures for spreading of manure and digestates. CH_4 emissions are calculated separately for each animal subcategory in 3.A and 3.B. For categories 3.B and 3.D, N_2O emissions are calculated on the basis of an N-flow concept (cf. Chapter 5.1.2.4). In categories 3.G-I, CO_2 emissions are calculated for liming and urea application. In line with the IPCC's guidelines, these calculations also include the liming of forests. Emissions from digestion of energy crops are calculated in two separate sections: emissions from digesters and storage of digestates, in 3.J; and emissions from soils as a result of application of digestates, in 3.D.

Figure 48: The Py-GAS-EM model: Concept and content



Source: own illustration, Thünen-Institut

5.1.2.3 Treatment of CH_4 within the emissions inventory

The Py-GAS-EM inventory model is used to calculate CH_4 emissions from enteric fermentation and VS excretions of agricultural livestock (cf. Chapters 5.2 and 5.3.2), taking account of slurry-based and straw-based systems and their typical forms of storage. Anaerobic digestion of manure and energy crops in biogas plants is included in the calculations (cf. Chapters 5.1.3.6.5 and 5.1.4).

5.1.2.4 The nitrogen flow concept (3.B, 3.D)

With the Py-GAS-EM model, N-species emissions are calculated on the basis of the N-flow concept (Dämmgen & Hutchings, 2005), ; cf. in this connection Chapter 4.2 in Vos et al. (2026).

To make it possible to apply the concept, the relevant animal N excretions have to be determined (cf. Chapter 5.1.3.4). For suckler cows, dairy heifers and female beef cattle, male beef cattle, swine, laying hens, pullets, broilers, ducks and turkeys (males and hens), N excretions are calculated as the difference between the amount of N taken in with feed and basic and

performance-based N requirements (animal weight, weight gain, annual milk yield or egg production (i.e. numbers of eggs) and, if relevant, numbers of young). The N intake with feed is determined on the basis of animal energy requirements and the energy and N content of the feed. As of the present 2026 submission, N excretions for dairy cows are estimated from milk yield along with urea concentration and protein content of the milk. For other animals, N excretion data are taken or derived from the German technical literature or from IPCC (2019).

In the case of N excretions, a distinction is made between the two fractions "organic N" and "TAN readily converted into NH_3" (TAN – "total ammoniacal nitrogen"). TAN is present in the urine of mammals; in the Py-GAS-EM model, in each case TAN is considered to be equivalent to the N content of urine. Poultry excrete "UAN" (uric acid nitrogen); in the inventory, UAN is considered equivalent to TAN. As a result of the manner in which the relevant emission factors are defined, NH_3 emissions are calculated primarily in proportion to the available TAN quantity, while N_2O emissions, NO emissions and N_2 emissions are calculated in proportion to the available N quantity. For this reason, the calculations take account of two parallel N pools. These are (1) the entire N quantity available at the relevant stage being considered, i.e. the sum of organic N and TAN, and (2) TAN by itself.

The N excretions determined for a given animal category are divided into housing emissions and pasture emissions. This division is made in accordance with the percentages of time the relevant animals spend in housing and on pasture.

In the case of solid manure systems, N inputs from bedding material are also taken into account along with N excretions.

For each animal category, the amounts of N occurring in housing systems are divided in accordance with the relative shares of the animal housing systems commonly used in Germany. N losses from NH_3 emissions are subtracted from the TAN pool and from the total N pool. The remaining N and TAN amounts for all stables are combined separately for slurry-based systems and then for straw-based systems and are transferred to storage systems.

The inventory takes account of air scrubbing systems in swine and poultry husbandry; cf. Chapter 4.2.2 in Vos et al. (2026). The N removed in air-scrubbing systems is treated as TAN, as if it were directly applied with manure (see below).

The total N and TAN amounts (for solid manure systems, including the N inputs from straw bedding) accruing to the storage systems are divided, separately for the categories solid manure and slurry, among the different storage systems commonly used in Germany, in accordance with the applicable percentage shares. Anaerobic digestion of manure in biogas plants is included in the calculations (cf. Chapter 5.1.3.6.5). From storage, NH_3 emissions from the TAN pool and the total N pool occur. The N losses occurring as a result of N_2O, NO and N_2 emissions are calculated as a total for housing systems and for storage systems and then subtracted from the total N pool. At the same time, these N losses are subtracted from the TAN pool, using the ratio of the TAN quantity to the total N quantity. The remaining N/TAN quantities are spread. The N removed in air-scrubbing systems is added to the TAN pool.

After storage, the N and TAN quantities left over in the manure are transferred to the transport module, which then distributes the manure among the NUTS-3 regions (see Chapter 5.1.2.5).

The amount of nitrogen to be applied is divided among the various application methods and incorporation times for farm manure that are common in Germany. This is carried out in accordance with the different application techniques' relative proportions of the total amount of manure applied, differentiated by animal category and by the categories of solid manure and

liquid manure. The N_2O emissions released from agricultural soils as a result of application of manure and digestates of manure, are calculated in proportion to the N quantity applied.

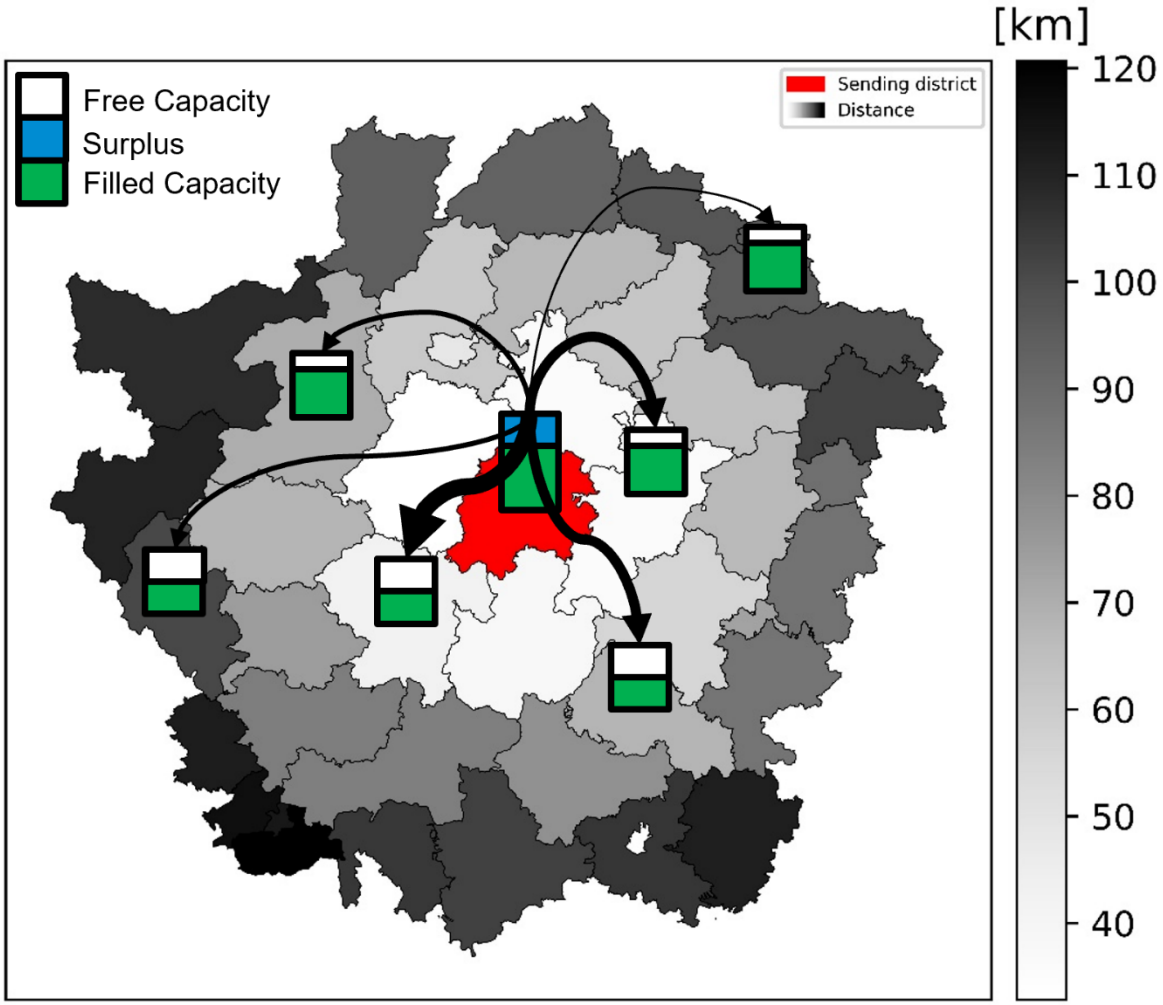
The N_2O emissions from grazing are calculated from the total N quantity excreted during grazing. The N flows that occur in connection with digestion of energy crops along with storage and application of the resulting digestates are treated separately from the N flows for animal husbandry. The former are calculated on the basis of the N quantity in the digested energy crops (cf. Chapter 5.1.4.2) using a procedure analogous to that described above for animal N excretions.

In a procedure analogous to that used for manure application, the N_2O emissions from agricultural soils as a result of applying mineral fertiliser, sewage sludge, digestates of waste and biowaste/green waste compost are calculated in proportion to the N quantity applied.

5.1.2.5 Transport of fermentation substrates, digestates, and manure

As of the present 2026 submission, modelling is used to calculate data in connection with transporting manure, biogas substrates and digestates between NUTS-3 regions. The method used for this is described in detail in Chapter 1.2 of Vos et al. (2026). Modelling enables periods of time and regions to be accounted for where no transport data has been collected, while also ensuring consistency between the modelled mass flows of biomass digestion. This allows the inventory to provide a more realistic distribution of N inputs in agricultural soils. In the model, transportable types of manure from animal husbandry (poultry manure, cattle slurry, cattle solid manure, swine slurry and solid swine manure), energy crops used for digestion in biogas plants, digestates from biogas plants and reported manure categories for imports from other EU countries (cf. Chapter 5.1.5.1.2) are transported separately. Drivers for transports in the model are nitrogen surpluses and fertiliser requirements and substrate requirements of biogas plants. The model accounts for the distance between NUTS-3 regions. Fertilisers imported from the Netherlands are transported the same way and distributed among the German NUTS-3 regions.

Figure 49: Basic approach for transport modelling. Transport from a NUTS-3 region with nitrogen surplus depends on the surplus amount, the distance from other NUTS-3 regions and their capacity to receive nitrogen



Source: own illustration, Thünen-Institut

Manure transport between 2014 and 2024 that was documented within the scope of the Lower Saxony Ordinance on "Reporting requirements for manure" (WDüngMV) forms the basis of the design, parametrisation and validation of the transport model. The NUTS-2 region with Germany's highest livestock density is in Lower Saxony; however, Lower Saxony also has agricultural regions with a low livestock density, meaning that a large proportion of Germany's manure transport is attributable to Lower Saxony. This data set was provided by the Lower Saxony Chamber of Agriculture and includes the net transport of individual manure types between NUTS-3 region in Lower Saxony along with imports and exports from and to other federal states and EU countries. In addition, the data set provides insights into which reported transport was intended for digestion at biogas plants.

5.1.3 Characterisation of animal husbandry

5.1.3.1 Animal categories (3.A, 3.B)

For calculation of emissions from animal husbandry in German agriculture, animal stocks are divided into subcategories to permit description of substocks that are homogeneous with regard

to performance and housing systems. This amounts to a Tier 2 method in accordance with (IPCC, 2006a), Chapter 10.2.2. Table 210 compares the animal categories to be reported on in the CR tables with the animal categories used in the German inventory.

The CRF categories "mules and asses" and "buffalo" are reported as "IE", since the numbers of animals in those categories are included in the figures for "horses" and "other cattle" (cf. Chapter 5.1.3.2.2).

Since the 2024 submission, the categories deer, rabbits, ostriches and fur-bearing animals have been reported to ensure consistency with the EU NEC Directive's (Directive 2016/2284/EU) (cf. EU (2016)) provisions on pollutant reporting. An expert review called for these animal categories to be introduced to ensure the completeness of the inventory.

Table 210: CRF animal categories and the sub-divisions used for purposes of German emissions reporting (3.A, 3.B)

CRF animal categories		Animal categories in the German inventory
1	Dairy cows	"Dairy cows" [a]
	Other cattle	"Calves"(up to 4 months old) [a]
		"Dairy heifers" [b] / "Female beef cattle" [b] | (Young female cattle older than 4 months) [a]
		"Male beef cattle"(Young male cattle older than 4 months) [a]
		"Suckler cows" [a]
		"Male cattle older than 2 years" [a]
2	Sheep	"Mature sheep"
		"Lambs"
3	Swine	Gilts
		"Old sows" (incl. suckling piglets up to 8 kg)
		"Weaners"
		"Fattening pigs"
		"Boars"
	Buffalo	--- [a]
	Camels	--- [c]
	Deer	"Deer"
	Goats	"Goats"
	Horses	"Heavy horses" [d]
		"Light horses and ponies"
	Mules and asses	--- [d]
4	Poultry	"Laying hens"
		"Broilers"
		"Pullets"
		"Geese"
		"Ducks"
		"Turkeys, males"
		"Turkeys, females"
	Rabbits	"Rabbits"
	Reindeer	--- [c]
	Ostriches	"Ostriches"
	Fur-bearing animals	"Fur-bearing animals"

[a] Until 2012, the German inventory included buffalo with suckler cows; as of 2013, the official animal population figures for the categories “other cattle” and “dairy cows” include buffalo. For details, cf. Chapter 2.3.1 in Vos et al. (2026),

[b] For definitions of dairy heifers and female beef cattle, cf. Chapter 2.2 in Vos et al. (2026).

[c] These animals do not occur in Germany.

[d] Until 2009, the German inventory included mules and asses with light horses and ponies; as of 2010, the official animal population figures for horses include mules and asses.

5.1.3.2 Animal place data (3.A, 3.B)

The Py-GAS-EM inventory model calculates in chronological increments of one year. It cannot model intera-annual fluctuations, including fluctuations of animal populations. The German inventory is thus based on the assumption that the numbers of occupied and unoccupied animal places, as shown by official statistics as of a specified reference date (cf. Chapter 5.1.3.2.1) remain constant throughout the course of the relevant year. It can be shown that, in the case of categories of animals with lifetimes of less than one year, this concept correctly takes account of the vacancies occurring between any two production cycles; cf. Chapter 1.1.2.2 in Vos et al. (2026).

For purposes of inventory calculations, the numbers of occupied animal places found as of the reference date are interpreted as the applicable numbers of animals. This approach corresponds to the definition of AAP (“average annual population”) in IPCC (2006b Vol 4, Section 10.2.2): Vol. 4, Section 10.2.2., which has also been adopted by EMEP (cf. (EMEP, 2023) 3B-13).

5.1.3.2.1 Surveys of the Federal and federal state statistical offices

The Federal Statistical Office and the statistical offices of the German federal states carry out agricultural structure surveys that, in addition to collecting other data, carry out censuses of cattle, swine, sheep, horses (as of 2010: equids) and poultry. In the periods 1990-1996 and 1999-2007, such agricultural structural surveys were carried out every other year. In 2010, they were carried out in the framework of the 2010 agricultural census (Landwirtschaftszählung 2010 (StBA, 2010)), a more extensive census. Thereafter, they were carried out again in 2013, 2016, 2020 and 2023. The 1990, 1992, 1994 and 1996 surveys were each carried out on 3 December, while the reference date for the surveys carried out in 1999-2007 was 3 May and that for the surveys carried out in 2010, 2013, 2016, 2020 and 2023 was 1 March.

In addition to the agricultural structure surveys, annual livestock censuses are carried out (Statistisches Bundesamt, FS 3, R 4.1). Until 1998, such surveys were carried out semiannually for cattle and sheep (June, December), every four months for swine (April, August, December), and every two years, in even-numbered years (in December), for all animal species, i.e. also for horses and poultry. In each case, the reference date was the third calendar day of the month. Since 1999, the livestock census for cattle and swine has been carried out twice annually, as of the reference dates 3 May and 3 November. For the sheep census, the reference date was 3 May in the period 1999-2009. In 2010, it was 1 March. As of 2011, it was 3 November.

Census data from official surveys are thus available for cattle, swine and sheep for all years since 1990. In the inventories until 1998, the December data were used (for sheep, the June data). Thereafter, until 2010, the May data were used (for sheep, in 2010: 1 March, since neither May nor November data were available). By agreement with the Federal Statistical Office, the November reference date is to be used as of 2011 (European Parliament (EP), 2008 Article 4). These figures are in accordance with the figures the Federal Statistical Office has provided to EUROSTAT. The change in the reference date, to 3 November, does not significantly affect the population figures in the case of cattle and swine. Among the figures for sheep, livestock population figures had to be corrected; cf. Chapter 5.1.3.2.2.

The numbers of goats in Germany were not surveyed between the years 1977 and 2010. Until 2004, the Federal Ministry of Food and Agriculture (BMEL) estimated goat populations at the national level. As of 2005, this time series was continued through estimates of the Federal Statistical Office. In 2010, the total number of goats (reference date: 1 March) was officially determined for the first time, in the framework of the 2010 agricultural census (StBA, 2010). The resulting figure is considerably lower than the estimates obtained in previous years. By agreement with the Federal Statistical Office, these estimates, which are also reported to EUROSTAT, continue to be used in the inventory. Official goat population figures obtained by the Federal Statistical Office are available for 2013, 2016, 2020 and 2023 (reference date: 1 March).

For horses/equids and poultry, population figures are available only at intervals of two to three years, from agricultural structure surveys (reference dates: until 1998, 3 December; for 1999-2007, 3 May; in 2010, 2013, 2016, 2020 and 2023, 1 March). By agreement with the Federal Statistical Office, the population figures were not adjusted to take account for the variations in reference dates.

The 2013 poultry counts carried out by the Federal Statistical Office and the statistical offices of the federal states were tied to a revision of the relevant reporting groups. The revision was carried out because previous surveys (most recently, in 2010) had failed to take account of a number of large poultry flocks due to the rules for selection of the farms to be surveyed applicable at the time. The poultry counts obtained in 2013 are thus considerably higher than the surveys from prior years would have led one to expect. The Federal Statistical Office has not corrected the official poultry counts for earlier years through 2010. As a result, the counts show a marked increase in the period between 2010 and 2013 that does not reflect the actual development of poultry populations. As of the 2024 submission, therefore, the poultry counts for the period prior to 2013 are being upwardly corrected (see below).

For the animal categories deer, rabbits, ostriches and fur-bearing animals, no official counts are carried out by federal and federal state statistical offices. Consequently, the relevant counts were derived from other sources; cf. in this regard Vos et al. (2026), Chapter 2.3.5.

For the purposes of inventory calculations and in the interest of conformance with emissions reporting requirements, a number of data gaps had to be closed, and some of the animal place figures had to be adjusted. This, as well as how buffalo, mules and asses are taken into account, are discussed in Chapter 5.1.3.2.2.

5.1.3.2.2 Special aspects of animal place figures in the inventory

Since 2008, cattle population figures have been taken from the HIT database (StMELF, diverse Jahrgänge) of the Bavarian State Ministry for Food, Agriculture, Forestry and Tourism (Bayerisches Staatsministerium für Ernährung, Landwirtschaft, Forsten und Tourismus - StMELF), in which all cattle are individually registered. Due to the survey thresholds applied, the new survey method results in systematically higher population figures from 2008 onwards compared to earlier years in which not all animals were counted. A comparison carried out by the Federal Statistical Office for 2007 reveals that the population figures for cattle shown in HIT are 2.9% higher than those resulting from the conventional survey method (for dairy cows alone, the population figures are 2.8% higher). The Federal Statistical Office reports that the cattle time series for the period prior to 2008 will not be adjusted in this regard. As a result, emissions from keeping of cattle are slightly underestimated for the years 1990 to 2007. The figures for dairy cows and male cattle > 2 years are taken directly from the statistics. Until 2007, the figures for suckler cows also include the figures for cows for fattening and for slaughter (thereafter, separate records have no longer been kept for that category). In the inventory, “calves” include only calves up to the age of 4 months. The relevant statistics keep records for

calves up to the age of 8 months, however (prior to 2008, for calves up the age of 6 months). For this reason, the applicable numbers of animals have to be calculated out of the remaining categories in the official statistics, and this affects the numbers of male beef cattle, female beef cattle and dairy heifers (for definitions of dairy heifers and female beef cattle; cf. Chapter 2.2 in Vos et al. (2026). The total number of other cattle in the inventory always corresponds to the total number of other cattle surveyed, however. For details, cf. Chapter 2.3.1 in Vos et al. (2026).

As of time series year 2013, the cattle numbers reported by the Federal Statistical Office, by categories (calves, heifers, cows, etc.) also include a breakdown of the total number of cattle by breeds. That breakdown also includes a sum total figure for bison and buffalo. However, it is not possible to break this sum down in accordance with the various relevant categories (calves, heifers, cows, etc.) (Spielmanns, 2020). As a result, it is not possible to calculate the applicable number of buffalo from the aforementioned figures for cattle. For this reason, as of the 2015 submission, the inventory no longer lists buffalo as a separate category (included elsewhere, IE); their emissions are included in those of cattle. However, buffalo counts had to be properly allocated to cattle counts for the years prior to 2013 to be included. While the Federal Statistical Office has not published any buffalo counts for that period, it proved possible to close the gap for the years 2000-2012 with figures provided by the German buffalo association (Deutscher Büffelverband); cf. Chapter 2.3.1 in Vos et al. (2026). Based on a recommendation in the final report for the "Initial Review under the Kyoto Protocol and Annual 2006 Review under the Convention," for the years prior to 2000 the time series for the buffalo population at the national level was completed using linear extrapolation of data for the years 2000-2012. (For the years 1990 to 1995, the calculated buffalo numbers were negative and were replaced by zeros.) Since no information on the structure of the buffalo population is available for all years up to 2012, for that period all buffalo were assigned to the cattle category "suckler cows." Proof of the correctness of this approach is presented in Chapter 2.3.1 of Vos et al. (2026). Any errors that may have occurred by including buffalo in the cattle category as described above are considered to be negligible, since the ratio of buffalo counts to cattle counts for the entire time series as of 1990 ranges from zero to a figure lower than 0.1% (cf. Chapter 2.3.1 of Vos et al. (2026)).

For swine as well, several of the categories used in official surveys were modified to obtain animal categories that were as homogeneous as possible. The official numbers of animals for piglets weighing up to 20 kg animal^{-1} and for young pigs and fattening pigs weighing at least 20 kg animal^{-1} were converted using the procedure described in Haenel et al. (2011) into numbers of animals for the inventory categories "weaners" and "fattening pigs". This conversion has no impact on the total number of swine, however. For purposes of emission calculation, the number of piglets weighing up to 8 kg is deducted from that total number, however. This approach is based on an inventory concept where piglets weighing up to 8 kg are considered suckling piglets that, with regard to their emissions, are implicitly included in calculations for old sows.

The official population numbers for sheep were corrected for all years as of 2010; cf. Chapter 2.3.4 in Vos et al. (2026). This was done to take account of the change in the relevant survey date from spring (until 2009, May/June) to 1 March (2010) and to 3 November (since 2011). The correction compensates for the apparent reduction in the number of lambs that this change entails (as well as the corresponding reduction in the total number of sheep).

The official goat population figures for 2010, 2013, 2016, 2020 and 2023 were used as a basis for calculating the unavailable counts for the intervening years using linear interpolation. The numbers of animals for 2024 were estimated using a linear extrapolation of the trend between 2020 and 2023.

In the inventory, population figures for horses are subdivided into two categories – "heavy horses" and "light horses and ponies" – to take account of the differences in emissions behaviour between the two categories. The 2010 agricultural census and 2013, 2016, 2020 and 2023 censuses counted the "numbers of equids" rather than numbers of horses. The equid figures include the counts for mules and asses. The numbers for mules and asses cannot be separated out of the equid data (included elsewhere, IE). As of the 2015 submission, therefore, the inventory no longer includes "mules and asses" as a separate category. Until the year 2009, the count for mules and asses was added to the count for light horses and ponies. According to data of the association of parties interested in donkeys and mules (Interessengemeinschaft für Esel und Maultiere (IGEM)) (Schmutz, 2009), the applicable number for mules and asses was estimated at 8,500 mules and asses per year. Gaps within the time series for horses were closed using linear interpolation. The numbers of animals for 2024 were estimated using a linear extrapolation of the trend between 2020 and 2023. The numbers of horses in the official statistics only include horses kept by agricultural businesses. The actual number of horses kept in Germany is much higher. According to a representative study by IPSOS (IPSOS, 2019), there were approximately 1,247,000 horses in Germany in 2019. This is 2.75 times the number of animals included in the agricultural statistics. A preceding study from 2001(IPSOS, 2001) estimates that there are well over 1 million horses and ponies. Since the 2025 submission, the number of horses derived from agricultural statistics has been multiplied by a factor of 2.75 for the entire time series, in order to avoid an underestimation of the emissions from horses.

Until 2007, in contrast to actual housing practice (placement in stalling systems, as laying hens, as soon as they complete their 18th week of life; this is also the practice taken into account in the inventory) pullets were officially counted until they reached the age of 6 months. In the inventory, therefore, a fraction of the pullets was shifted into the laying hen category, while the sum total for pullets and laying hens was not changed; cf. Chapter 2.3.3 in Vos et al. (2026). The next poultry count after 2007 took place in 2010. As of that count, shifting of figures between the pullet and laying hen categories is no longer required, since the relevant populations have been counted in accordance with actual housing practice.

The correction of the poultry counts for the period prior to 2013 (see above) was carried out for the animal categories laying hens, pullets and broilers in the federal state of Lower Saxony, since almost all of the major poultry farms not included in the poultry counts before 2013 are located in Lower Saxony. In a first step, the poultry count for the year 2010 was corrected. This was accomplished by assuming that the trend seen between the survey years 2013 and 2016 also applies to the period between the survey years 2010 and 2013. The resulting poultry count for 2010 was assumed to be correct, and the factor f_{2010} was then determined on the basis of the relationship between the corrected poultry count for 2010 and the count determined in a survey. For laying hens, pullets and broilers, the values of f_{2010} are about 1.6, 2.2 and 1.8, respectively. The poultry counts obtained for 1990 were assumed to be correct, since, in all likelihood, no major farms were in operation at that time that were not included in the statistics. For the year 1990, the factor f_{1990}, expressing the ratio between the corrected and recorded poultry count, is 1 in each case. For the survey years between those two years (1992, 1994, 1996, 1999, 2003 and 2007), such factors were determined by linear interpolation between 1 (f_{1990}) and the relevant f_{2010}. The resulting factor was then multiplied in each case by the relevant animal count determined by survey.

For all poultry categories, gaps in the animal number time series were closed using linear interpolation. Other than with laying hens, the 2023 values were applied to the year 2024. With laying hens, the count for 2024 was estimated using the numbers for 2023 and the trends on housing numbers published by the Federal Statistical Office.

In the inventory, the official census data for turkeys were broken down by the categories "turkeys, males" and "turkeys, females" for all years since 1990 to take account of the differences in growth.

5.1.3.2.3 Animal place data used in the inventory (3.A, 3.B)

Table 211 presents a compilation of the animal place figures on which German reporting is based. The years listed correspond to the years that are used, in the following chapters, in time series. The complete time series for the animal population data is provided in Chapter 2.3 of Vos et al. (2026). The sharp decrease in the numbers of animals at the beginning of the 1990s is a direct result of structural change in the German agricultural sector following German reunification. In eastern Germany in particular, large herds were trimmed. Since 2017, the numbers of dairy cows and other cattle have decreased considerably. In the swine category as well, a noticeable decrease has occurred since 2017. It follows a period of years with no consistent trend. For dairy cows and other cattle, the animal counts for the year 2024 are the lowest seen throughout the entire relevant period since 1990. For swine, this was the case in 2023. The reason for the decrease cannot be unambiguously determined. Examples of possible reasons for this include an unfavourable economic framework; a lack of feed, resulting from the widespread drought that prevailed in Germany between 2018 and 2020; and a reaction, on the part of farmers, to the tighter regulations introduced by the new Fertiliser Ordinance (DüV, 2017). The sheep counts have remained roughly constant since 2015. Goat counts have exhibited a slightly increasing trend since 2014, while horse counts have also been increasing slightly since 2016. Poultry counts have remained at about the same level since 2016.

With regard to the uncertainties for the population figures, cf. Table 250 in Chapter 5.1.6.

Table 211: Animal place figures used in reporting (3.A, 3.B), in thousands

	Dairy cows	Other cattle	Swine	Sheep	Goats	Horses	Poultry	Deer	Rabbits	Ostriches	Fur-bearing animals
1990	6,355	13,133	26,502	3,266	90	1,373	113,879	156	1,851	0	180
1995	5,229	10,661	20,387	2,991	100	1,744	119,644	204	1,566	1	180
2000	4,570	9,969	21,768	2,743	140	1,374	139,218	252	1,269	2	180
2005	4,236	8,800	22,743	2,643	170	1,398	149,030	262	997	4	153
2010	4,183	8,629	22,244	2,245	150	1,270	169,704	270	864	5	122
2015	4,285	8,351	22,979	1,867	136	1,233	174,827	277	721	8	34
2016	4,218	8,249	22,761	1,851	139	1,215	173,574	279	691	7	25
2017	4,199	8,082	22,921	1,863	143	1,223	173,468	280	643	7	15
2018	4,101	7,848	22,019	1,846	147	1,231	173,361	282	608	8	5
2019	4,012	7,628	21,626	1,814	151	1,240	173,255	283	594	7	5
2020	3,921	7,380	21,622	1,780	155	1,248	173,148	285	548	8	0
2021	3,833	7,207	19,729	1,795	157	1,278	171,201	286	470	6	0
2022	3,810	7,187	17,692	1,806	160	1,308	169,255	288	431	5	0
2023	3,713	7,123	17,525	1,848	163	1,338	167,308	289	423	5	0
2024	3,589	6,872	17,643	1,824	165	1,368	167,583	291	422	4	0

5.1.3.2.4 Comparison with livestock population figures of the FAO (3.A, 3.B)

The United Nations Food and Agriculture Organization (FAO) publishes global livestock census data in its FAOSTAT Internet database (FAO, 2024). In general, the German figures in FAOSTAT

come from the German Federal Statistical Office, which is also the data source for the German inventory. Nonetheless, numerous discrepancies result, for cattle, swine, sheep, goats, horses and poultry, when the data of FAOSTAT (as of 15 August 2024: time series through 2022, for poultry and horses only through 2017, for poultry also data for 2020) and the data used in the 2025 submission are compared: from 1990 to 2022, less than 15% of the FAOSTAT figures agree with the corresponding German data (even when the figures rounded to whole 100s of animals are taken into account).

The main reasons for the differences – large, in part – between the FAOSTAT data and the German data are that FAOSTAT has assigned a number of entries to the wrong years, and that it is inconsistent in its choice of methods for closing data gaps.

In the following section, the most important results of the data comparison are listed.

Cattle: The FAOSTAT animal population data agree with the official German data only for the years 2014-2022. Prior to the year 2000, the FAOSTAT figures are shifted by a year with respect to the German figures. For example, the cattle population figure that Germany listed for 1998 is listed by FAOSTAT for 1999. In the years 2011-2013, FAOSTAT uses the data from the May census, while the German inventory – in accordance with an EU provision (cf. Chapter 5.1.3.2.1) – uses the data from the November census.

Swine: In general, the swine census figures listed by FAOSTAT cannot be compared with the corresponding inventory figures, since the inventory, for methodological reasons, deducts the numbers of piglets that weigh less than 8 kg (cf. Chapter 5.1.3.2.2). A comparison of a) the FAOSTAT swine population figures and b) the swine population figures of the Federal Statistical Office without deduction of suckling piglets shows that the FAOSTAT figures, like the FAOSTAT cattle census figures for the period prior to 2000, are shifted – erroneously – by one year. With the exception of the years 2011-2013, in which the FAOSTAT figures are consistent with the May census, while the inventory, in accordance with an EU requirement (cf. Chapter 5.1.3.2.1), uses the November census data for the calculation, there is a high degree of similarity between the animal count time series.

Sheep: In the periods 1991, 1993-2000 and 2005-2009, the FAOSTAT figures are very similar to the data of the Federal Statistical Office. They are consistent (taking account of rounding to 100s of animal places) only for the years 2007-2009, however. In the years 1990, 1992, 1993 and 2001-2004, there are discrepancies - some of them significant - that cannot be explained with the available information. As of 2010, the two time series cannot be compared, since the official sheep population figures are corrected in the inventory (cf. Chapter 5.1.3.2.2).

Goats: For the years prior to the period 1991 to 2002, the FAOSTAT goat counts are shifted by one year with respect to the corresponding German figures. For example, FAOSTAT's goat count for 1991 is the same as the German goat count for 1990. For the years 1990, 2003, 2005, 2007, 2008, 2013 and 2016, the FAOSTAT figures agree with the corresponding German figures. For those years in between the above years, in which Germany neither collected nor estimated data in this category, FAOSTAT lists data that must be the result of estimations, although FAOSTAT states that those data are official data. These estimates are implausible especially for the period as of 2011, since they contradict the trends obtained using linear interpolation between the supporting years.

Horses (including mules and asses): The FAOSTAT figures for the period prior to 2010 list horse-only counts, i.e. do not include mules and asses. When the added mules and asses are deducted from the uncorrected inventory figures (not multiplied by 2.75) (cf. Chapter 5.1.3.2.2), for purposes of comparison, the FAOSTAT figures show a one-year lag behind the German

figures until the year 2004. In this context, it should be noted that the livestock population figures given by FAOSTAT often differ from those listed in official German statistics. As of 2005, the FAOSTAT data and the German data agree only for the years 2013 and 2016. FAOSTAT has no horse counts for Germany for the period after 2017. In the years between 2005 and 2016 in which Germany collected no data in this category, the FAOSTAT estimates - like those for goats - show an implausible chronological progression.

Poultry: In nearly all years with animal censuses, the FAO poultry counts largely agree with the relevant uncorrected poultry counts (1994, 1999, 2003, 2005, 2007, 2010, 2013, 2016 and 2020; after 2020, and between 2017 and 2020, the FAOSTAT data does include any poultry counts for Germany). The results of the censuses for 1990, 1996 and 2001 were incorrectly entered in FAOSTAT for the following year. In addition, FAOSTAT's closures of data gaps for the period as of 2010 are just as implausible as in the case of goats and horses, resulting in an erratic time series from 2010 onwards.

5.1.3.3 Performance, energy and feed data (3.A, 3.B)

As a result of quality assurance measures and the availability of updated input data, changes have been made to the submission for the preceding year that affect input data, performance, energy requirements and feed intake. The most important changes in terms of their impacts are provided in Chapter 5.1.7.3.

Table 212 shows the mean animal weights for dairy cows, other cattle, swine and poultry. The mean animal weight for dairy cows is obtained from the starting and final weights (averaged over the German federal states, and weighted with the animal numbers at the federal state level); cf. Chapter 2.4.1 in Vos et al. (2026). With regard to calculation of the mean animal weights for other cattle, swine and poultry, also see Chapter 2.4.1 in Vos et al. (2026).

Table 212: Average animal weights (3.A, 3.B), in [kg/animal]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Dairy cows	566.9	581.9	591.1	592.3	592.6	587.7	584.4	587.3	588.4	595.5	601.3	603.4	600.1	603.8	605.0
Other cattle	316.3	328.6	338.1	334.9	337.1	335.3	335.6	336.1	337.7	340.5	342.2	343.0	343.9	346.1	347.6
Swine	73.9	76.7	75.7	75.7	74.6	73.2	73.3	73.2	73.6	73.5	73.4	74.8	73.8	73.7	74.3
Poultry	1.61	1.57	1.60	1.64	1.62	1.70	1.70	1.69	1.69	1.68	1.68	1.65	1.62	1.60	1.60

The animal weights for sheep, goats and horses are not directly included in the emissions calculations, but were estimated for CRF-3.B: Sheep, 50 kg animal^{-1}; goats, 40 kg animal^{-1}; and horses, 490 kg animal^{-1}; cf. Chapter 2.4.1 in Vos et al. (2026).

Table 213 shows daily milk yield from dairy cows, expressed as an average for Germany as a whole; it is obtained by dividing the annual milk yield by 365 days.

Table 213: Mean daily milk yield for dairy cows (3.A, 3.B), in [kg/d]

1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
13.4	15.4	17.3	19.2	20.2	21.6	22.0	22.0	22.9	23.4	24.0	24.0	24.0	25.1	25.9

For dairy cows, dairy heifers and female beef cattle, male beef cattle, suckler cows, sows, weaners and fattening pigs, the gross energy (GE) intake is calculated as a function of performance. Cf. Chapter 2.4.5 in Vos et al. (2026). Such calculations are based on the IPCC

concept (IPCC (2006b Vol 4, Chapter 10.2.2)), to the effect that feeding precisely meets animals' energy requirements. The energy requirements for dairy cows are given in terms of the "net energy for lactation (NEL)" (cf. Kirchgessner et al. (2008)), while the term "metabolic energy (ME)" is used for other animals for which the German inventory includes energy requirements calculations (for example, cf. Gesellschaft für Ernährungsphysiologie (2006)).

The NEL and ME requirements figures comprise all of the sub-requierements (maintenance, growth, production of young and products, grazing) relevant for the applicable animal category in each case. The quantity of feed, of a given composition, required to meet NEL and ME energy requirements is calculated on the basis of the energy requirements and the mean NEL and ME energy content of the feed. The GE intake for a given animal is calculated on the basis of the feed quantity ingested and the mean GE content of the feed.

The GE intake figure for boars is a standard value. For calves, and male cattle older than 2 years, GE intake is derived from standard values for ME intake. Cf. Chapter 2.4.5 in Vos et al. (2026). No GE intake figures are determined for the remaining animal categories (sheep, goats, horses, poultry, deer, rabbits, ostriches and fur-bearing animals).

Table 214 shows the daily GE intake for dairy cows, other cattle and swine.

Table 214: Mean daily GE intake (GE) (3.A), in [MJ/place]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Dairy cows	246.7	270.2	289.7	306.0	315.0	325.4	329.0	329.1	336.2	343.7	349.6	350.8	347.8	359.4	366.0
Other cattle	100.1	104.0	106.9	106.6	108.1	108.2	108.2	108.6	109.0	110.0	110.9	111.7	111.5	112.1	112.6
Swine	30.4	32.0	32.8	33.0	33.5	34.7	35.0	35.2	35.5	35.6	35.9	36.4	36.3	36.5	37.1

Table 215 to Table 217 show, for dairy cows, other cattle and swine, the input data for the VS calculation on which the calculation of CH_4 emissions from manure management is based (cf. Chapter 5.3.2.2.1). The data include dry matter (DM) intake, digestibility of organic matter and ash content of feed. For details on DM intake, we refer to Chapter 2.4.6 in Vos et al. (2026). No DM intake figures are determined for sheep, goats, horses, geese, deer, rabbits, ostriches and fur-bearing animals, because no data on feeding are available. Neither are any standard values available. For this reason, the VS excretion figures are obtained by other methods; cf. Chapter 5.1.3.5.

Table 215: Daily dry matter intake (3.B), in [kg/place]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Dairy cows	13.5	14.8	15.8	16.7	17.2	17.7	17.9	17.9	18.3	18.7	19.0	19.0	18.9	19.5	19.8
Other cattle	5.5	5.7	5.8	5.8	5.9	5.9	5.9	5.9	6.0	6.0	6.1	6.1	6.1	6.1	6.2
Swine	1.6	1.7	1.8	1.8	1.8	1.9	1.9	1.9	2.0	2.0	2.0	2.0	2.0	2.0	2.0

The mean digestibility and the mean ash content of feed were determined largely on the basis of German standard values for the various feed components (DLG, 2005, 2014), supplemented by information provided by experts (Spiekers, 2019). Missing data were estimated on the basis of other sources (including Beyer and Jentsch (2004); information provided by producers).

Table 216: Digestibility of organic matter in feed (3.B), in %

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Dairy cows	75.5	75.4	75.6	75.9	75.8	75.8	75.8	75.8	75.9	76.0	76.0	76.1	76.0	76.2	76.3
Other cattle	74.5	74.3	74.1	74.2	74.1	74.1	74.1	74.1	74.1	74.0	74.0	74.0	74.0	73.9	73.9
Swine	82.9	82.9	82.9	83.6	84.3	84.4	84.4	84.4	84.4	84.4	84.4	84.4	84.4	84.4	84.4

Table 217: Ash content of feed (3.B), in [kg/kg]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Dairy cows	0.084	0.084	0.083	0.082	0.078	0.075	0.075	0.075	0.075	0.075	0.074	0.074	0.074	0.074	0.074
Other cattle	0.089	0.090	0.090	0.090	0.089	0.088	0.088	0.088	0.088	0.087	0.087	0.087	0.087	0.087	0.087
Swine	0.057	0.057	0.048	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046

The following chapters present further information related to animal husbandry, e.g. excretion data (N, VS).

None of the animal models used call for mean percentages of pregnant animals as input figures. For cattle, they are reported in CRT Table 3.A, however, in the interest of completeness.

5.1.3.4 N excretions (3.B)

The manner in which N excretions are determined is described in Chapter 4.1.2 in (Vos et al., 2026).

For dairy cows, dairy heifers and female beef cattle, male beef cattle, suckler cows, swine (except for boars), laying hens, pullets, broilers, ducks and turkey cocks and turkey hens, N excretions are calculated as a function of performance. For other animals, the N excretion values are taken or derived from the relevant German technical literature.

Calculation of N excretions as a function of performance is based, except in the case of dairy cows, on the assumption that feeding precisely meets energy requirements (cf. Chapter 5.1.3.3). The N quantity ingested by an animal is obtained from the ingested quantity of feed and the mean N quantity of the feed ration that conforms to relevant national feeding recommendations. Growth-related N retention, N output from products (milk/eggs) and N losses from pregnancy/offspring are all deducted from the ingested N quantity. The remaining N quantity is the N excretion figure.

As of the present 2026 submission, N excretions for dairy cows are modelled from milk yield along with urea content and the protein content of the milk from the cow. In Germany, milk constituents are recorded representatively during milk testing, with anonymised data on individual farms provided by the milk recording systems of the different federal states. The modelling used is described in Honig et al. (2024): Dairy cows largely excrete surplus nitrogen as urea in their urine. The urea concentration in urine is closely linked to the urea concentration in milk. Based on experimental data from 1628 lactating dairy cows of various breeds at 11 German research institutions between 2018 and 2021 were used to develop a linear model to estimate dairy cows' daily N excretions during lactation based on milk yield, milk urea and milk protein values. Data from 12 German research institutions (1,664 dairy cows of various breeds during lactation) were used to validate the model. Holstein Friesians were chosen for the emissions inventory as they are the most prevalent breed in Germany. Details regarding the calculation are provided in Chapter 4.1.2 in (Vos et al., 2026).

The following parameters are used to calculate N excretions:

- Dairy cows: milk yield, milk protein content, milk urea content;
- Suckler cows: milk yield, animal weight, weight gain, numbers of births per year (constant values in each case), feed characteristics (these vary, because grazing periods vary)
- Dairy heifers, female beef cattle and male beef cattle: weight gain, final weight and feed characteristics;
- Swine: animal weight; for sows, also number of piglets per year; for weaners and fattening pigs, also weight gain and feed characteristics;
- Laying hens, pullets, ducks, turkeys: weight gain, final weight, and feed characteristics; for laying hens, also egg production and egg weights;
- Broilers: Gross meat quantities at slaughter, feed characteristics.

For animal categories with grazing, calculated N excretions per animal place and year are broken down into in-pasture and in-housing excretions, since only in-housing excretions can enter into calculation of N_2O emissions in 3.B. Calculation of N_2O emissions in 3.D takes account of N excretions in pasture. N excretions are divided into in-housing and in-pasture categories in accordance with the relative time proportions for time in housing and time on pasture (cf. Annex 7.3.1, Table 510).

Table 218 shows the time series for N excretions. The N excretions for goats, which are not listed, are constant over time (11.0 kg place^{-1} a^{-1}). The same holds for deer (16.0 kg place^{-1} a^{-1}), rabbits (0.8 kg place^{-1} a^{-1}), ostriches (15.6 kg place^{-1} a^{-1}) and fur-bearing animals (4.59 kg place^{-1} a^{-1}).

Table 218: Annual N excretions (3.B(b)), in [kg/place]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Dairy cows	106.3	110.8	114.3	117.5	114.3	115.2	116.8	118.7	120.3	121.4	119.7	117.0	116.1	118.6	120.2
Other cattle	37.9	39.9	41.3	41.2	42.1	42.5	42.5	42.7	42.9	43.4	43.7	43.9	43.9	44.2	44.4
Swine	12.8	13.1	13.0	12.8	12.6	12.4	12.4	12.3	12.2	12.1	12.1	12.3	12.2	12.2	12.3
Sheep	7.7	7.7	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8
Horses	48.2	48.1	49.0	48.8	48.8	54.0	55.0	56.1	57.1	58.2	59.2	59.2	59.2	59.2	59.2
Poultry	0.7	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7

Table 219 shows the annual N excretions for the four manure management systems “slurry-based (without digestion),” “straw-based (without deep bedding and without digestion),” “deep bedding (without digestion)” and “digestion” as well as for “grazing”.

Table 219: Annual totals for N excretions, broken down by manure management systems (3.B(b)) and grazing systems (3.D), in [Gg/a]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Total	1688.2	1460.9	1398.0	1340.5	1309.8	1339.9	1330.7	1332.8	1308.7	1290.1	1262.7	1216.9	1182.9	1180.1	1168.4
Slurry-based [a]	915.6	865.5	834.8	759.7	630.0	595.8	596.8	600.9	593.3	589.4	568.8	526.9	499.6	516.0	508.8

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Straw-based [a]	484.7	350.1	331.1	327.5	318.5	276.0	266.2	259.4	251.3	242.6	238.4	235.4	229.1	232.3	233.0
Deep bedding [a]	48.5	50.1	53.7	61.8	68.5	89.9	93.8	97.2	99.3	102.2	99.3	96.1	94.7	95.1	92.0
Digestion	0.0	0.6	5.4	36.3	146.3	235.6	233.1	235.2	227.1	220.4	223.1	228.0	229.0	205.0	204.8
Grazing	239.4	194.6	173.2	155.3	146.5	142.7	140.9	140.1	137.7	135.6	133.1	130.5	130.5	131.7	129.8

[a] Without digestion

[b] Without deep bedding and without digestion

5.1.3.5 VS excretions (3.B)

The VS excretions for dairy cows, other cattle, swine and poultry (exception: geese) are calculated using the national procedure of Dämmgen et al. (2011), cf. Ch. 4.1.1 in Vos et al. (2026).

Equation 12: Calculation of VS excretions

$$VS_{\mathrm{i}} = m_{\mathrm{feed,\ DM,\ }i} \cdot (1 - X_{\mathrm{DOM,\ i}}) \cdot (1 - x_{\mathrm{ash,\ feed}})$$

- VS_{i} VS excretions for animal category i (in kg place^{-1} d^{-1})
- $m_{\mathrm{feed,\ DM,\ i}}$ Dry matter intake, animal category i (in kg place^{-1} d^{-1})
- $X_{\mathrm{DOM,\ i}}$ Digestibility of organic matter, animal category i (in kg kg^{-1})
- $X_{\mathrm{ash,\ i}}$ Ash content of feed, animal category i (in kg kg^{-1})

For an overview of input data for dairy cows, other cattle and swine, cf. Chapter 5.1.3.3.

For all other animal categories, constant VS excretions are anticipated and calculated accordingly. This is not the case with sheep and horses as their populations of large and small animals vary from year to year. In addition, the assumed change to feeding practices for large horses between 2010 and 2020 led to a significant increase in VS excretions among horses during this period.

The mean VS excretions calculated for dairy cows, other cattle, swine, poultry, sheep and horses are shown in Table 220.

Table 220: Daily VS excretions for dairy cows, other cattle, swine, poultry, sheep and horses (3.B(a)), in [kg/place]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Dairy cows	3.02	3.33	3.54	3.70	3.82	3.96	4.00	4.00	4.08	4.15	4.21	4.22	4.19	4.30	4.36
Other cattle	1.27	1.33	1.38	1.37	1.39	1.40	1.40	1.40	1.41	1.42	1.44	1.45	1.45	1.46	1.47
Swine	0.27	0.28	0.29	0.28	0.27	0.29	0.29	0.29	0.29	0.29	0.29	0.30	0.30	0.30	0.30
Poultry	0.019	0.018	0.019	0.020	0.020	0.022	0.023	0.023	0.023	0.023	0.022	0.022	0.022	0.022	0.022
Sheep	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
Horses	2.36	2.36	2.39	2.39	2.38	2.72	2.78	2.85	2.92	2.99	3.05	3.05	3.05	3.05	3.05

Table 221 shows the daily VS excretions for the remaining animal categories, including the subcategories of sheep and horses. Cf. Chapter 4.1.1 in Vos et al. (2026).

Table 221: Daily VS excretions for sheep, goats, horses and other animals (3.B(a)), in [kg/place]

	VS [kg place^{-1} d^{-1}]
Mature sheep	0.53
Lambs	0.21
Goats	0.30
Heavy horses	2.59 (until 2010) - 3.46 (from 2020)
Light horses and ponies	1.73
Deer	0.30
Rabbits	0.10
Ostriches	1.16
Fur-bearing animals	0.14

5.1.3.6 Housing systems, storage systems and application procedures (CRF 3.B, 3.D)

5.1.3.6.1 Frequency distributions (3.B, 3.D)

The German inventory uses annual frequency distributions, broken down by animal subcategories, for the various husbandry systems (proportions for pasture grazing/stable housing; proportions for different housing systems), manure storage systems and manure application techniques, and time allotted to pasture grazing. The data for manure digestion and storage of digestion residues are discussed in Chapter 5.1.3.6.5 . Data collection and processing for the inventory, at the level of the German federal states, is described in detail in Chapter 2.5 in Vos et al. (2026). With regard to description of the frequency distributions at the level of Germany as a whole, we refer to Annex 7.3.1 in the present NID.

The following tables show, for the important animal categories “dairy cows,” “other cattle,” “swine” and “poultry,” how the animal populations break down, in terms of percent of excreted VS, with respect to the various categories of manure management systems. The changes with respect to the 2025 submission result primarily from updating of input data for manure digestion; cf. Chapter 5.1.3.6.5.

Table 222: Slurry-based systems without digestion, in % of excreted VS (3.B(a))

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Dairy cows	53.0	69.4	72.2	70.3	61.2	57.6	58.5	59.0	59.9	60.8	59.9	58.0	58.9	60.7	60.3
Other cattle	58.0	55.1	51.3	44.3	34.4	31.7	31.9	31.9	32.3	32.5	32.1	31.2	31.2	32.2	31.9
Swine	81.2	87.5	89.3	87.5	77.8	70.9	71.1	71.1	71.4	72.1	71.9	70.9	66.8	70.6	71.1

Table 223: Straw-based systems without digestion, in % of excreted VS (3.B(a))

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Dairy cows	26.9	15.1	14.7	15.4	14.9	10.9	10.1	9.3	8.6	7.8	7.8	7.7	7.6	7.7	7.7
Other cattle	19.8	18.4	19.1	21.1	22.9	17.1	15.9	14.8	13.8	12.7	12.7	12.5	12.5	12.7	12.8
Swine	16.6	10.5	8.6	7.5	6.2	4.2	3.9	3.6	3.4	3.1	3.0	3.0	3.0	3.0	3.0
Poultry	100.0	99.9	99.2	95.6	87.3	76.7	76.7	77.1	77.9	77.6	76.5	77.1	72.9	74.1	74.5

Table 224: Deep bedding systems without digestion, in % of excreted VS (3.B(a))

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Dairy cows	0.1	0.2	0.2	0.2	0.5	2.3	2.7	3.1	3.4	3.8	3.8	3.8	3.8	3.8	3.8
Other cattle	7.3	9.6	10.9	14.1	15.8	19.7	20.5	21.3	22.1	22.9	22.8	22.6	22.5	22.7	22.5
Swine	2.2	1.9	1.6	1.4	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3

Table 225: All systems with digestion, in % of excreted VS (3.B(a))

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Dairy cows	0.003	0.045	0.45	2.9	13.6	20.6	20.6	20.7	20.5	20.2	21.1	23.1	22.3	20.4	20.9
Other cattle	0.003	0.032	0.27	2.0	7.7	11.4	11.3	11.4	11.1	11.0	11.5	12.8	12.8	11.1	11.4
Swine	0.004	0.061	0.50	3.7	14.7	23.6	23.7	23.9	24.0	23.6	23.8	24.8	28.9	25.2	24.7
Poultry	0.005	0.074	0.55	4.0	12.3	22.6	22.6	22.2	21.3	21.5	22.6	22.0	26.1	24.8	24.4

Table 226: Grazing, in % of excreted VS (3.B(a))

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Dairy cows	20.0	15.3	12.5	11.2	9.8	8.5	8.2	7.9	7.6	7.3	7.3	7.3	7.4	7.3	7.3
Other cattle	14.9	16.9	18.5	18.5	19.1	20.1	20.3	20.5	20.7	21.0	21.0	20.9	21.0	21.3	21.5
Poultry	0.0	0.1	0.2	0.3	0.5	0.7	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.1

5.1.3.6.2 Bedding material in solid manure systems

In solid manure systems, additional nitrogen enters the system through the bedding material. In the inventory, this nitrogen is taken into account in calculation of N_2O and NO emissions from manure management. Table 510 in Annex 7.3.1 lists the applicable bedding material quantities, as fresh matter, for the various different animal housing procedures. With a dry matter content of 86%, and an N quantity of 0.58% in dry matter (cf. Chapter 4.2.1 in Vos et al. (2026)), this results in the bedding material N quantities listed in Table 227 for the various animal categories.

Table 227: Annual totals for N inputs through bedding material in straw-based systems, in [Gg]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Total	64.1	55.1	50.5	50.4	50.2	50.3	49.8	49.6	49.1	48.6	47.9	47.4	47.5	47.5	47.0
Dairy cows	17.2	7.6	7.1	6.7	6.7	6.5	6.3	6.2	5.9	5.7	5.6	5.5	5.4	5.3	5.1
Other cattle	24.0	21.1	21.5	21.4	23.3	24.4	24.4	24.3	24.0	23.7	22.9	22.4	22.3	22.1	21.4
Swine	3.18	1.78	1.56	1.38	1.15	0.95	0.92	0.89	0.83	0.78	0.78	0.70	0.62	0.62	0.62
Sheep	0.83	0.75	0.70	0.68	0.58	0.47	0.47	0.47	0.47	0.46	0.45	0.45	0.45	0.47	0.46
Goats	0.04	0.05	0.07	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08
Horses	18.0	22.8	18.3	18.6	16.8	16.4	16.1	16.2	16.3	16.5	16.6	17.0	17.4	17.8	18.2
Poultry	0.84	1.01	1.27	1.51	1.52	1.54	1.50	1.48	1.46	1.44	1.43	1.34	1.25	1.17	1.17
Deer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rabbits	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Ostriches	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
Fur-bearing animals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

5.1.3.6.3 Maximum methane producing capacity Bo (3.B(b))

For purposes of emission calculation (cf. Chapter 5.3.2.2.1), the methane formation related to manure storage is characterised by the animal-specific maximum methane formation rate B_o and the storage-specific methane conversion factor MCF. With regard to the MCF, cf. Chapter 5.1.3.6.4.

Table 228 shows the B_o values used and the origins of the relevant data. For cattle and swine, the data are national data. For the other animals, apart from pullets, geese and deer, IPCC default values were used. No IPCC default values are available for pullets, geese and deer. In a conservative approach, the (IPCC (2006b): Vol. 4) default value for laying hens has been adopted for pullets. For the B_o for geese, a value of 0.36 m^3 kg^{-1} has been adopted, in accordance with Chapter 4.4.1.1 in Vos et al. (2026). For deer, the default value given in (IPCC (2006b): Vol. 4) default value for goats was used.

Table 228: Maximum methane producing capacity B_o (3.B(b))

[m^3 kg^{-1}]	B_o	Source
Cattle	0.23	(Dämmgen, Amon, et al., 2012)
Swine	0.30	(Dämmgen, Amon, et al., 2012)
Sheep	0.19	(IPCC, 2006b Vol 4, 10.82)
Goats	0.18	(IPCC, 2006b Vol 4, 10.82)
Horses	0.30	(IPCC, 2006b Vol 4, 10.82)
Laying hens	0.39	(IPCC, 2006b Vol 4, 10.82)
Broilers	0.36	(IPCC, 2006b Vol 4, 10.82)
Ducks	0.36	(IPCC, 2006b Vol 4, 10.82)
Turkeys	0.36	(IPCC, 2006b Vol 4, 10.82)
Pullets	0.39	Assumption (see text)
Geese	0.36	Chapter 4.4.1.1 in Vos et al. (2026)
Deer	0.18	Assumption (see text)
Rabbits	0.32	IPCC (2019), Table 10.15
Ostriches	0.25	IPCC (2019), Table 10.15
Fur-bearing animals	0.25	IPCC (2019), Table 10.15

Table 229: Average maximum methane formation capacity for B_o for poultry (3.B(b)), in m^3 kg^{-1}

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Poultry	0.378	0.376	0.373	0.371	0.370	0.371	0.371	0.371	0.384	0.385	0.386	0.386	0.389	0.389	0.389

5.1.3.6.4 Methane conversion factors MCF (3.B)

In CRF 3.B(a), the MCF values for the various national manure management categories are to be reported under “Additional Information”. In Germany, the categories are “slurry-based without digestion”, “straw-based without digestion” (heap), “deep bedding without digestion”, “digestion” and “pasture”. The values are weighted average values, over all animal categories, based on the MCF values described below. The category “slurry-based without digestion” includes all animals housed in slurry-based systems with no digestion of the animals’ manure. The categories “straw-based without digestion (solid manure storage systems)” and “deep

bedding without digestion" should be understood in the same way. The "digestion" category includes all animals whose manure is digested.

Table 230 shows the MCF values for cattle, broken down by the storage systems commonly used in Germany. The national values proposed by Dämmgen, Amon, et al. (2012) are in boldface type. In a conservative approach, chosen due to a lack of IPCC default values or national values, the MCF applying to "liquid manure without natural crust" was used for "liquid manure with solid cover" (including tent structures), "liquid manure with floating chopped-straw cover" and "liquid manure with floating cover foil". The values for deep bedding and pasture were taken from IPCC (2006b Vol 4, 10.44).

Table 230: Methane conversion factors *MCF* (in % of B_o) for cattle (3.B(a))

		MCF [%]
Liquid manure	Open tank, without natural crust	17
	Solid cover	17
	Natural crust	10
	Floating cover (chopped straw)	17
	Floating cover (cover foil)	17
	Below slatted floor > 1 month	17
Solid manure	Deep bedding	17
	Heap	2
Pasture		1

Table 231 lists the methane conversion factors MCF for manure storage in swine husbandry. As was the case for the cattle data, the values are national values (Dämmgen, Amon, et al., 2012), default values from IPCC (2006b Vol 4, 10.44) or conservative assumptions in cases in which no MCF is known. For cattle, the MCF for "deep bedding" is the same as that for liquid manure without natural crust, and thus the same relationship has been assumed to hold for swine. Free-range management of swine ("pasture") plays a very insignificant role in Germany and is thus not taken into account in the inventory. Any excretions on pasture are included in the other housing systems (included elsewhere, IE).

Table 231: Methane conversion factors *MCF* (in % of B_o) for swine (3.B(a))

		MCF [%]
Liquid manure	Open tank, without natural crust	25
	Solid cover	25
	Natural crust	15
	Floating cover (chopped straw)	25
	Floating cover (cover foil)	25
	Below slatted floor > 1 month	25
Solid manure	Deep bedding	25
	Heap	3

The average methane conversion factors for slurry-based systems without digestion, for dairy cows, other cattle and swine, depend on the frequency of the various applicable housing procedures and thus are not constant, as Table 232 shows.

Table 232: Average methane conversion factors *MCF* (in % of B_o) for slurry-based systems without digestion (3.B(a))

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Dairy cows	14.3	14.0	14.0	14.3	14.6	14.5	14.5	14.5	14.5	14.4	14.4	14.5	14.4	14.5	14.5
Other cattle	14.6	14.4	14.6	14.8	14.9	14.8	14.8	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7
Swine	24.7	23.7	23.6	22.7	22.2	22.7	22.8	22.9	23.0	23.0	23.0	23.1	23.0	23.1	23.1

For storage of manure from other animals, default values from IPCC (2006b Vol 4, 10.44) are used (cf. Table 233).

Table 233: Methane conversion factors MCF (in % of B_o) for goats, sheep, horses, deer, rabbits, ostriches, fur-bearing animals and poultry (3.B(a))

	MCF [%]
Heap	2
Poultry manure	1.5
Pasture	1

For systems in which manure is digested, a variable MCF results, when the various contributions from pre-storage systems, digesters and systems for storage of digestion residues are taken into account (cf. Chapter 5.1.3.6.5).

5.1.3.6.5 Manure digestion and storage of digestates (3.B)

According to IPCC (2006b, Vol. 4, Tab. 10.17), anaerobic digestion of manure and storage of the resulting digestates is considered to be a separate storage system type. In line with the German situation, this storage type is taken into account for cattle, swine and poultry (Haenel and Wulf (2016); Chapters 2.6 and 4.4 in Vos et al. (2026)). The time series for the activity data were provided by KTBL (Grebe et al., 2025) primarily on the basis of data of the Deutsches Biomasseforschungszentrum (DBFZ; German biomass research centre).

(Grebe et al., 2025) Grebe, Wulf, and Häußermann (2024) derived the applicable annual electrical work $W_{el,\,dig}$, differentiated by German federal state and plant performance classes from data of the registry of biogas plants (Biogasanlagenregister). In the process, consideration of the factor “equivalent electrical work” makes it possible to take account also of those biogas plants that solely feed biomethane into the gas network, i.e. without producing any electricity. The work-specific substrate input s_i was calculated separately for cattle slurry, cattle manure, swine slurry and poultry manure, using data from 1,664 biogas plants. The time series were updated for the 2025 submission. Instead of the percentage share of total manure production, the time series now use the absolute amounts of N required for digestion, calculated from cattle slurry, swine slurry, cattle manure and poultry manure. In contrast with the 2025 submission, they no longer need to be made available in the same federal state. Instead, input to the biogas plants of every NUTS-3 region is provided by way of a transport algorithm, possibly from other NUTS-3 regions (cf. Chapter 5.1.2.5).

Table 234 shows the absolute N quantities of cattle slurry, cattle manure, swine slurry and poultry manure digested at biogas plants, as well as their total. For solid swine manure, no digestion is taken into account, since the relevant data are of uncertain reliability, due to the small quantities of solid manure involved.

Table 234: N quantities of manure digested at biogas plants, in [Gg N]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Total	0.04	0.55	4.7	32.0	129.7	208.7	206.6	208.4	201.7	195.8	198.5	203.5	204.2	183.0	183.0
Cattle slurry	0.03	0.34	3.0	18.6	80.0	121.7	120.5	122.1	118.5	115.1	116.6	123.3	118.0	107.0	107.0
Cattle solid manure	0.00	0.03	0.2	1.7	6.3	9.6	9.5	9.6	9.2	9.1	9.2	10.2	10.7	8.9	8.9
Swine slurry	0.01	0.13	1.1	8.4	32.3	53.0	52.4	53.0	50.9	48.8	49.0	47.4	49.1	42.4	42.4
Poultry manure	0.00	0.05	0.4	3.3	11.2	24.4	24.1	23.7	23.1	22.9	23.7	22.7	26.3	24.7	24.7

The data in Table 234 are also used to calculate the share of stored VS quantities that undergo digestion.

The total MCF for digestion of manure and slurry in biogas plants, including pre-storage systems and systems for storage of digestates, is calculated in accordance with a national method; cf. Equation 13. For derivation of this equation, cf. Chapter 4.4.1.2 in Vos et al. (2026).

Equation 13: Calculation of total MCF for digestion of manure and slurry in biogas plants, including pre-storage systems and systems for storage of digestates

$$MCF\% = MCF\%_{\mathrm{ps}} + (100\ \% - MCF\%_{\mathrm{ps}}) \cdot \left((1-\mu_{\mathrm{rg}}) \cdot L_{\mathrm{dig}} + \mu_{\mathrm{rg}} \cdot \frac{MCF\%_{\mathrm{residues}}}{100\ \%}\right)$$

where

- $MCF\%$ = Total MCF for the system “pre-storage system + digester + system for storage” (in %)
- $MCF\%_{\mathrm{ps}}$ = MCF for the pre-storage system (in %)
- μ_{rg} = Potential for residual gas production with respect to B_o (with $0 \le \mu_{\mathrm{rg}} \le 1\ m^3\ m^{-3}$)
- L_{dig} = Relative leakage rate of the digester with respect to the quantity of CH_4 produced in the digester (with $0 \le L_{\mathrm{dig}} \le 1\ m^3\ m^{-3}$)
- $MCF\%_{\mathrm{residues}}$ = MCF for the system for storage of digestates (in %)

Table 235 shows the methane conversion factors $MCF\%_{ps}$ for pre-storage systems. For derivation of this equation, cf. Chapter 2.6 in Vos et al. (2026).

Table 235: Methane conversion factors for pre-storage systems (in % of B_o)

	$MCF\%_{ps}$ [%]
Cattle slurry	1.7
Cattle solid manure	0.2
Swine slurry	2.5
Poultry manure	0.15

Based on (Grebe et al., 2025), the potential residual CH_4 gas volume μ_{rg} relating to B_o was set at 4.6% (or 0.046 m^3 m^{-3}), cf. Chapter 2.6 in Vos et al. (2026).

In accordance with Bachmaier and Gronauer (2007), Börjesson and Berglund (2007), Gärtner et al. (2008) and Roth et al. (2011), the leakage rate of the digester L_{dig} is set at 1% or 0.01 m^3 m^{-3} (Grebe et al., 2025). In a 2016 study, the German Environment Agency also applied a leakage rate of 1% from Fehrenbach et al. (2016, p. 113).

A leakage rate is assumed even for a gas-tight system for storage of residues from manure digestion; that leakage rate is assumed to be the same as that of the digester. Taking into account the relative share of gas-tight storage systems in relation to all storage of digestates, the result is Equation 14.

Equation 14: Calculation of *MCF* for storage of digestates

$$MCF\%_{residues} = x_{gts} \cdot (100 \cdot L_{sto,\ gt}) + (1 - x_{gts}) \cdot MCF\%_{ngts}$$

where

- $MCF\%_{residues}$ = MCF for the system for storage of digestates (in %)
- x_{gts} = Relative share of gas-tight storage of digestates (in kg kg^{-1})
- $L_{sto,\ gt}$ = Relative leakage rate for gas-tight storage of digestates ($L_{sto,\ gt}$ = L_{dig})
- $MCF\%_{ngts}$ = MCF for non-gas-tight systems for storage of digestates (in %)

In general, digestates are in a liquid state. For non-gas-tight storage of digestates, it is assumed that a natural floating crust forms, as a result of co-digestion of energy crops, which increases the dry matter content in the digestates. This type of storage is thus similar to open storage of undigested cattle slurry with a natural floating crust. For this reason, the relevant MCF for undigested cattle slurry is used for $MCF\%_{ngts}$: 10% (cf. Chapter 5.1.3.6.4).

Table 236 shows the fraction of gas-tight storage of residues from manure digestion, as a percentage share of all storage of residues from manure digestion, and in percent of N inputs. The data were derived by (Grebe et al., 2025) from the input quantities of digestion substrates, broken down by German federal state and by plant output classes, as well as by the percentage shares of biogas plants with gas-tight, covered storage of digestion residues, with respect to the output classes prevailing in Germany. The sharp increase, from 2011 to 2012, in the use of gas-tight storage of digestates is attributed to the 2012 German act on electricity feed-in (Energieeinspeisegesetz, EEG), which mandates gas-tight covers for all digestate storage systems of biogas plants that have installed capacity of at least 75 kW and that went into operation on or after 1 January 2012. For 2024, the values for 2023 were retained due to a lack of new data.

Table 236: Percentage shares for storage of digestates in gas-tight and non-gas-tight storage systems (in % of the N inputs in biogas plants)

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
gas-tight	0.0	4.5	9.1	15.2	40.6	61.3	62.7	64.1	65.5	69.1	72.7	76.4	76.8	79.8	79.8
non-gas-tight	100.0	95.5	90.9	84.8	59.4	38.7	37.3	35.9	34.5	30.9	27.3	23.6	23.2	20.2	20.2

The total MCF values resulting from Equation 13, for the systems "pre-storage systems + digester + system for storage of digestates", for dairy cows, other cattle, swine and poultry, are listed in the following table.

Table 237: Average methane conversion factors MCF (in % of B_o) for manure management systems with digestion (3.B(a))

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Dairy cows	3.00	3.01	3.00	2.97	2.88	2.80	2.80	2.79	2.79	2.77	2.76	2.74	2.74	2.73	2.73
Other cattle	3.00	2.92	2.88	2.83	2.73	2.63	2.62	2.61	2.61	2.59	2.58	2.56	2.54	2.54	2.54
Swine	3.88	3.86	3.84	3.82	3.72	3.63	3.63	3.62	3.62	3.60	3.59	3.57	3.57	3.55	3.55
Poultry	1.56	1.54	1.52	1.50	1.39	1.31	1.30	1.30	1.29	1.27	1.25	1.23	1.23	1.22	1.21

The reduction of CH_4 emissions from manure management that is related to digestion depends on the fraction of manure that is digested, as well as on the relative frequency of gas-tight systems for storage of digestates. The reductions resulting in Germany are given in Chapter 5.3.2.2.3.

Table 238 lists the N_2O emissions that the inventory takes account of for the various relevant subsystems and manure types. For details, cf. Chapters 4.3.2.2 and 4.4.2.2 in Vos et al. (2026).

N_2O and NO emissions from agricultural soils, resulting from application of digestion residues, are described in Chapter 5.5.

Table 238: Calculation of N_2O emissions from digestion

		Slurry	Solid manure/poultry manure
Pre-storage systems		0	Equation 15
Digesters		0	0
System for storage of digestates	gas-tight	0	0
	non-gas-tight	Equation 16	Equation 16

Equation 15: Calculation of N_2O emissions from systems of pre-storage of solid manure and poultry manure

$$E_{\text{N2O-N, dig, ps}} = (N_{\text{excr, dig}} + N_{\text{straw, dig}}) \cdot EF_{\text{N2O-N, dig, ps}}$$

where

- $E_{\text{N2O-N, dig, ps}}$ = N losses from N_2O emissions from pre-storage of solid manure or poultry manure (in kg N_2O-N a^{-1})
- $N_{\text{excr, dig}}$ = Fraction of annual in-stable N excretions that goes to digestion (in kg a^{-1})
- $N_{\text{straw, dig}}$ = Fraction of annual N inputs from bedding material that goes to digestion (in kg a^{-1})
- $EF_{\text{N2O-N, dig, ps}}$ = N_2O-N emission factor for pre-storage of solid manure or poultry manure (in kg N_2O-N per kg N)

Equation 16: Calculation of N_2O emissions from non-gas-tight storage of digestates

$$E_{\text{N2O-N, dig, ngts}} = (1 - x_{\text{gts}}) \cdot N_{\text{tot, dig, ferm}} \cdot EF_{\text{N2O-N, dig, ngts}}$$

where

- $E_{\text{N2O-N, dig, ps}}$ = N losses from N_2O emissions from non-gas-tight storage of digestates (in kg N_2O-N a^{-1})
- x_{gts} = Relative share of gas-tight storage of digestates (in kg kg^{-1})
- $N_{\text{tot, dig, ferm}}$ = Total N quantity from digestates that leaves the digester (in kg a^{-1})
- $EF_{\text{N2O-N, dig, ngts}}$ = N_2O-N emission factor for non-gas-tight storage of digestates (in kg N_2O-N per kg N)

The N_2O emission factors used in the inventory are listed in Table 239. For the derivation of these factors, we refer to Chapter 2.6 in Vos et al. (2026).

Table 239: N_2O-N emission factors for manure pre-storage and for storage of digestates

	[kg kg^{-1}]	Solid manure	Poultry manure
Pre-storage systems	$EF_{\text{N2O-N, dig, ps}}$	0.001	0.0001
Systems for storage of digestates, non-gas-tight	$EF_{\text{N2O-N, dig, ngts}}$	0.005	0.005

The N quantity in digestates at the beginning of storage ($N_{tot,\text{ dig, ferm}}$) is calculated with inclusion of the N losses from pre-storage. It is assumed that no N losses from digesters occur.

The procedure for calculating NO emissions occurring in connection with manure digestion is similar to that for calculating N_2O emissions. As is customary in the German inventory's sections on manure management (cf. Chapter 4.3.2.2 in Vos et al. (2026)), the NO-N emission factor is assumed to be one-tenth of the N_2O-N emission factor.

To calculate the N_2O emissions that result indirectly from agricultural soils due to deposition of reactive nitrogen (cf. Chapter 5.5.2.1.2), one must also calculate the NH_3 emissions that occur in connection with digestion of manure. NH_3 emissions are calculated for pre-storage of solid manure and poultry manure, for non-gas-tight storage of digestates and for application of digestates. On the other hand, for pre-storage of slurry, for digesters and for gas-tight storage of digestates, it is assumed that NH_3 emissions either do not occur or are negligible. For details on the extensive subject of NH_3 calculation methods, see Chapters 4.3.1.2 and 2.6 in Vos et al. (2026).

5.1.4 Digestion of energy crops: Concept and activity data

5.1.4.1 The concept, and its consideration in the CR tables

The inventory covers the six energy crop categories that are the most important in Germany in terms of quantities: maize silage, grass silage, whole plant silage, wheat grain, rye grain and Corn Cob Mix (CCM). They differ only slightly in terms of their key characteristics (N and VS content in dry matter, maximum methane formation potential B_o; cf. (Grebe et al., 2025). This makes it possible to treat the total dry matter for all included energy crops as a single energy crop category. The procedure for calculating the emissions is similar to that for calculating emissions

from digestion of solid manure (cf. Chapter 5.1.3.6.5), with the exception that no pre-storage is included.

In practice, manure and energy crops are normally digested together. Nonetheless, the emissions occurring in connection with digestion of these two substrate categories are calculated separately to better show the contribution that energy crop digestion makes to the greenhouse gas balance.

For further details on emission calculation in connection with digestion of energy crops, see Chapters 5.1 and 2.6 in Vos et al. (2026).

The following emissions are calculated that result, directly or indirectly, from digestion of energy crops, as well as from storage and application of digestates:

- Digester (in 3.J)
  - CH_4 (from leakage)
- Storage (in 3.J)
  - CH_4 (from leakage)
  - direct N_2O
  - N_2O resulting indirectly from deposition of NH_3 and NO from storage
  - NO
- Application (in 3.D)
  - direct N_2O
  - N_2O resulting indirectly from deposition of NH_3 and NO from application
  - N_2O resulting indirectly from leaching/surface runoff of the nitrogen applied by the spreading of digestates
  - NO

The emissions from digesters and systems for storage of digestates (CH_4, N_2O, indirect N_2O from deposition of NH_3 and NO from storage) are described in Chapter 5.9 and reported under 3.J in CR Table 3. The direct and indirect N_2O emissions occurring as a result of spreading of digestates are described in Chapter 5.5 and reported under 3.D (CRF 3.D: D1.b.iii, 3.D.2.a and 3.D.2.b). The NO emissions resulting from application of digestates are also reported under 3.D as NO_x emissions.

5.1.4.2 Activity data and parameters

The activity data used in calculation of the emissions consist of the total quantities of energy crop dry matter that are input into digestion; cf. Table 240. The applicable substrate quantities were derived and provided in connection with calculations related to manure digestion (cf. Chapter 5.1.3.6.5). The data were updated, solely for the year 2023, by (Grebe et al., 2025) with respect to the 2025 submission. The values from 2023 were retained due to a lack of data for 2024. 2023 is the only year for which values were also provided at NUTS-3 level.

A weighted average B_o value of 0.38 m^3 kg^{-1} was derived from the B_o values for the six energy crop categories (cf. Chapter 5.1.4.1) using the IPCC default value for the density of methane (0.67

kg m^{-3}). The following weighted averages for the VS and N content result (with respect to dry matter): VS content, 0.947 kg kg^{-1}; N content, 0.0146 kg kg^{-1}.

The VS quantity required for calculation of the CH_4 emissions is obtained by multiplying the dry matter by the average VS content; cf. Table 240.

The N quantities required for calculation of the N emissions are obtained with the help of the relevant N content; cf. Table 240.

Table 240: Dry matter, VS quantity and N quantity in the energy crops used in biogas plants, in [Gg]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Dry matter	3.3	42.2	366.0	3,089	11,164	20,118	20,011	19,683	19,397	19,400	19,815	19,440	20,881	20,223	20,223
VS	3.1	40.0	346.6	2,925	10,572	19,052	18,950	18,640	18,369	18,372	18,765	18,410	19,775	19,151	19,151
N	0.05	0.62	5.3	45	163	294	292	287	283	283	289	284	305	295	295

In accordance with (Grebe et al., 2025), the leakage rates for digesters and gas-tight systems for storage of digestates are considered to be the same as those used for manure digestion (cf. Chapter 5.1.3.6.5).

Table 241 shows the fractions of gas-tight storage of residues of energy crop digestion as percentages of the input fresh matter (Grebe et al., 2025). Since no data on frequencies of use of gas-tight storage were available for 2024, the relevant figures for 2023 were retained for that year. The sharp increase, from 2011 to 2012, in the use of gas-tight storage of digestates is attributed to the 2012 German act on electricity feed-in (Energieeinspeisegesetz, EEG), which mandates gas-tight covers for all digestate storage systems of biogas plants that have installed capacity of at least 75 kW and that went into operation on or after 1 January 2012. The data differ from those for storage of manure digestates (cf. Table 236). This is due to the fact that the total fraction of energy crops, with respect to the manure/energy crop substrate mix, increases with plant (i.e. facility) size (a relationship that also holds for the covered-system fraction of systems for storage of digestates). Energy crop digestion residues are distributed across NUTS-3 region boundaries using a transport model; cf. Chapter 5.1.2.5.

Table 241: Percentage share for systems for gas-tight and non-gas-tight storage of digestates of energy crops (in % of the fresh matter inputs into digestion)

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
gas-tight	0.0	4.7	9.4	15.8	42.2	65.2	67.1	69.1	71.0	74.9	78.7	82.6	82.0	85.8	85.8
non-gas-tight	100.0	95.3	90.6	84.2	57.8	34.8	32.9	30.9	29.0	25.1	21.3	17.4	18.0	14.2	14.2

A range of different application methods and different incorporation periods for cropland and grassland are used. The NH_3 emission factors for the different combinations involved vary. For calculation of direct N_2O emissions from application of digestates, only the N quantity applied needs to be taken into account. The indirect N_2O emissions from application-related deposition of reactive nitrogen, on the other hand, depend on total NH_3 emissions from application of digestates – and, thus, on the relative frequencies of the various application methods and incorporation periods used. The relative frequency figures used were obtained from surveys carried out by the Federal Statistical Office in 2011 (for the year 2010), 2016 (for the year 2015) and 2020 (for the year 2019); cf. Annex 7.3.1, Table 512.

5.1.5 Concept and activity data for emissions from agricultural soils and crops

5.1.5.1 N_2O emissions from agricultural soils (3.D)

5.1.5.1.1 Concept for calculation of direct emissions from agricultural soils

Tier 2 emission factors are used for direct N_2O emissions from application of mineral fertiliser, manure, sewage sludge and other organic fertilisers and N_2O emissions from crop residues. The Tier 2 emission factors, which differ by region at the NUTS-3 level, were derived by Mathivanan et al. (2021). Details on the distribution of N quantities at the NUTS-3 level are provided in Chapter 5.1.5.1.2 and in Chapter 5.1.2.5 which covers the transport module. Tier 1 emission factors from IPCC (2019) are being used from the 2025 submission for N_2O emissions from mineralisation of organic substances in mineral soils and from grazing. For mineralisation in organic soils, Tier 2 emission factors from Tiemeyer et al. (2020) are used.

5.1.5.1.2 The N quantities behind direct N_2O emissions (3.D)

Since no data on mineral fertiliser application are collected, the inventory considers the N quantities from mineral fertiliser application to be the same as the N quantities given by official statistics on sales of mineral fertilisers. The delay in the relevant surveys amounts to half a year. For purposes of the inventory, all of the mineral fertiliser sold in the second half of year j-1, and all of the mineral fertiliser sold in the first half of year j, is assigned to year j. Multiple-year averaging of mineral-fertiliser data has been carried out in order to approximate storage effects, for purposes of the inventory (this has included use of the following averages: for the period 1990-2023, a moving, centred three-year average; for 2024, a weighted average of 2023 (with weighting of 1/3) and 2024 (with weighting of 2/3)). This approach follows the examples of Austria (with an average over two years) and France (average over three years)(UNFCCC, 2025).

The N quantity in applicated spread manure is calculated with the N-flow concept (cf. Chapter 4.2 in Vos et al. (2026)), cf. Table 242. The leached N quantities refer to leaching in connection with field edge storage of solid manure, cf. Chapter 5.1.5.1.5 (IPCC, 2019; LAWA, 2019).

Table 242: Calculation of the N quantities in applicated manure (including digestates of manure) (3.D), in [Gg]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
N excretions [a]	1448.8	1266.3	1224.9	1185.2	1163.3	1197.2	1189.8	1192.7	1171.0	1154.5	1129.6	1086.4	1052.4	1048.4	1038.6
+ bedding material-N [b]	64.1	55.1	50.5	50.4	50.2	50.3	49.8	49.6	49.1	48.6	47.9	47.4	47.5	47.5	47.0
- (NH_3-N + NO-N) [c]	-245.5	-206.7	-202.6	-201.9	-194.3	-191.1	-188.0	-187.4	-182.0	-177.8	-173.2	-165.1	-157.1	-156.0	-155.0
- N_2O-N [d]	-7.7	-6.7	-6.4	-6.3	-6.1	-5.8	-5.7	-5.6	-5.5	-5.4	-5.2	-5.0	-4.9	-4.9	-4.8
- N_2 [e]	-23.2	-20.2	-19.1	-18.8	-18.2	-17.3	-17.0	-16.9	-16.4	-16.1	-15.6	-14.9	-14.6	-14.7	-14.5
- N leached	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Outcome	**1236.4**	**1087.8**	**1047.3**	**1008.5**	**994.8**	**1033.3**	**1028.8**	**1032.3**	**1016.2**	**1003.9**	**983.4**	**948.7**	**923.3**	**920.4**	**911.2**

[a] Total N excretions after deduction of excretions during grazing; cf. Table 219 in the present NID (cf. CR Table 3.B(b))

[b] cf. Table 227 in the present NID

[c] cf. cell S31 in CR Table 3.B(b)

[d] cf. Table 282 in the present NID (corresponds to cell X34 in CR Table 3.B(b), multiplied by the molar ratio 28/44)

[e] N_2 emissions from manure management are calculated as three times the N_2O-N emissions (cf. Vos et al. (2026), Chapter 4.2.4)

The N quantity that is applied with digestates from digestion of energy crops is obtained as the N quantity in the energy crops input into digestion, minus the N losses due to emissions from the storage of digestates.

The N quantities in digestates of waste in compost of biowaste and in compost of green waste were derived from the waste statistics of the Federal Statistical Office.

Data on imports of manure are provided solely for imports from the Netherlands, which publishes figures on its relevant exports to Germany. The N quantity resulting from application of imported manure is obtained from statistics of the Netherlands's Centraal Bureau voor de Statistiek (CBS); cf. CBS (2025). The share of Dutch exports that goes to Germany, and the relevant types of imported manure (and their share of the total imported quantity), are obtained from statistics of the Dutch organisation Rijksdienst voor Ondernemend Nederland (RVO); cf. RVO (2025). For the years 1990-2009, no data were available on how the imported quantities break down into the various types of manure involved. For this reason, the distribution used for the year 2010 was also applied to those years.

For each Land in Germany, N quantities from sewage sludge application are calculated from data of the German Environment Agency (UBA) (Section III 3.3) and (since 2009) of the Federal Statistical Office (Section G 202). Since no data were available for 2024, the relevant figure for 2023 was retained for that year. According to the Federal Statistical Office, the decrease in the N quantity between 2016 and 2017 is probably related to the amendments of the Ordinance on Sewage Sludge (Klärschlammverordnung; 2017) and the Fertiliser Ordinance (Düngemittelverordnung; 2015). These amendments impose restrictions on application of sewage sludge on agricultural areas.

The direct N_2O emissions from N excretions during grazing are calculated in proportion to the N quantity excreted in pasture (cf. Chapter 5.1.3.4).

The quantities of N remaining in the soil in crop residues are obtained from the relevant areas under cultivation, yields and crop-specific N content data. The data on cultivated areas and fresh matter yields are reported by the Federal Statistical Office (Statistisches Bundesamt, FS 3, R 3). The data are converted into dry matter yields with the help of dry matter content data given by the Fertiliser Ordinance (DüV, 2017). The relative N quantities contained in crop residues are taken from the Fertiliser Ordinance (DüV, 2007, 2017) and from a list prepared by the Institute of Vegetable and Ornamental Crops (Feller et al., 2011). The N quantities removed from relevant areas, for bedding material in animal husbandry, are deducted. Since the 2025 submission, the calculation method also includes cover crop residues. With regard to the input data and calculation methods, cf. Chapters 2.8.6 and 5.3.1 in Vos et al. (2026).

In the present NID, the method for determining N mineralisation in mineral cropland soils is described in Chapter 6 (cf. Chapters 6.1.2.6, 6.4.2.7.3 and 6.5.2.3.2). The N quantity from mineralisation was derived from net carbon mineralisation using the RothC model based on a 100 m x 100 m grid in the LULUCF sector. The derived quantity depends heavily on the weather, meaning that it varies considerably from year to year. Only carbon losses for points located on the LULUCF grid are taken into consideration; points where carbon sequestration takes place are assumed not to emit any nitrous oxide from mineralisation.

To calculate direct N_2O emissions from soils, one requires N input data for the NUTS-3 regions. In the inventory model, the distribution of manure and digestates is calculated from activity data at the NUTS-3 level. Since the 2026 submission, it is no longer assumed that manure is applied in the same NUTS-3 region in which it is produced. Instead, a transport model is used (cf. Chapter 5.1.2.5). For the German federal states (NUTS-1 regions), data on the N quantity in sewage

sludge are available; they are provided by the Federal Statistical Office on an annual basis. The data are apportioned to the NUTS-3 regions based on their populations. The N quantities in digestates of waste, in compost of biowaste, and in compost of green waste are available only at the national (Germany) level. In a first step, they were distributed among the federal states according to population size and then distributed among the NUTS 3 regions within the federal states according to agricultural area. The N quantities obtained from imported manure are also available only at the national (Germany) level. As with domestic manure, they are distributed among the NUTS-3 regions using the transport module.

After multiple-year averaging, the amount of mineral fertiliser N applied is available at the national level (Germany). Accordingly, the distribution of mineral fertiliser quantities of applied in the NUTS-3 regions has to be modelled.

Since the 2026 submission, distribution for every year within the time series is based on a method from the AGRUM-DE project which modelled nitrogen balances within the scope of monitoring nitrogen emissions to water bodies (EU Water Framework Directive) (Zinnbauer et al. (2023), Chapter 4.1.4.3).

Here, the first step is to calculate the N requirement for each year and region based on crop type and location using linear yield-dependent functions. In the second step, the amount of nitrogen (N) returned to the soil by the previous crop is subtracted from the N requirement. Since the Py-GAS-EM model aims to avoid dependencies between individual years in the time series, it is assumed that the previous crops in a NUTS-3 region are roughly equivalent to the crops grown in the current year, and the amount returned to the soil is calculated based on the crops grown in the current year.

The third step involves calculating N requirements from mineral fertiliser by deducting the N quantities from manure, digestates, sewage sludge and composts available for plant uptake after application in the NUTS-3 region as well as N fixation from legumes. The remaining N amount is the required quantity of mineral fertiliser N. The requirement for a specific NUTS-3 region is divided by the total sum of requirements for all NUTS-3 regions in Germany for that year in order to determine what proportion of the mineral fertiliser quantity specified for the federal territory for that year is applied in the corresponding NUTS-3 region.

This approach is described in more detail in AGRUM (2024) Chapter 4.1.4.3 and in Chapter 2.8 of (Vos et al., 2026).

Many of the input data and N quantities used to calculate direct N_2O emissions have changed since the 2025 submission. These changes are described in Chapter 5.1.7.3.

Table 243 shows the N quantities from various sources that are used as a basis for calculating direct N_2O emissions (cf. Chapter 5.5.2.1.1).

Table 243: N quantities on which calculation of direct N_2O emissions from agricultural soils are based (3.D), in [Gg]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Mineral fertiliser	2194.7	1722.9	1921.6	1796.6	1635.4	1736.2	1730.7	1622.0	1499.3	1403.7	1326.6	1244.8	1123.2	1047.7	1028.4
Manure, including digestates from manure digestion	1236.4	1087.8	1047.3	1008.7	996.0	1036.0	1031.9	1035.6	1019.6	1007.4	987.0	952.5	927.1	924.2	915.1
Digestates of energy crops	0.0	0.6	5.1	43.4	158.7	289.1	287.8	283.3	279.5	280.0	286.5	281.6	302.4	293.3	293.3
Digestates of waste	0.0	0.0	1.6	5.0	10.5	15.1	14.0	13.8	14.0	13.8	13.4	15.1	15.6	17.5	18.2

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Compost of biowaste	4.5	19.5	31.9	28.8	22.6	22.6	23.3	21.9	25.1	24.3	25.4	23.0	23.1	19.9	18.5
Compost of green waste	1.1	4.9	7.7	9.5	11.3	13.7	14.3	14.9	14.9	15.9	16.7	15.9	15.9	14.6	13.8
Imported manure	5.2	19.3	15.6	21.5	28.2	28.8	30.3	27.5	22.2	21.3	18.1	15.3	14.2	16.6	16.5
Sewage sludge	27.4	35.3	33.0	27.4	26.3	18.9	18.8	14.0	13.3	16.1	13.9	12.0	12.1	10.4	10.4
Grazing	239.4	194.6	173.2	155.3	146.5	142.7	140.9	140.1	137.7	135.6	133.1	130.5	130.5	131.7	129.8
Crop residues	678.2	660.6	718.2	746.6	760.0	841.0	842.1	880.5	739.7	814.9	838.1	865.2	847.6	856.0	848.4
Mineralisation	299.2	324.6	362.8	265.2	217.8	219.5	274.5	347.6	188.5	289.5	253.2	306.2	245.5	489.8	119.3

A notable point in the time series of the N quantities of crop residues is the significant decline in the N quantities of crop residues from 2017 to 2018. This is primarily attributed to the difficult cultivation conditions and, in many cases, very small harvests that resulted from the extremely hot, dry weather that prevailed in 2018. The very wet conditions that prevailed in some regions of Germany at the end of the year in 2017, i.e. at the sowing time for winter crops, are seen as another factor. The N quantity of mineral fertiliser applied has been steadily decreasing since 2016. It is likely that, in addition to the drought and the effects of the Ukraine war, this is mainly due to stricter legal regulations, in particular by the Fertiliser Ordinance DüV (2017). The prominent peak in the quantity of nitrogen from mineralisation in 2023 is attributable to it being a year with widespread favourable mineralisation conditions. This was in contrast to several previous years of unfavourable mineralisation conditions where a lot of degradable organic carbon had accumulated in the soils.

5.1.5.1.3 Areas of organic soils under cultivation (3.D)

Table 244 shows the applicable areas of organic soils under cultivation, broken down by cropland and grassland (in the strict sense). The data were provided by the LULUCF sector and correspond to the areas identified in the LULUCF sector (cf. Chapter 6.1.2.2.2). In the LULUCF sector, the total grassland area includes additional categories not used for agricultural purposes. The grassland areas include all subareas, regardless of the distance to the groundwater level. The fact that no N_2O is emitted in areas in which the distance to the groundwater level is very small is reflected in the implied emission factors (IEFs); cf. Chapter 5.5.2.1.1.

Table 244: Areas of organic soils under cultivation (3.D) in [1,000 ha]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Total	1406.9	1401.6	1395.9	1389.4	1382.0	1374.1	1371.6	1369.1	1366.6	1364.1	1361.6	1358.1	1354.6	1351.1	1347.6
Cropland	319.9	324.7	330.9	339.4	351.7	370.6	366.8	363.0	359.2	355.4	351.6	347.0	342.4	337.9	333.3
Grassland	1087.0	1076.9	1065.0	1050.0	1030.3	1003.5	1004.8	1006.1	1007.4	1008.7	1010.0	1011.1	1012.1	1013.2	1014.2

5.1.5.1.4 Deposition of reactive nitrogen (3.B, 3.D, 3.J)

Deposition of reactive nitrogen is derived from the NH_3 and NO emissions from the German agricultural sector, as calculated in the inventory. This is carried out for the NH_3 and NO sources "housing and storage" (3.B), "storage of digestates of energy crops" (3.J) and "application and grazing" (3.D). "Soils" comprises emissions from the application of mineral fertiliser, manure, manure digestates, sewage sludge and other organic fertilisers (digestates of energy crops, digestates of waste, compost of biowaste, compost of green waste, imported manure), emissions from grazing and the NH_3 emissions from crop residues.

Table 245 shows, for categories 3.B, 3.D and 3.J, the quantities of reactive nitrogen on which the calculations of indirect N_2O from N deposition are based.

Since the 2026 submission, the default EF_4 climate zone classifications from IPCC (2019) are used as the emission factors: 0.014 kg kg^{-1} for a wet climate and 0.005 kg kg^{-1} for a dry climate. The shares of NUTS-3 regions that fall into each climate class are calculated annually in high resolution using precipitation and evapotranspiration data provided by the German Meteorological Service (Deutscher Wetterdienst - DWD); cf. Chapter 5.3.5.2.2.

Table 245: Sectors 3.B, 3.D and 3.J: Quantities of reactive nitrogen from deposition of NH3 and NO, in [Gg]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
3.B, Manure, including digestates from manure digestion	245.5	206.7	202.6	201.9	194.3	191.1	188.0	187.4	182.0	177.8	173.2	165.1	157.1	156.0	155.0
3.D, Soils	443.7	372.1	372.8	356.0	368.4	392.9	391.5	375.5	351.6	335.0	295.9	286.7	282.8	276.2	272.3
3.J, Digestates of energy crops	0.0	0.0	0.1	1.0	2.4	2.6	2.5	2.3	2.1	1.8	1.6	1.3	1.4	1.1	1.1

5.1.5.1.5 Leaching and surface runoff (3.D, 3.B)

A Tier 3 method has been used to calculate N_2O emissions from leaching and surface runoff in sector 3.D. The method is described in detail in Eysholdt et al. (2022): the method is based on the calculation of N surpluses, of which a certain share – which has been modelled, and which varies at the NUTS-2 level – is leached as nitrate into groundwater or enters receiving streams through lateral run-off. The N surpluses are calculated by first determining the total amount of nitrogen available (N in the quantities applied with mineral fertiliser, manure, sewage sludge and other organic fertilisers, as well as the N quantities provided by grazing, crop residues and mineralisation). The nitrogen present in then harvested quantities of crops is deducted from those surpluses, along with the N quantities present in the NH_3 emissions occurring in application of all N-containing sources. The share of the N surpluses that is leached has been modelled by Eysholdt et al. (2022) at the NUTS-2 level. For details, cf. Chapter 5.3.2.1 in Vos et al. (2026). The default EF_5 is used as the emission factor, from IPCC (2019), 0.011 kg kg^{-1}.

N_2O emissions from leaching and surface runoff were also calculated for sector 3.B, since data on field storage of manure are available from the 2020 agricultural census (LZ2020). Leaching is assumed only for this share of manure storage, since with all other types of storage the legal provisions applying to construction of storage facilities prevent leaching. Pursuant to the German Working Group on water issues of the Federal States and the Federal Government (LAWA, 2019), field edge storage sites have to be covered with a waterproof cover after four weeks at the latest. This means that leaching out of N occurs only in the first four weeks of storage. The leached-out fraction of the stored N quantity ($Frac_{LEACHMS}$) is calculated with (IPCC, 2019) – cf. Chapter 4.4.3 in Vos et al. (2026) – and amounts to 0.00333 kg kg^{-1}. The default EF_5 is used as the emission factor, from IPCC (2019), 0.011 kg kg^{-1}. The calculated quantities of leached nitrogen are shown in Table 246.

Table 246: Leached N quantity (incl. surface runoff) 3.B. and 3.D, in [Gg]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
3.B	0.13	0.07	0.07	0.07	0.07	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.03	0.03	0.03
3.D	522.1	394.9	420.0	362.2	342.1	393.6	403.5	389.3	412.4	368.9	332.4	297.1	294.6	311.9	223.6

5.1.5.2 CO_2 emissions from liming and urea application (3.G-I)

The inventory differentiates between dolomite and the limestone in order to take account of how the two groups differ in carbonate carbon content, as well as in their CO_2 emission factors. With regard to limestone, application of calcium ammonium nitrate is considered as a separate case. The CO_2 emissions from such application are reported under CRF 3.I ("Other carbon-containing fertilisers"). Otherwise, CO_2 emissions from application of limestone and dolomite are reported under CRF 3.G. In accordance with the IPCC requirements (IPCC (2006b Vol 4, Chapter 11.3)), the reported CO_2 emissions include both the emissions from the agricultural sector and from liming in the forestry sector (IPCC (2006b)).

No data on applied quantities of lime fertiliser are available. For this reason, the applied quantities are considered to be equal to the product quantities sold and statistically recorded (Statistisches Bundesamt, FS 4, R 8.2). The delay in the relevant surveys amounts to half a year. For purposes of the inventory, it is assumed that all of the lime fertiliser sold in the second half of year j-1, and all of the lime fertiliser sold in the first half of year j, is applied (spread) in year j. Then, in a procedure similar to that used for mineral fertiliser (cf. Chapter 5.1.5.1.2), multiple-year averages are obtained.

Calcium carbonate, compound lime, carbolic lime ("Carbokalk"), residual lime and calcium ammonium nitrate are all taken into account. For purposes of emissions calculations, product quantities reported in units of CaO or N are converted into units of $CaCO_3$, for limestone, and of $CaMg(CO_3)_2$, for dolomite.

Dolomite's share of the total quantity of fertiliser lime is not recorded statistically. For purposes of the inventory, that share has been calculated on the basis of an expert judgement (Müller, 2016), according to which the lime fertiliser used in the forestry sector consists of one-third $MgCO_3$, and the use of dolomite in the agricultural sector is negligible.

Table 247 shows the lime fertiliser quantities for both the agriculture and forestry sectors on which the emissions calculations are based; cf. Chapter 2.8.1 in Vos et al. (2026). The discrepancies in the data for 2023, with respect to the 2025 submission, result from inclusion of the data for 2024 within the overarching average.

Table 247: Lime fertiliser quantities (3.G and 3.I), in [Gg]

	Limestone [in $CaCO_3$]	Dolomite [in $CaMg(CO_3)_2$]	Calcium ammonium nitrate [in $CaCO_3$]
1990	4205.3	733.6	1160.1
1995	2436.0	436.1	885.2
2000	3468.8	354.8	833.2
2005	3021.5	205.8	698.9
2010	3325.0	180.4	584.6
2015	4156.4	161.5	524.3
2016	4126.2	139.0	513.0
2017	4269.1	124.2	484.2
2018	4528.3	115.3	460.7
2019	4525.0	100.3	441.4
2020	4455.0	104.0	421.5
2021	4397.7	99.9	399.0

	Limestone [in $CaCO_3$]	Dolomite [in $CaMg(CO_3)_2$]	Calcium ammonium nitrate [in $CaCO_3$]
2022	4415.5	108.7	357.9
2023	4309.8	88.9	335.9
2024	4244.9	81.3	329.0

The CO_2 emissions from urea application are calculated in proportion to the quantities of applied urea listed in Table 248 (including applied urea ammonium nitrate solution). These values were derived stoichiometrically (multiplied by the molar ratio 60/28) from the urea N quantities reported in official statistics and were included in the moving temporal average mentioned above in connection with liming.

Table 248: Applied quantities of urea, including urea ammonium nitrate solution (3.H), in [Gg]

1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
654.5	625.3	808.8	874.2	969.2	1079.3	1111.6	981.2	825.3	678.7	590.8	541.8	500.5	473.9	450.3

5.1.5.3 NMVOC emissions from agricultural crops

Table 249 shows, by way of example for the first time series year and the last, the input data calculated for the NMVOC emission calculation for agricultural crops pursuant to EMEP (2023) -3D-21 and EMEP (2023) -3D-44 (cf. Chapter 5.5.2.1.5). The data on cultivated areas and fresh matter yields are reported by the Federal Statistical Office (Statistisches Bundesamt, FS 3, R 3). The data are converted into dry matter yields with dry matter content data given by the Fertiliser Ordinance (DüV, 2007, 2017). The relative emission durations for wheat, rye, rape and grass were taken from EMEP (2023) -3D-21 and applied analogously to the other crops involved.

Table 249: Input data for calculation of NMVOC emissions from agricultural crops (overview)

Crop	Cultivation area [1,000s of ha]		Fresh matter yield [Mg ha^{-1}]		Dry matter content [kg kg^{-1}]	Relative emission duration [a a^{-1}]
	1990	2024	1990	2024		
Wheat	2419.9	2566.9	6.3	7.1	0.86	0.3
Rye	1067.1	535.5	3.8	4.8	0.86	0.3
Barley	2612.5	1659.8	5.4	6.4	0.86	0.3
Oats	533.5	164.7	4.5	4.5	0.86	0.3
Triticale	77.3	265.6	5.1	5.7	0.86	0.3
Grain for whole plant harvest	0.0	123.1	0.0	28.0	0.35	0.3
Grain maize	228.4	498.4	6.8	10.1	0.86	0.3
Silage maize	1365.4	2048.6	40.4	44.4	0.28	0.3
Rape	557.5	1085.6	3.0	3.3	0.91	0.3
Root crops	1249.6	719.5	40.6	68.6	0.22	0.3
Grass clover ley, alfalfa, forage grass	856.6	688.0	34.0	39.1	0.20	0.5
Legumes	121.2	285.0	3.4	3.2	0.86	0.3
Pastures and meadows	5417.2	4452.5	31.1	31.9	0.20	0.5

5.1.6 Total uncertainty of all GHG emissions in Sector 3

Along with calculation of emissions, the total uncertainty for all GHG emissions in Sector 3 was calculated. This was done in accordance with "Approach 1", which is described in IPCC (2006b Vol 1, Chapter 3) and based on Gaussian error propagation calculation. By way of convention, it is ignored that such error propagation calculations assume a normal distribution. Some of the activity data and emission factors that enter into the calculation either do not fulfil this assumption or cannot be checked in this regard. For the present greenhouse gas inventory for the agricultural sector, the standard version of "Approach 1" described in IPCC (2006b Vol 1, Chapter 3) has been used as a basis: The emission factors of the various time series years are assumed to be correlated, but the activity data are assumed not to be correlated from year to year. For asymmetric distributions, the larger of the two intervals [2.5 percentile; average] and [average; 97.5 percentile] was used, as required by IPCC (2006b Vol 1, Chapter 3) for "Approach 1". (For the German Environment Agency's uncertainties calculation, using "Approach 2" for the greenhouse gas report as a whole, the upper and lower bound of the 95% confidence interval, and the type of distribution involved, were provided in the CSE for all uncertainties of agricultural figures.) Further details on uncertainties calculation for the German inventory are presented in Chapter 6 in Vos et al. (2026).

Table 250 shows, for the last time series year, the total uncertainty as calculated with "Approach 1" for all emissions of the "agriculture" sector (Sector 3). Table 250 also shows the uncertainty for the overall trend since 1990. All emissions values are given in CO_2 equivalents.

In the interest of clarity, Table 250 uses the collective animal categories "other cattle," "swine," "sheep," "horses" and "poultry". The activity data and emission factor uncertainties given for these collective categories were derived from the uncertainties in the animal subcategories used in the Py-GAS-EM model by means of error propagation calculations. An overview similar to the one shown in Table 250, but with all individual animal subcategories, is provided in Chapter 6.10 in Vos et al. (2026).

The activity data and emission factor uncertainties for the various mineral fertiliser categories were also aggregated by means of error propagation calculations. The aggregated uncertainties for application of manure and manure digestates given in Table 250 were aggregated using error propagation calculations, and taking account of the uncertainties for the application contributions of the various individual animal categories.

The uncertainties for the emission factors clearly tend to be considerably higher than those for the activity data, and thus they predominate in the combined uncertainty in the column "Combined uncertainty as % of total national emissions".

The total uncertainty for the emissions in source sector 3 (animal husbandry, cultivation of agricultural soils, digestion of energy crops) is 14.9% (valid for the year 2024). The uncertainty for the trend for the period 1990-2023 is 5.6%.

Table 250: Total uncertainties calculation for emissions from Sector 3

Source category EntFer = Enteric Fermentation MM = Manure Management DEC = Digestion of Energy Crops	Gas	Base year emissions, in CO_2 equivalent (GWP_{CH4} = 28, (GWP_{N2O} = 265)	Year 2023 emissions, in CO_2 equivalents	Activity data uncertainty (half the 95% confidence interval)	Emission factor uncertainty (half the 95% confidence interval)	Combined uncertainty (half the 95% confidence interval)	Auxiliary calculations[A]	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Square of "Uncertainty introduced into the trend in total national emissions" [B]
		kt a^{-1}	kt a^{-1}	%	%	%		%	%	%	%	
EntFer, dairy cows	CH_4	20,188.8	14,788.1	4	20	20.4	32.0	0.00	0.20	0.07	1.13	1.28
EntFer, other cattle	CH_4	15,273.6	9,267.3	2.2	10.7	10.9	3.6	0.02	0.13	0.25	0.39	0.21
EntFer, swine	CH_4	757.3	588.7	3.0	15.3	15.6	0.0	0.00	0.01	0.01	0.03	0.00
EntFer, sheep	CH_4	651.2	364.7	10	30	31.6	0.0	0.00	0.00	0.04	0.07	0.01
EntFer, goats	CH_4	22.7	41.6	10	30	31.6	0.0	0.00	0.00	0.01	0.01	0.00
EntFer, horses	CH_4	623.8	629.9	10	30	31.6	0.1	0.00	0.01	0.07	0.12	0.02
EntFer, deer	CH_4	87.2	162.8	200	30	202.2	0.4	0.00	0.00	0.04	0.62	0.39
EntFer, rabbits	CH_4	18.7	4.3	200	30	202.2	0.0	0.00	0.00	0.00	0.02	0.00
EntFer, ostriches	CH_4	0.0	0.6	200	30	202.2	0.0	0.00	0.00	0.00	0.00	0.00
EntFer, fur animals	CH_4	0.5	0.0	200	30	202.2	0.0	0.00	0.00	0.00	0.00	0.00
MM, dairy cows	CH_4	2,521.5	2,499.5	4	20	20.4	0.9	0.01	0.03	0.18	0.19	0.07
MM, other cattle	CH_4	2,683.8	1,468.8	2.2	11.1	11.3	0.1	0.01	0.02	0.07	0.06	0.01
MM, swine	CH_4	3,045.2	1,945.3	3.0	16.1	16.4	0.4	0.00	0.03	0.05	0.11	0.01
MM, sheep	CH_4	25.2	14.1	10	30	31.6	0.0	0.00	0.00	0.00	0.00	0.00
MM, goats	CH_4	0.6	1.0	10	30	31.6	0.0	0.00	0.00	0.00	0.00	0.00
MM, horses	CH_4	119.4	153.9	10	30	31.6	0.0	0.00	0.00	0.03	0.03	0.00
MM, poultry	CH_4	83.3	141.1	6.3	10.1	11.9	0.0	0.00	0.00	0.01	0.02	0.00
MM, deer	CH_4	0.6	1.1	200	30	202.2	0.0	0.00	0.00	0.00	0.00	0.00
MM, rabbits	CH_4	8.1	1.9	200	30	202.2	0.0	0.00	0.00	0.00	0.01	0.00
MM, ostriches	CH_4	0.0	0.1	200	30	202.2	0.0	0.00	0.00	0.00	0.00	0.00
MM, fur animals	CH_4	0.9	0.0	200	30	202.2	0.0	0.00	0.00	0.00	0.00	0.00
MM, direct N_2O, dairy cows	N_2O	1,313.2	643.8	4	100	100.1	1.5	0.00	0.01	0.41	0.05	0.17
MM, direct N_2O, other cattle	N_2O	1,068.0	680.5	2.2	52.0	52.1	0.4	0.00	0.01	0.06	0.03	0.00
MM, direct N_2O, pigs	N_2O	444.5	270.5	3.0	78.5	78.6	0.2	0.00	0.00	0.05	0.02	0.00
MM, direct N_2O, sheep	N_2O	50.7	28.3	10	100	100.5	0.0	0.00	0.00	0.01	0.01	0.00
MM, direct N_2O, goats	N_2O	2.9	5.3	10	100	100.5	0.0	0.00	0.00	0.00	0.00	0.00
MM, direct N_2O, horses	N_2O	293.7	343.7	10	100	100.5	0.4	0.00	0.00	0.18	0.07	0.04
MM, direct N_2O, poultry	N_2O	33.1	38.3	6.3	54.8	55.2	0.0	0.00	0.00	0.01	0.00	0.00
MM, direct N_2O, deer	N_2O	0.0	0.0	200	100	223.6	0.0	0.00	0.00	0.00	0.00	0.00
MM, direct N_2O, rabbits	N_2O	6.3	1.4	200	100	223.6	0.0	0.00	0.00	0.00	0.01	0.00

Source category EntFer = Enteric Fermentation MM = Manure Management DEC = Digestion of Energy Crops	Gas	Base year emissions, in CO_2 equivalent (GWP_{CH4} = 28, (GWP_{N2O} = 265)	Year 2023 emissions, in CO_2 equivalents	Activity data uncertainty (half the 95% confidence interval)	Emission factor uncertainty (half the 95% confidence interval)	Combined uncertainty (half the 95% confidence interval)	Auxiliary calculations[A]	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Square of "Uncertainty introduced into the trend in total national emissions" [B]
MM, direct N_2O, ostriches	N_2O	0.0	0.0	200	100	223.6	0.0	0.00	0.00	0.00	0.00	0.00
MM, direct N_2O, fur animals	N_2O	3.4	0.0	200	100	223.6	0.0	0.00	0.00	0.00	0.00	0.00
MM, indirect N_2O, all animals (deposition)	N_2O	1,265.7	828.5	40	120	126.5	3.9	0.00	0.01	0.13	0.63	0.42
MM, indirect N_2O, all animals (leaching)	N_2O	0.6	0.2	200	100	223.6	0.0	0.00	0.00	0.00	0.00	0.00
Soils, mineral fertilisers	N_2O	5,786.9	2,661.2	0.5	21.9	21.9	1.2	0.02	0.04	0.44	0.03	0.20
Soils, spreading of manure	N_2O	3,395.1	2,516.0	9.1	18.2	20.4	0.9	0.00	0.03	0.02	0.44	0.19
Soils, other organic fertilisers (spreading)	N_2O	28.4	958.5	8.2	32.7	33.7	0.4	0.01	0.01	0.41	0.15	0.19
Soils, sewage sludge	N_2O	71.8	23.5	10	40	41.2	0.0	0.00	0.00	0.02	0.00	0.00
Soils, crop residues	N_2O	1,743.6	2,151.2	50	40	64.0	6.7	0.01	0.03	0.48	2.05	4.45
Soils, organic soils	N_2O	3,266.6	3,175.6	0.09	196	196.0	136.3	0.01	0.04	2.18	0.01	4.76
Soils, mineralisation	N_2O	747.7	298.1	23.3	80	83.3	0.2	0.00	0.00	0.26	0.13	0.08
Soils, grazing	N_2O	512.3	256.4	20	300	300.7	2.1	0.00	0.00	0.45	0.10	0.22
Soils, indirect N_2O (deposition)	N_2O	2,349.0	1,407.9	50	120	130.0	11.8	0.00	0.02	0.46	1.34	2.02
Soils, indirect N_2O (leaching, run-off)	N_2O	2,391.4	1,024.5	200	100	223.6	18.5	0.01	0.01	0.94	3.91	16.18
DEC, digester and storage	CH_4	0.3	1,445.3	10	20	22.4	0.4	0.02	0.02	0.39	0.28	0.23
DEC, storage, direct N_2O	N_2O	0.1	87.1	10	100	100.5	0.0	0.00	0.00	0.12	0.02	0.01
DEC, storage, indirect N_2O (deposition)	N_2O	0.0	5.6	10	120	120.4	0.0	0.00	0.00	0.01	0.00	0.00
Liming, without dolomite	CO_2	1,850.3	1,867.7	3	3	4.2	0.0	0.01	0.03	0.02	0.11	0.01
Liming, dolomite	CO_2	349.7	38.8	100	3	100.0	0.0	0.00	0.00	0.01	0.07	0.01
Liming, calcium ammonium nitrate	CO_2	510.4	144.8	3	3	4.2	0.0	0.00	0.00	0.01	0.01	0.00
Application of urea	CO_2	480.0	330.2	1	1	1.4	0.0	0.00	0.00	0.00	0.01	0.00
Total		74,078.1	53,307.9									
					Percentage uncertainty in total inventory: 14.9				Trend uncertainty (percentage): 5.6			

A The data in this column describes auxiliary data needed to derive the percentage uncertainty in total inventory in the bottommost cell of this column. In order to calculate the data, the calculation approach provided by IPCC (2006a Vol 1, 3.31, Table 3.2, column H) has been used. Note, however, that the column heading as prescribed by IPCC (2006a Vol 1, 3.31, Table 3.2, column H) ("Contribution to Variance by Category") does not correctly describe the data in column H. Hence the column heading has been modified.

B The column heading as prescribed by IPCC (2006a Vol 1, 3.31, Table 3.2, column M)("Uncertainty introduced into the trend in total national emissions"), has been modified in order to match the formula provided by IPCC (2006a Vol 1) and applied in the table above to calculate the data in this column.

5.1.7 Quality assurance and control

The relevant involved experts and the Single National Entity (SNE) have carried out general quality control (QC) - and additionally for category 3. J, category-specific quality control - and quality assurance (QA) in accordance with the requirements of the QSE manual and its associated applicable documents.

5.1.7.1 The Thünen Institute's quality management for emissions inventories

The Thünen Institute's quality management for emissions inventory preparation has been developed in line with the IPCC guidelines and the QSE manual (Chapter 1.5.1). The framework for the quality management and the process for carrying it out are described in detail in the relevant concept (BMELV, 2016) and in the provisions for implementation of the concept (Thünen-Institut (TI), 2016). Documents of importance for quality control are added to the inventory description that is archived by the Single National Entity. The requirements and procedures set forth by the provisions for implementation of the concept were fully complied with. The following sections discuss important quality control aspects for the present submission.

5.1.7.2 Input data, calculation procedures and emissions results

Checking of the emissions calculations and of the NID included the following:

In the framework of inventory improvement, and in the run-up to emissions reporting for 2026, the following conceptual changes were made (cf. Chapter 5.1.7.3 and Chapter 1.3 in Vos et al. (2026)):

- Inclusion of transporting substrates to biogas plants and manure between NUTS-3 regions by introducing a transport module into the PY-GAS-EM model.
- The spatial distribution of synthetic N fertiliser quantity across NUTS-3 regions is no longer temporally static, i.e. it changes depending on the cultures cultivated.
- For the first time, emission factors disaggregated by climate as per (IPCC, 2019) are applied to emissions from grazing and indirect emissions from deposition. To this end, comprehensive precipitation and evapotranspiration data were used to determine the share of agricultural land with a dry or wet climate for each NUTS-3 region and each year.
- The animal category sows was divided into gilts and old sows (who have had at least one litter)
- N excretions from dairy cows are now derived from the milk urea content, milk yield and milk protein content rather than the assumed feed

The other calculation methods formally agree with those used for the 2025 emissions report.

The activity data have been checked for plausibility and consistency and updated, as necessary, on the basis of newer data.

It has been ensured that the areas of the organic soils used for cropland or as managed grassland are consistent across the LULUCF (Chapter 4.B, 4.C) and Agriculture (3.D) sections.

Every single time series of the emissions results for the 2026 submission was checked for consistency with the corresponding time series in the 2025 submission. All discrepancies can be explained as the result of updating of input data and/or calculation procedures.

The fluctuations and trends in the time series can be explained, and the most important of these are described in the NID.

The activity data and emissions results were compared with corresponding data of central European countries that are either direct neighbours of Germany or that have comparable agricultural practices. In most cases, the German data fall within the middle range, or are at the level found in one or more of the countries being compared, or are at the level of an IPCC (2006b) or IPCC (2019) standard value. Any important departures from these criteria discrepancies can be justified in each individual case.

The input data and calculation results for all relevant emission sources in agricultural sector emissions reporting are provided, as background for the results presented in the NID 2026 and the CR tables in an EXCEL file that is available as a supplement to Vos et al. (2026) (cf. Chapter 1.3. in Vos et al. (2026)).

The data in the NID text were checked for consistency by comparing them with the calculation results.

To ensure that the activity data and emission factors (IEFs) were correctly entered into the Central System of Emissions (CSE) database on which the CR tables are based, the emissions as calculated with the CSE were compared with the emissions as calculated with the Py-GAS-EM inventory model.

5.1.7.3 Changes since the previous submission

As a result of improvements to the inventory or the availability of updated input data, numerous changes were made compared to the submission for the previous year. The most important changes, in terms of their impact, are provided below. In particular, cases in which preliminary data for 2023 has been replaced by final data in Submission 2025 are not listed here (for a full list of changes, cf. Chapter 1.3 in Vos et al. (2026).

- Manure management and soils: Inclusion of transporting substrates to biogas plants and manure between NUTS-3 regions by introducing a transport module into the PY-GAS-EM model.
- Synthetic nitrogen fertilisers: The spatial distribution of fertiliser quantity across NUTS-3 regions is no longer temporally static, i.e. it changes depending on the cultures cultivated and the yields.
- Synthetic nitrogen fertiliser: The NH_3 emission factor for straight fertilisers (0.084 kg NH_3 per kg N) used in the 2025 submission was corrected in EMEP (2023) to 0.024 kg NH_3 per kg N).
- Emissions from grazing and indirect emissions from deposition: As a result of a recommendation following a review, emission factors differentiated by climate as provided by IPCC (2019) are used for the first time. To this end, comprehensive precipitation and evapotranspiration data for every NUTS-3 region and year were used to determine the share of agricultural land with a dry or wet climate.
- Dairy cows: N excretions are now derived from the milk urea content, milk yield and milk protein content rather than the modelled feed.
- Dairy cows: The official final milk yields for 2023 are significantly higher than the provisional numbers used in the 2025 submission. This is due to an improved calculation

method which will continue to be used in future and was also applied to 2022. For reporting purposes, an approach was developed to revise upwards the milk yields prior to 2022.

- Swine: The animal category sows was divided into gilts and old sows (who have had at least one litter), with different weights and, in turn, different energy requirements and feeding.
- Horses: N and VS excretions were corrected upwards from the year 2020 as a result of updated feed recommendations for heavy horses. Until 2010, the values from submission 2025 were used, with linear interpolation used for the years between 2010 and 2020. The Tier 1 emission factor for enteric fermentation for light horses and ponies was updated from 12.0 to 11.4 for the entire time series according to footnote 2 of Table 10.10 in (IPCC, 2019).
- Deer: Interpolation using new data for 2023 slightly reduces the number of animals from 2009.
- Manure imports: A correction of the Dutch export data led to a minimal change in N quantities from 2010.
- Crop residues: The number of grassland cuts was updated based on a new method to identify outliers for the entire time series.
- Manure digestion: Due to the newly introduced substrate transports, the input value now used is the absolute N quantity that goes to digestion rather than the percentage share of digested manure N of the total manure production. Until the 2025 submission, housing emissions were not taken into account when calculating the N quantities input into digestion. This has now been corrected, meaning that the shares of manure input into digestion are higher than previously reported.
- N mineralisation in mineral soils: The data for N mineralisation were obtained from the Tier-3 calculation method used in the mineralisation and carbon balance processes of the LULUCF sector. The data show much higher interannual fluctuations, and are on average higher in the 2026 submissions than in the 2025 submission. This is largely the case because mineralisation in grassland, which was previously reported under LULUCF, is now also reported in addition to mineralisation in cropland, as per (IPCC, 2006a). The interannual fluctuations are attributable to using the RothC soil carbon model based on actual weather data for the first time (cf. Chapters 6.1.2.7, 6.4.2.7.3 and 6.5.2.3.2).
- Cultivated organic soils: The data was obtained from the calculation methods for mineralisation and carbon balance processes in the LULUCF sector. The data are updated annually. At the start of the time series, the total area of cultivated organic soils is about 2% higher than the corresponding values in the 2025 submission. This difference not only decreases over the years and reverses from 2005 onwards. At the end of the time series, the total area is about 0.2% smaller compared to the 2025 submission.

5.1.7.4 Verification

The national emissions results calculated with the Py-GAS-EM inventory model cannot be compared with other data from Germany, since no such data are available. Instead, (cf. Chapter 5.1.7.2) the input data and emissions results have been compared with corresponding data of other countries and with IPCC (2006b) default values. That process is discussed in the present NID, in the relevant subchapters.

In the framework of a verification project for the 2014 NIR, an external expert (Zsolt Lengyel, Verico SCE) reviewed the German emissions calculations. That review found that the input data

are consistent, and that the calculations are consistent and have been carried out in accordance with the methodological requirements set forth in the IPCC Guidelines.

Furthermore, the Py-GAS-EM model is continuously validated and verified in the framework of the European Agricultural Gaseous Emission Inventory Research network (EAGER) group and through review of modules by KTBL.

5.1.7.5 Reviews and reports

The ERT recommendations from the reviews, up to and including that of the 2020 submission, were implemented by the 2023 submission and thus are not detailed here.

The IPCC did not review the 2021, 2023 and 2024 submissions.

The ERT for the 2022 submission review recommended that the NID's transparency be improved with regard to changes in the weight and N excretions of dairy cows. In the 2024 submission, detailed information on this subject were added to Chapter 5.1.3.3. In addition, it was also recommended that transparency be improved with regard to derivation of the Tier 2 emission factors for direct N_2O emissions from soils that have been used since the 2022 submission. In the 2024 submission, further information on this subject was added to Chapter 5.5.2.1.1. As the final point of that review. improved transparency with regard to the activity data for sewage sludge application was recommended. As a result, the activity data have been reviewed and corrected, in cooperation with the Federal Statistical Office.

In the various EU reviews of the submissions since 2019, pursuant to Article 19(2) of EU Regulation 525/2013 (EU, 2013b), no requirements whatsoever for changes in the inventory methods or input data have emerged (EEA, 2019, 2020, 2021, 2022).

In its review of submission 2025 pursuant to Article 38/(1a) of EU Regulation 2018/1999 (EU, 2018b) and Article 4(3) of EU Regulation 2018/842 (EU, 2018a), TERT recommended using the default emission factors disaggregated by climate (wet/dry) from (IPCC, 2019) to determine indirect emissions from atmospheric deposition because part of Germany is in a dry climate. In submission 2025, only the default IPCC emission factor for wet climates was used. For the years 2021-2023, the 2025 submission was subject to a technical correction based on the assumption that 41% of Germany's surface area belongs to a dry climate. In the 2026 submission, this recommendation was implemented using annual data on the spatial distribution of wet and dry climate conditions.

5.2 Enteric fermentation (3.A)

5.2.1 Category description (3.A)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
L/T	3 A, Enteric Fermentation	dairy cows	CH_4	20188.82	1.57	14788.07	2.09	-26.75
L/T	3 A, Enteric Fermentation	non-dairy cattle	CH_4	15273.58	1.19	9267.27	1.31	-39.32
L/-	3 A, Enteric Fermentation	other animals	CH_4	2161.42	0.17	1792.61	0.26	-17.06

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier1/Tier2/Tier3	M/Q/AS/RS/NS	CS/D

The category "Dairy cows" is the most important emissions source within the category Enteric fermentation. For methane, it is a key category in terms of emissions level and trend. This is due to the large numbers of animals and the high performance involved. The category "Other cattle" is also a key category in terms of emissions level. The category "Other animals" is a key category in terms of the level.

CH_4 from enteric fermentation is produced as a result of microbial transformations in the digestive tract. The quantities released per animal and unit of time depend on the animal species in question, individual animal performance and feed composition.

The CH_4 emissions trend is shaped by decreasing animal populations - for cattle especially throughout the entire period and for all animal categories in the early 1990s - and by improved feed digestibility, which is partly offset by increasing GE intake levels in connection with increases in milk yield and animal weights.

Table 251 shows the change of CH_4 emissions from enteric fermentation for the entire livestock population since 1990 as well as the percentage shares of these emissions with respect to the total emissions from the German agricultural sector, broken down by CH_4 and greenhouse gas (GHG, in CO_2 equivalents). The percentage shares of the total emissions differ, since GHG also includes N_2O and CO_2 emissions.

Table 251: CH_4 emissions from enteric fermentation (3.A): Changes since 1990 and percentage share of Germany's agricultural emissions (3.A)

[%]	Change since 1990	Share of total agricultural emissions (CH_4 or GHG)	
		1990	**2024**
CH_4	-29.6	81.6	77.1
GHG (CO_{2eq})		50.8	48.5

5.2.2 Methodological issues (3.A)

5.2.2.1 Methods (3.A)

The CH_4 emissions from enteric fermentation of dairy cows are calculated with a national method (Tier 3). For suckler cows, a Tier 2 method based on that used for dairy cows has been used. For other cattle and swine, the calculation is carried out using a Tier 2 method (IPCC, 2006b Vol 4, 10.24). Figures for sheep, goats, horses, deer, rabbits, ostriches and fur-bearing animals are calculated using a Tier 1 method that employs default emission factors (cf. Chapter 5.2.2.2).

In the national method for calculation of CH_4 emissions from enteric fermentation in dairy cattle (Dämmgen, Rösemann, et al., 2012), the emission factor is calculated pursuant to Kirchgessner et al. (1994) as a function of intake of raw fibre, N-free extracts, raw protein and fat:

Equation 17: Calculation of the CH4 emission factor for dairy cows (national method)

$$EF_{\mathrm{CH4,\,ent}} = a \cdot M_{\mathrm{XFi}} + b \cdot M_{\mathrm{NFE}} + c \cdot M_{\mathrm{XP}} + d \cdot M_{\mathrm{XF}} + e$$

where

- $EF_{CH4,\,ent}$ Emission factor for CH_4 from enteric fermentation (in kg place^{-1} a^{-1} CH_4)
- A = Coefficient (a = 0.079 kg kg^{-1})
- M_{XFi} = Raw fibre intake (in kg place^{-1} a^{-1})
- B = Coefficient (b = 0.010 kg kg^{-1})
- M_{NFE} = Intake of N-free extracts (in kg place^{-1} a^{-1})
- C = Coefficient (c = 0.026 kg kg^{-1})
- M_{XP} = Intake of raw protein (in kg place^{-1} a^{-1})
- D = Coefficient (d = 0.212 kg kg^{-1})
- M_{XF} = Intake of fat (in kg place^{-1} a^{-1})
- E = Constant (e = 365 · 0.063 kg place^{-1} a^{-1})

The intake of raw fibre, N-free extracts, raw protein and fat is determined from the basic feed composition data and the quantities of ingested feed (cf. Chapter 5.1.3.3).

The methane conversion factor is calculated from those figures using the GE intake (cf. Chapter 5.1.3.3):

Equation 18: Calculation of the methane conversion factor…

$$x_{\mathrm{CH4,GE}} = \frac{\eta_{\mathrm{CH4}} \cdot EF_{\mathrm{CH4,\,ent}}}{GE}$$

where

- $x_{CH4,\,GE}$ = Methane conversion factor for dairy cows (in MJ MJ^{-1})
- η_{CH4} = Energy content of methane (η_{CH4} = 55.65 MJ (kg CH_4)$^{-1}$)
- $EF_{CH4,\,ent}$ = Emission factor for CH_4 from enteric fermentation (in kg place^{-1} a^{-1} CH_4)
- *GE* = Gross energy intake (in MJ place^{-1} a^{-1} GE)

As a result of increasing milk yields, the feed intake and, thus, the GE intake, for dairy cows increase over the years, with the relative fraction of more easily digestible concentrated feed, i.e. as a share of the total ration, growing and thereby supplanting basic feed; cf. Chapter 2.4.5 in (Vos et al., 2026). As a result of this shifting within feed rations, the increase in the CH_4 emissions from enteric fermentation, as calculated with Equation 17, is smaller than the increase in the GE intake. This results, in turn, in a decreasing trend in the methane conversion factor over the years, which is tied to the trend in milk yield; cf. Table 252 and Chapter 5.2.2.3.

Table 252: Dairy cows: milk yield, GE intake, enteric fermentation-related CH_4 emissions and methane conversion factor (3.A)

	1990	2023
Average daily milk yield [kg animal place^{-1} d^{-1}]	13.4	25.1
Annual GE intake [GJ animal place^{-1} a^{-1}]	90.0	131.2
Annual CH_4 emissions from enteric fermentation [kg animal place^{-1} a^{-1}]	113.5	154.3
Methane conversion factor [MJ MJ^{-1}]	0.070	0.062

For suckler cows, use of the new model, which is based on that used for dairy cows (cf. (Vos et al., 2026), Chapter 3) yields variable methane conversion factors between 0.086 and 0.084 MJ MJ^{-1}.

The Tier 2 method that is used for other cattle and swine calculates the emission factor from the gross energy intake (GE) (cf. Chapter 5.1.3.3) and the methane conversion factor in accordance with the following formula:

Equation 19: Calculation of the CH_4 emission factor (Tier 2 method, , IPCC (2006b Vol 4, 10.31))

$$EF_{\mathrm{CH4,\,ent}} = GE \cdot \frac{x_{\mathrm{CH4,GE}}}{\eta_{\mathrm{CH4}}}$$

where

- $EF_{CH4,\,ent}$ = Emission factor for CH_4 from enteric fermentation (in kg place^{-1} a^{-1} CH_4)
- GE = Gross energy intake (in MJ place^{-1} a^{-1} GE)
- $x_{CH4,\,GE}$ = Methane conversion factor (in MJ MJ^{-1})
- η_{CH4} = Energy content of methane (η_{CH4} = 55.65 MJ (kg CH_4)$^{-1}$)

The category-specific methane conversion factors for the various subcategories of the other cattle are given in Table 253. Due to changes in the composition of the overall population, the weighted average value for all other cattle varies slightly over the years. Table 253 shows the average value for all other cattle for the first and last year of the time series.

Table 253: Methane conversion factors for other cattle (3.A)

	MJ MJ-1	Source
Dairy heifers and female beef cattle, male beef cattle, mature males > 2 years	0.063	IPCC (2019), Vol.4, Tab. 10.12
Suckler cows	0.086 - 0.084	Vos et al. (2026), Chapter 3.1
Calves	0.041	Vos et al. (2026), Chapter 3.2
Average value for all other cattle, 1990	0.0631	Calculation
Average value for all other cattle, 2024	0.0650	Calculation

Table 254 shows the national category-specific methane conversion factors for the various swine categories (Dämmgen, Schulz, et al., 2012), along with the weighted average values for all

swine in the first and last year of the time series. The average values differ as a result of the changes in the composition of the overall swine population.

Table 254: Methane conversion factors for swine (3.A)

	MJ MJ-1
Sows	0.0071
Weaners	0.0044
Fattening pigs	0.0046
Boars	0.0071
Average values for all swine, 1990	0.0051
Average values for all swine, 2024	0.0049

With regard to the emission factors calculated with Equation 19, cf. Chapter 5.2.2.2.

A general description of calculation of CH_4 emissions from enteric fermentation is provided in Chapter 3 in Vos et al. (2026). Animal-specific details are also provided in Chapter 3 in Vos et al. (2026).

5.2.2.2 Emission factors (3.A)

Table 255 shows the CH_4 emission factors calculated per animal place for enteric fermentation of dairy cows, other cattle and swine.

Table 255: CH_4 emission factors for enteric fermentation, referenced to animal place (3.A), in [kg place^{-1} a^{-1}]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Dairy cows	113.5	122.3	128.7	133.4	133.9	135.6	136.7	136.8	138.8	140.9	142.6	142.9	142.1	145.3	147.1
Other cattle	41.5	44.1	45.8	45.7	46.2	46.1	46.1	46.3	46.5	46.9	47.3	47.6	47.5	47.9	48.2
Swine	1.02	1.07	1.09	1.09	1.10	1.12	1.13	1.14	1.15	1.15	1.15	1.17	1.17	1.17	1.19

Table 256 shows the inventory's Tier 1 emission factors for sheep, goats, horses, deer, rabbits, ostriches and fur-bearing animals. The values shown have been used for the entire time series. The emission factors for lambs and light horses/ponies have been derived from the Tier 1 emission factors for adult sheep and heavy horses, respectively; cf. Chapter 3.3 in Vos et al. (2026). The emission factor for rabbits has been derived from the emission factor for horses, as described in remark 2 for Table 10.10 in IPCC (2019), for details, cf. Chapter 3.3 in Vos et al. (2026). Because the compositions of the small animal/large animal populations do not remain constant, the emission factors reported in the CR tables vary slightly from year to year for sheep overall and for horses overall. Table 256 shows the average value for the last time series year.

Table 256: Tier 1 emission factors for CH_4 from enteric fermentation (3.A.), in kg place^{-1} a^{-1}

	EF	Average value for 2024	Source
Mature sheep	9.0	7.1	Regarding the derivation, cf. Chapter 3.3 in Vos et al. (2026)
Lambs	4.0		Regarding the derivation, cf. Chapter 3.3 in Vos et al. (2026)
Goats	9.0		IPCC (2006b Vol 4, Table 10.10) IPCC (2019), Table 10.10

	EF	Average value for 2024	Source
Heavy horses	18.0	16.4	IPCC (2019), Table 10.10
Light horses/ponies	11.4		Regarding the derivation, cf. Chapter 3.3 in Vos et al. (2026)
Deer	20.0		IPCC (2019), Table 10.10
Rabbits	0.36		Regarding the derivation, cf. Chapter 3.3 in Vos et al. (2026)
Ostriches	5.0		IPCC (2019), Table 10.10
Fur-bearing animals	0.10		Regarding the derivation, cf. Chapter 3.3 in Vos et al. (2026)

5.2.2.3 Emissions (3.A)

The calculated CH_4 emissions from enteric fermentation for all German animal husbandry are listed in Table 257.

Table 257: CH_4 emissions from enteric fermentation (3.A), in [Gg]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Total	1343.7	1186.5	1117.4	1041.4	1027.3	1032.9	1022.7	1014.8	999.6	988.4	973.6	955.1	945.5	943.9	923.1
in % of 1990	100.0	88.3	83.2	77.5	76.5	76.9	76.1	75.5	74.4	73.6	72.5	71.1	70.4	70.2	68.7
Dairy cows	721.0	639.7	588.1	565.3	560.1	581.2	576.5	574.3	569.1	565.4	559.1	547.9	541.3	539.6	528.1
Other cattle	545.5	469.8	456.4	402.1	398.8	385.2	380.1	373.9	364.7	357.6	349.0	342.9	341.7	341.1	331.0
Swine	27.0	21.9	23.8	24.8	24.4	25.8	25.7	26.1	25.2	24.8	25.0	23.1	20.7	20.6	21.0
Sheep	23.3	21.2	19.7	19.0	16.0	13.3	13.2	13.3	13.2	12.9	12.7	12.8	12.9	13.2	13.0
Other animals	26.9	33.8	29.4	30.1	28.0	27.3	27.1	27.3	27.5	27.7	27.8	28.4	28.9	29.4	30.0

In the main, the emissions trend since 1990 and, in particular, the decrease seen as of 2015, have been shaped by the following factors:

- the trend in numbers of animals (cf. Chapter 5.1.3.2.3), especially with regard to cattle, which make a significant contribution to emissions from enteric fermentation (the dairy cow population in 2024 was about 44% lower than it was in 1990; the corresponding figure for other cattle is about 48% lower than the figure in 1990);
- continual increases in performance (milk yield, animal weights, weight gains); cf. Chapter 5.1.3.3;
- a considerable decrease, over the years, in the methane conversion factor for dairy cows (cf. Chapter 5.2.2.1).

5.2.3 Uncertainties and time series consistency (3.A)

Table 250 in Chapter 5.1.6 shows the uncertainties in activity data and emission factors that have been used in estimating the total uncertainty of the German GHG inventory.

The uncertainties for the emission factors for CH_4 from enteric fermentation are default values taken from IPCC (2006b Vol 4, 10.33). With regard to the uncertainty for the activity data (numbers of animals), cf. Chapter 6.3 in (Vos et al., 2026).

The emissions time series are consistent, since they were calculated with the same method for all years of the report period, and since the input data are also consistent and complete.

5.2.4 Category-specific QA/QC and verification (3.A)

With regard to quality control and quality assurance, we refer to Chapter 5.1.7.

As part of verification, the German animal husbandry data for dairy cows, other cattle and swine were compared with the corresponding IPCC default values and with relevant data of neighbouring countries, including data from the UK (Table 258 and Table 259). At the time the German 2026 emissions report was being prepared, the results of the other countries' 2026 emission reporting were not yet known. For this reason, data from 2025 reports are being used for those countries, while the German data have been taken from the current 2026 report. The international comparison is being carried out for 2023 (the last time series year in the 2025 report).

Table 258 shows, for dairy cows, the national mean figure for the animal place-related emission factor (implied emission factor, IEF), GE intake and milk yield (which is the key factor affecting emissions levels). The CH_4 conversion factor is also included. It is used to calculate the share of GE intake that is converted into methane energy and lost with emitted methane (cf. the method description in Chapter 5.2.2.1).

Of the nine countries compared with Germany, Denmark has the highest IEF, while the UK has the lowest. Germany's IEF is slightly above the median. This also applies to its GE intake and milk yield figures. With regard to methane conversion factors, only Poland has used the IPCC (2006) default value of 6.5%. Only the value used by Switzerland is higher than the IPCC (2006) default value. The remaining countries' methane conversion factors are lower than the IPCC (2006) default value, where the value for Austria correspondsto the IPCC (2019) default value for medium producing cows.

Table 258: CH_4 emissions from enteric fermentation of dairy cows, in various countries – a comparison of Implied Emission Factors (IEFs) for the time series year 2023

	IEF_{CH4}	CH_4 conversion factor Y_m	GE intake	Milk yield
	[kg place^{-1} a^{-1}]	[MJ MJ^{-1}]	[MJ place^{-1} d^{-1}]	[kg place^{-1} d^{-1}]
Austria	130.51	0.0630	315.8	19.96
Belgium	124.75	0.0610	312.3	23.57
Czech Republic	150.70	0.0615	373.6	26.34
Denmark	161.87	0.0577	426.4	29.15
France	148.83	0.0631	359.6	22.39
Germany	**145.33**	**0.0617**	**359.4**	**25.10**
Netherlands	139.78	0.0582	298.4	24.92
Poland	127.23	0.0650	298.4	18.91
Switzerland	139.61	0.0690	308.5	19.38
United Kingdom	123.28	0.0645	291.4	22.52
IPCC (2006b Vol 4, 10.15 bis 10.31, 10.72)[a]	117	0.065	Equation 10.3-10.16	16.44

Source: Germany: 2026 submission; other countries: UNFCCC (2025)

NE, NA, n/a: no data available

[a] calculated from the annual milk yield assumed in IPCC (2006b Vol 4), 6000 kg place-1 a-1

Table 259 shows the IEF and the GE intakes for the group of other cattle and for all swine combined.

For other cattle, the IEF values range from 35.32 kg place^{-1} a^{-1} (Netherlands) to 70.08 kg place^{-1} a^{-1} (Czech Republic). The latter value is considerably higher than the IPCC default value of 57 kg place^{-1} a^{-1}. Germany's IEF and GE intake values lie somewhat below the median.

With regard to swine, five of the countries considered use the IPCC default value for the IEF. The five countries that calculate the IEF obtain results that are lower than the IPCC default value. This could indicate that the IPCC default value is too high for the circumstances prevailing in central Europe. France's IEF, in the context of this international comparison, seems unrealistically low. The German IEF is the highest among those of all countries that calculate an IEF. GE intake is reported only by Austria, Denmark, Germany and Switzerland. Germany's GE value is the highest.

Table 259: Methane emissions from enteric fermentation of other cattle and swine, in various countries – a comparison of Implied Emission Factors (IEFs) for the time series year 2023

	Other cattle		Swine	
	IEF_{CH4} [kg place^{-1} a^{-1}]	GE intake [MJ place^{-1} d^{-1}]	IEF_{CH4} [kg place^{-1} a^{-1}]	GE intake [MJ place^{-1} d^{-1}]
Austria	56.35	147.30	0.97	30.12
Belgium	46.13	122.02	1.50	NE
Czech Republic	70.08	172.01	1.50	NA
Denmark	40.51	137.36	1.03	26.09
France	53.09	125.29	0.74	NE
Germany	**47.88**	**112.13**	**1.17**	**36.53**
Netherlands [a]	35.32	90.19	1.50	NA
Poland	51.15	119.99	1.50	n/a
Switzerland [a]	45.93	119.15	1.06	25.77
UK [b]	54.11	103.55	1.50	n/a
IPCC (2006b)	57	Equation 10.3-10.16	1.5	Equation 10.3-10.16

Source: Germany: 2026 submission; other countries: UNFCCC (2025)

NE, NA, n/a: no data available

[a] Other cattle: Calculated from CRF data

[b] UK, other cattle: Cattle, not including dairy cows, and not including dairy replacements (with calves)

5.2.5 Category-specific recalculations (3.A)

Table 260 shows, for dairy cows, other cattle and swine, GE intake in comparison to the corresponding data in the 2025 submission. For dairy cows, the differences are mainly attributable to the higher milk yield across the entire time series when compared with the 2025 submission. The distinction between gilts and old sows who have had at least one litter results in a lower total GE intake of pigs compared with the 2025 submission; cf. Chapter 5.1.7.3. For the remaining animals, GE intake does not enter into emissions calculations. For this reason, those animals are not included in Table 260.

Table 260: Comparison of the average daily GE intakes for dairy cows, other cattle and swine as reported in the 2025 and 2026 submissions (3.A), in MJ/animal

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023
Dairy cows, 2026	246.7,	270.2,	289.7,	306.0,	315.0,	325.4,	329.0,	329.1,	336.2,	343.7,	349.6,	350.8,	347.8,	359.4
Dairy cows, 2025	241.3,	264.0,	283.0,	298.8,	307.5,	318.9,	322.3,	322.5,	329.4,	336.7,	342.5,	343.7,	341.6,	350.1
Other cattle, 2026	100.1,	104.0,	106.9,	106.6,	108.1,	108.2,	108.2,	108.6,	109.0,	110.0,	110.9,	111.7,	111.5,	112.1
Other cattle, 2025	100.1,	104.0,	106.9,	106.6,	108.1,	108.2,	108.2,	108.6,	109.0,	110.0,	110.9,	111.7,	111.5,	112.1
Swine, 2026	30.4,	32.0,	32.8,	33.0,	33.5,	34.7,	35.0,	35.2,	35.5,	35.6,	35.9,	36.4,	36.3,	36.5
Swine, 2025	30.9,	32.5,	33.4,	33.5,	34.0,	35.2,	35.5,	35.7,	36.0,	36.1,	36.4,	36.9,	36.8,	37.0

Table 261: Comparison of the CH_4 emission factors (enteric fermentation) for dairy cows, other cattle and swine (3.A), referenced to animal place, as reported in the 2025 and 2026 submissions (3.A), in [kg/place]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023
Dairy cows, 2026	113.5	122.3	128.7	133.4	133.9	135.6	136.7	136.8	138.8	140.9	142.6	142.9	142.1	145.3
Dairy cows, 2025	111.5	120.2	126.5	131.3	131.7	133.8	134.8	134.9	136.9	139.0	140.6	141.0	140.3	142.8
Other cattle, 2026	41.5	44.1	45.8	45.7	46.2	46.1	46.1	46.3	46.5	46.9	47.3	47.6	47.5	47.9
Other cattle, 2025	41.5	44.1	45.8	45.7	46.2	46.1	46.1	46.3	46.5	46.9	47.3	47.6	47.5	47.9
Swine, 2026	1.02	1.07	1.09	1.09	1.10	1.12	1.13	1.14	1.15	1.15	1.15	1.17	1.17	1.17
Swine, 2025	1.05	1.10	1.12	1.12	1.12	1.15	1.15	1.16	1.17	1.17	1.18	1.19	1.19	1.20

The discrepancies with respect to the 2025 submission that are seen in Table 261 (emission factors) and Table 262 (emissions) are also due to the reasons mentioned in connection with Table 260. In addition, emissions from horses are slightly lower than those reported in the 2025 submission since the emission factor for light horses and ponies has been updated (cf. Chapter 5.1.7.3). The total emissions for all animals are higher than in the 2025 submission.

Table 262: Comparison of the CH_4 emissions (enteric fermentation) for all animals, dairy cows, other cattle, swine, sheep, goats and horses as reported in the 2025 and 2026 submissions (3.A), in [Tg]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023
All animals, 2026	1.344	1.186	1.117	1.041	1.027	1.033	1.023	1.015	1.000	0.988	0.974	0.955	0.945	0.944
All animals, 2025	1.332	1.176	1.108	1.033	1.019	1.026	1.016	1.008	0.993	0.981	0.967	0.948	0.939	0.935
Dairy cows, 2026	0.721	0.640	0.588	0.565	0.560	0.581	0.577	0.574	0.569	0.565	0.559	0.548	0.541	0.540
Dairy cows, 2025	0.709	0.628	0.578	0.556	0.551	0.573	0.569	0.566	0.561	0.558	0.551	0.540	0.535	0.530
Other cattle, 2026	0.545	0.470	0.456	0.402	0.399	0.385	0.380	0.374	0.365	0.358	0.349	0.343	0.342	0.341
Other cattle, 2025	0.545	0.470	0.456	0.402	0.399	0.385	0.380	0.374	0.365	0.358	0.349	0.343	0.342	0.341
Swine, 2026	0.027	0.022	0.024	0.025	0.024	0.026	0.026	0.026	0.025	0.025	0.025	0.023	0.021	0.021
Swine, 2025	0.028	0.022	0.024	0.025	0.025	0.026	0.026	0.027	0.026	0.025	0.025	0.024	0.021	0.021

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023
Sheep, 2026	0.023	0.021	0.020	0.019	0.016	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
Sheep, 2025	0.023	0.021	0.020	0.019	0.016	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
Goats, 2026	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Goats, 2025	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Horses, 2026	0.022	0.028	0.023	0.023	0.021	0.020	0.020	0.020	0.020	0.020	0.021	0.021	0.022	0.022
Horses, 2025	0.023	0.029	0.023	0.023	0.021	0.020	0.020	0.020	0.020	0.021	0.021	0.021	0.022	0.022

5.2.6 Planned improvements (3.A)

No further improvements are planned at present.

Where previous reports have listed improvements in this chapter, those improvements are presented as an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

5.3 Manure management (3.B)

5.3.1 Category description (3.B)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
L/T	3 B, Manure Management	dairy cows	CH_4	2521.46	0.20	2499.53	0.36	-0.87
-/-	3 B, Manure Management	non-dairy cattle	CH_4	2683.78	0.21	1468.79	0.21	-45.27
L/-	3 B, Manure Management	swine	CH_4	3045.17	0.24	1945.35	0.28	-36.12
-/-	3 B, Manure Management	other animals	CH_4	238.01	0.02	313.14	0.05	31.56
-/-/2	3 B, Manure Management	dairy cows	N_2O	1313.24	0.11	643.84	0.10	-50.97
-/-/2	3 B, Manure Management	non-dairy cattle	N_2O	1068.01	0.09	680.49	0.10	-36.28
L/-	3 B, Manure Management	swine	N_2O	444.50	0.04	270.47	0.04	-39.15
-/-/2	3 B, Manure Management	other animals	N_2O	390.15	0.04	417.04	0.06	6.89
-/-/2	3 B, Manure Management	deposition and leaching	N_2O	1266.26	0.10	828.68	0.12	-34.56

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 2	M/Q/AS/RS/NS	CS/D
N_2O direct	Tier 2	M/Q/AS/RS/NS	CS/D
N_2O indirect	Tier 1	M/Q/AS/RS/NS	CS/D
NO_X	Tier 2	M/Q/AS/RS/NS	CS
NMVOC	Tier 2 / Tier 1	RS/NS	D

For CH_4 emissions from swine, manure management is a key category in terms of emissions level. The 3.B. category manure management for dairy cows is a key category for CH_4 in terms of emissions level and trend, a key category for swine only in terms of emissions level, and a key category for N_2O and CH_4 in terms of Approach 2 analysis. N_2O emissions of other cattle and

other animals, and indirect N_2O from deposition have also been identified as key categories using an Approach 2 analysis.

In sector 3.B, Germany reports on CH_4, N_2O, NO and NMVOC from manure management.

CH_4 occurs when methanogenic bacteria break down organic substances in anaerobic environments. Direct N_2O emissions are produced by nitrification and denitrification processes that take place during storage of manure and of digestates. NO is produced through nitrification in surface layers of manure storage facilities. NMVOC emissions are released from silage fodder and from manure storage facilities.

Reporting on manure management also covers indirect N_2O emissions. These emissions can arise during decomposition processes in the soil from reactive nitrogen originating from the deposition of NH_3 and NO from manure and digestate management, as well as from nitrogen leaching and surface runoff from manure and digestate management. For water protection purposes, seeping/leaching and uncontrolled surface runoff from management of manure and digestates are to be prevented (Council of the European Union, 1991). For this reason, field storage of manure leads to only very slight quantities of indirect N_2O emissions from leaching/surface runoff.

The relevant emissions are calculated in relation to a range of factors, including animal category; animal excretions (which, in turn, are a function of animal performance and diet); the amounts of time spent by relevant animals in various defined areas (pastures, stables); the types of stables used; nitrogen inputs from bedding material (straw); and the type of manure storage involved.

Table 263 shows the changes over time in emissions from all manure management since 1990. In addition, for the initial and end years of the time series, it shows these emissions' shares of relevant total emissions from the German agricultural sector. With regard to the absolute emissions levels, cf. Chapters 5.3.2.2.3, 5.3.3.1.4 and 5.3.4.2.3. The emissions decrease seen since 1990 is due primarily to changes in livestock populations. In the case of CH_4 and N_2O, emission reductions through manure digestion also have an impact.

Table 263: Percentage changes of emissions from manure management (Index: MM) since 1990 and such emissions' percentage shares of total agricultural emissions of CH_4, N_2O, GHG and NMVOC (3.B)

[%]	Change since 1990	Share of total agricultural emissions (CH_4, N_2O, GHG, NMVOC)	
		1990	2024
$CH_{4,\,MM}$	-26.6	18.4	18.6
N_2O_{MM}, direct	-37.4	13.0	11.6
N_2O_{MM}, indirect	-34.6	5.1	4.8
$CH_{4,\,MM}$ + N_2O_{MM} (as GHG in CO_{2eq})	-30.1	17.5	17.0
$NMVOC_{MM}$	-30.3	98.2	97.1

5.3.2 Methane emissions from manure management (3.B, CH_4)

5.3.2.1 Category description (3.B, CH_4)

Cf. Chapter 5.3.1.

5.3.2.2 Methodological issues (3.B, CH_4)

5.3.2.2.1 Methodology (3.B, CH_4)

For all animal categories, CH_4 emissions are calculated in accordance with the Tier 2 method:

Equation 20: Calculation of total CH_4 emissions from manure management

$$E_{\mathrm{CH4,\,MM}} = \sum_{\mathrm{i},\ j} n_i \cdot EF_{\mathrm{i,\,j}} = \sum_{\mathrm{i},\ j} n_i \cdot \alpha \cdot \rho_{\mathrm{CH4}} \cdot VS_i \cdot B_{\mathrm{o,\,i}} \cdot MS_{\mathrm{i,\,j}} \cdot MCF_{\mathrm{i,\,j}}$$

where

- $E_{\mathrm{CH4,\,MM}}$ = Total methane emissions from manure management (in kg a-1 CH4)
- n_{i} = Number of animal places of animal category i (in places)
- $EF_{\mathrm{i,\,j}}$ = Methane emission factor for animal category i in manure management system j (in kg place-1 a-1 CH_4)
- A = Factor for conversion of time units (α = 365 d a^{-1})
- ρ_{CH4} = Density of methane (ρ_{CH4} = 0.67 kg m^{-3})
- VS_{i} = VS excretions for animal category i (in kg $place^{-1}$ d^{-1})
- $B_{\mathrm{o,\,i}}$ = Maximum methane-producing capacity for animal category i (in m^3 kg^{-1} CH_4)
- $MS_{\mathrm{i,\,j}}$ = Relative proportion of housing places, for animal category i, whose excrement occurs in manure management system j (in place $place^{-1}$)
- $MCF_{\mathrm{i,\,j}}$ = Methane conversion factor for manure management system j (in m^3 m^{-3})[76]

With regard to the number of animal places n_i, cf. Chapter 5.3.2.2.1. The VS excretions are described in Chapter 5.1.3.5. With regard to the relative percentages of systems for storage of solid manure, slurry and digestion residues, and to time allotted to grazing, cf. Chapters 5.1.3.6.1 and Annex 7.3.1. The methane-producing capacity B_o and the methane conversion factors *MCF* are discussed in Chapters 5.1.3.6.3 and 5.1.3.6.4. According to IPCC, manure digestion, including storage of manure digestates, is a separate storage type. The B_o and *MCF* values for this are covered in Chapter 5.1.3.6.5.

5.3.2.2.2 Emission factors (3.B, CH_4)

Table 264 shows the time series for the emission factors referenced to animal place. They have been calculated using Equation 20 in Chapter 5.3.2.2.1. The emission factors include the emissions reduction effects resulting from manure digestion.

Table 264: CH_4 emission factors for manure management, referenced to animal place (3.B(a))

[kg $place^{-1}$ a^{-1}]	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Dairy cows	14.2	19.1	21.0	22.1	21.1	21.5	22.0	22.3	23.0	23.9	23.9	23.5	23.5	24.7	24.9
Other cattle	7.3	7.5	7.7	7.4	6.8	7.0	7.1	7.2	7.4	7.5	7.5	7.5	7.5	7.6	7.6
Swine	4.1	4.4	4.6	4.2	3.7	3.6	3.7	3.7	3.8	3.8	3.8	3.9	3.7	3.9	3.9

[76] The IPCC gives MCF in percent (of Bo); in the German inventory, the units m3 m-3, which are clearer in their reference, are used.

[kg place^{-1} a^{-1}]	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Sheep	0.28	0.27	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
Goats	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Horses	3.1	3.1	3.1	3.1	3.1	3.6	3.7	3.8	3.8	3.9	4.0	4.0	4.0	4.0	4.0
Poultry	0.026	0.025	0.025	0.027	0.027	0.030	0.030	0.030	0.031	0.031	0.030	0.030	0.030	0.030	0.030
Deer	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Rabbits	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Ostriches	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Fur-bearing animals	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17

5.3.2.2.3 Emissions (CRF 3.B, CH_4)

Table 265 shows the total CH_4 emissions from manure management, in both absolute values and relative percentage values, referenced to 1990.

Table 265: CH_4 emissions from manure management (3.B(a))

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Gg	303.2	279.9	281.8	264.4	238.2	244.1	245.5	247.5	246.1	246.7	243.6	230.8	219.0	224.5	222.4
% of 1990	100.0	92.3	93.0	87.2	78.6	80.5	81.0	81.6	81.2	81.4	80.4	76.1	72.2	74.1	73.4

The progression over time is due largely to the development in the sizes of animal populations (cf. Chapter 5.1.3.2), with the effects of such trends modified by emissions-increasing performance growth (cf. Chapter 5.1.3.3). Table 266 shows the emissions contributions of dairy cows, other cattle and swine, along with these three animal categories' (taken together, as a group) high percentage shares of the total emissions for all animals.

Table 266: CH_4 from manure management (dairy cows, other cattle, swine) in [Gg], and percentage contributions to total CH_4 emissions from manure management

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Dairy cows	90.1	99.8	96.2	93.4	88.1	92.0	92.9	93.6	94.5	95.7	93.8	89.9	89.5	91.5	89.3
Other cattle	95.8	80.4	76.5	65.1	58.7	58.2	58.5	58.2	57.7	57.4	55.7	53.9	53.7	54.4	52.5
Swine	108.8	90.2	100.2	96.5	82.0	83.6	83.9	85.2	83.1	82.7	83.2	76.0	64.9	67.6	69.5
Total	**294.7**	**270.4**	**272.9**	**255.0**	**228.8**	**233.8**	**235.2**	**237.0**	**235.3**	**235.8**	**232.7**	**219.9**	**208.0**	**213.5**	**211.2**
% share	97.2	96.6	96.8	96.5	96.1	95.8	95.8	95.8	95.6	95.6	95.5	95.3	95.0	95.1	95.0

The CH_4 emissions reductions achieved through manure digestion are shown in Table 267. Without digestion, these saved emissions would have been emitted in addition to the quantities shown in Table 265. The percentage reductions refer to the emissions that would have occurred without digestion.

Table 267: Absolute and percentage changes in CH_4 emissions achieved as a result of manure digestion in comparison to a situation with no digestion and no storage of digestates (negative sign: emission reduction)

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Gg	-0.009	-0.12	-1.0	-7.5	-31.4	-51.7	-10.9	-52.2	-50.8	-49.6	-50.9	-52.6	-52.7	-46.6	-46.6
%	-0.003	-0.04	-0.4	-2.8	-11.7	-17.5	-4.1	-17.4	-17.1	-16.7	-17.3	-18.6	-19.4	-17.2	-17.3

5.3.2.3 Uncertainties and time series consistency (3.B, CH_4)

Table 250 in Chapter 5.1.6 shows the uncertainties in activity data and emission factors that have been used in estimating the total uncertainty of the German GHG inventory.

The uncertainties for the emission factors for CH_4 for manure management are default values taken from IPCC (2006b Vol 4, Table 10.48). With regard to the uncertainty for the activity data (numbers of animals), cf. Chapter 6.3 in Vos et al. (2026).

The emissions time series are consistent since they were calculated with the same method for every year covered by the report period, and since the input data are also consistent and complete.

5.3.2.4 Category-specific QA/QC and verification (3.B, CH_4)

With regard to quality control and quality assurance, we refer to Chapter 5.1.7.

In the framework of verification, and in an approach similar to that used in Chapter 5.2.4, the results and input data obtained for 2023 were compared with those for 2023 of neighbouring countries and of the UK (2025 submission for 2023, UNFCCC (2025)).

Table 268 shows, for dairy cows, the IEF for CH_4 from manure management, and a number of important influencing factors. In accordance with the CRT requirements, the percentage shares for slurry systems, and the corresponding MCF values, refer only to slurry systems whose slurry is not digested in biogas plants.

The spread in the IEF values of the countries compared is relatively wide. As with the German IEF, the median (24.2 kg place^{-1} a^{-1}) is slightly higher than the IPCC's default value range for the IEF. The daily VS excretions calculated for Germany lie at the lower end of the scale at 85% of the median for the countries being compared and are about the same as the values for Belgium and Switzerland. The German MCF for slurry systems is also 85% of the median for the countries being compared, while the degree of use of slurry systems in Germany is about 116% of the median.

Table 268: CH_4 emissions from storage of manure from dairy cows, in various countries – a comparison of Implied Emission Factors (IEFs) and important emissions-relevant parameters for the time series year 2023

	IEF_{CH4}	VS excretions	Slurry systems (without digestion)	
			Frequency	Mean MCF
	[kg place^{-1} a^{-1}]	[kg place^{-1} d^{-1}]	[%]	[%]
Austria	21.51	5.05	53.45	8.49
Belgium	31.39	4.36	59.23	21.00
Czech Republic	12.19	6.33	10.70	17.00
Denmark	64.01	7.49	48.48	NO

	IEF_{CH4}	VS excretions	Slurry systems (without digestion)	
France	23.73	6.43	15.51	17.83
Germany	**24.65**	**4.30**	**60.80**	**14.46**
Netherlands	37.51	4.75	82.52	17.00
Poland	8.77	5.04	12.19	17.00
Switzerland	19.47	4.26	51.15	13.77
United Kingdom	38.03	5.25	60.56	17.00
IPCC (2006b), Western Europe, cool region 10°C/11°C	21 to 23	5.1	35.7	17 to 19

Source: Germany: 2026 submission; other countries: UNFCCC (2025)

Table 269 shows, for other cattle, the IEF for CH_4 from manure management, and a number of important influencing factors. At 12%, the German IEF lies slightly above the median of the broadly dispersed values of the countries being considered. The primary reason for the large fluctuation range seen in the IEF values – apart from differences in VS excretions and MCF values – is that the frequency of use of liquid manure systems differs very widely. In this area, Germany lies in about the third quartile. At 76% of the median, German VS excretions are between those reported by Belgium and the Netherlands.

As Table 270 indicates, Germany's IEF for CH_4 from manure management also lies in the middle of the range in the case of swine. VS excretions are around 116% of the median.

Table 269: CH_4 emissions from storage of manure from other cattle, in various countries – a comparison of Implied Emission Factors (IEFs) and important emissions-relevant parameters for the time series year 2023

	IEF_{CH4}	VS excretions	Slurry systems (without digestion)	
			Frequency	Mean MCF
	[kg place^{-1} a^{-1}]	[kg place^{-1} d^{-1}]	[%]	[%]
Austria	9.34	2.43	29.63	8.04
Belgium	6.89	1.74	15.77	21.00
Czech Republic	3.64	3.33	6.80	17.00
Denmark	27.07	2.67	40.71	NO
France	4.64	1.91	2.55	18.86
Germany	**7.64**	**1.46**	**30.97**	**14.67**
Netherlands [a]	7.84	1.18	67.52	17.00
Poland	1.70	1.81	6.19	17.00
Switzerland [a]	4.53	1.97	30.26	13.77
UK [b]	6.77	1.94	NO	NO
IPCC (2006b): Vol. 4, 10.38, 10.77, Western Europe, cool region 10°C/11°C	6 to 7	2.6	25.2	17 to 19

Source: Germany: 2026 submission; other countries: UNFCCC (2025)

[a] Calculated from CRF data

[b] UK: Cattle, not including dairy cows, and not including dairy replacements (with calves)

Table 270: CH_4 emissions from storage of manure from swine, in various countries – a comparison of Implied Emission Factors (IEFs) and important emissions-relevant parameters for the year 2023

	IEF_{CH4}	VS excretions	Slurry systems (without digestion)	
			Frequency	Mean MCF
	[kg place^{-1} a^{-1}]	[kg place^{-1} d^{-1}]	[%]	[kg place^{-1} a^{-1} CH_4]
Austria	1.78	0.32	67.04	3.39
Belgium	3.36	0.21	97.52	21.00
Czech Republic	1.76	0.31	17.90	17.00
Denmark	4.83	0.08	87.86	10.14
France	6.60	0.19	87.86	21.28
Germany	**3.86**	**0.30**	**70.89**	**22.71**
Netherlands	5.21	0.22	38.17	36.00
Poland	2.29	NA	NA	NA
Switzerland	3.89	0.31	78.39	13.77
United Kingdom	3.99	n/a	n/a	n/a
IPCC (2006b Vol 4, 10.80, 10.81), Western Europe, cool region 10°C/11°C	Sows, boars: 9 to 10 Other: 6	Sows, boars: 0.46 Other: 0.30		17 to 19

Source: Germany: 2026 submission; other countries: UNFCCC (2023c)

Table 271 shows, for poultry, the average IEF, the average VS excretions and the average animal weight, the last of which serves as an indicator of energy requirements and, thus, feed intake and excretions. Aside from the comparatively very high value of the Czech Republic, the IEF displays a range of 0.017 to 0.030 kg place^{-1} a^{-1}. The highest IEF in this category is reported by Germany. The reason for this is that Germany's VS excretions value is higher than those of other countries (at least of those eight countries that report VS excretions). While the German VS excretions figure marks the upper bound of the scale, Germany is part of a group, along with the UK, France, Belgium and the Netherlands, that have VS excretions figures that are a factor of around 2 higher than the lower bound of the IPCC default range. Average poultry weights are reported only by Austria, Belgium, the Czech Republic, Denmark and Germany. These values are all of a comparable magnitude. Germany's average poultry weight lies in the middle of the reported values.

Table 271: CH_4 emissions from storage of manure from poultry, in various countries – a comparison of Implied Emission Factors (IEFs) and important emissions-relevant parameters for the time series year 2023

	IEF_{CH4}	VS excretions	Mean animal weight
	[kg place^{-1} a^{-1}]	[kg place^{-1} d^{-1}]	[kg animal^{-1}]
Austria	0.020	0.015	1.62
Belgium	0.024	0.018	1.38
Czech Republic	0.097	NA	1.44
Denmark	0.025	0.003	2.00
France	0.023	0.018	NE
Germany	**0.030**	**0.022**	**1.60**

	IEF_{CH4}	VS excretions	Mean animal weight
Netherlands	0.033	0.020	NA
Poland	0.027	NA	NA
Switzerland	0.017	0.013	NA
United Kingdom	0.018	0.019	NE
IPCC (2006b Vol4, 10.82), W-Europe, cool region, developed countries	0.02 to 0.09 [a]	0.01 to 0.07 [a]	0.9 to 6.8 [a]

Source: Germany: 2026 submission; other countries: UNFCCC (2025)

[a] Low value: Laying hens; high value: Turkeys

5.3.2.5 Category-specific recalculations (3.B, CH_4)

Table 272 to Table 274 show, for dairy cows, other cattle, swine and poultry, a comparison of figures for VS excretions, emission factors and emissions as reported in the current submission and the previous year's submission.

Slight differences between the two submissions are apparent in the area of VS excretions of dairy cows and swine, for all years. These differences are essentially a consequence of the higher milk yield of dairy cows and, for pigs, a consequence of dividing swine into gilts and old sows who have had at least one litter; cf. Chapter 5.1.7.3. Differences in all animal categories are apparent in the emission factors and emissions. These differences are largely attributable to the introduction of transport of biogas substrates; cf. Chapter 5.1.7.3.

Table 272: Comparison of the VS emissions as reported in the 2025 and 2026 submissions (3.B(a)), in [kg place^{-1} d^{-1}]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023
Dairy cows, 2026	3.02	3.33	3.54	3.70	3.82	3.96	4.00	4.00	4.08	4.15	4.21	4.22	4.19	4.30
Dairy cows, 2025	2.96	3.26	3.47	3.63	3.75	3.90	3.93	3.94	4.01	4.08	4.14	4.15	4.13	4.21
Other cattle, 2026	1.27	1.33	1.38	1.37	1.39	1.40	1.40	1.40	1.41	1.42	1.44	1.45	1.45	1.46
Other cattle, 2025	1.27	1.33	1.38	1.37	1.39	1.40	1.40	1.40	1.41	1.42	1.44	1.45	1.45	1.46
Swine, 2026	0.265	0.280	0.289	0.281	0.274	0.285	0.287	0.289	0.291	0.292	0.294	0.298	0.297	0.299
Swine, 2025	0.271	0.286	0.295	0.286	0.280	0.290	0.292	0.294	0.297	0.297	0.299	0.303	0.302	0.304
Poultry, 2026	0.0188	0.0180	0.0186	0.0196	0.0197	0.0224	0.0225	0.0226	0.0227	0.0227	0.0224	0.0222	0.0220	0.0220
Poultry, 2025	0.0188	0.0180	0.0186	0.0196	0.0197	0.0224	0.0225	0.0226	0.0227	0.0227	0.0224	0.0222	0.0220	0.0220

Table 273: Comparison of the animal place-based CH_4 emission factors, as reported in the 2025 and 2026 submissions, for manure management (3.B(a)), in [kg place^{-1} a^{-1}]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023
Dairy cows, 2026	14.17	19.09	21.04	22.05	21.07	21.47	22.02	22.29	23.04	23.86	23.93	23.46	23.50	24.65
Dairy cows, 2025	13.88	18.69	20.61	21.65	20.90	21.47	21.99	22.20	22.92	23.76	24.00	23.75	23.74	24.23
Other cattle, 2026	7.30	7.54	7.68	7.40	6.81	6.97	7.09	7.20	7.35	7.53	7.54	7.48	7.47	7.64
Other cattle, 2025	7.30	7.54	7.68	7.43	6.98	7.23	7.33	7.43	7.58	7.75	7.79	7.78	7.74	7.76
Swine, 2026	4.104	4.424	4.603	4.242	3.685	3.637	3.685	3.719	3.775	3.823	3.846	3.854	3.666	3.856
Swine, 2025	4.169	4.503	4.689	4.356	3.891	3.946	3.993	4.035	4.086	4.131	4.156	4.202	4.063	4.096

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023
Poultry, 2026	0.0261	0.0248	0.0254	0.0267	0.0265	0.0295	0.0296	0.0298	0.0309	0.0308	0.0305	0.0301	0.0299	0.0298
Poultry, 2025	0.0261	0.0248	0.0254	0.0267	0.0265	0.0295	0.0297	0.0299	0.0300	0.0299	0.0295	0.0292	0.0287	0.0287

Table 274: Comparison of the CH_4 emissions, as reported in the 2025 and 2026 submissions, for manure management (3.B(a)), in [kt a^{-1}]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023
All animals, 2026	303.16	279.90	281.81	264.36	238.18	244.11	245.49	247.46	246.06	246.68	243.60	230.81	218.98	224.55
All animals, 2025	303.01	279.42	281.75	265.50	243.54	252.85	253.81	255.47	253.21	253.39	251.19	239.69	227.57	226.65
Dairy cows, 2026	90.05	99.83	96.15	93.43	88.14	92.01	92.85	93.60	94.47	95.70	93.83	89.92	89.51	91.54
Dairy cows, 2025	88.17	97.73	94.20	91.71	87.44	92.01	92.74	93.21	94.00	95.32	94.13	91.04	90.44	89.96
Other cattle, 2026	95.85	80.35	76.53	65.10	58.73	58.24	58.47	58.17	57.71	57.42	55.65	53.92	53.65	54.42
Other cattle, 2025	95.85	80.35	76.56	65.36	60.22	60.41	60.50	60.05	59.49	59.13	57.52	56.10	55.65	55.25
Swine, 2026	108.76	90.18	100.20	96.47	81.97	83.58	83.88	85.24	83.12	82.67	83.17	76.03	64.86	67.57
Swine, 2025	110.49	91.81	102.06	99.06	86.55	90.68	90.90	92.49	89.97	89.21	89.86	82.89	71.88	71.78
Poultry, 2026	2.97	2.97	3.54	3.97	4.50	5.17	5.16	5.18	5.19	5.17	5.11	4.99	4.85	
Poultry, 2025	3.56	3.49	4.08	4.47	5.01	5.81	5.82	5.85	5.88	5.88	5.83	5.85	5.90	

5.3.2.6 Planned improvements (3.B, CH_4)

No further improvements are planned at present.

Where previous reports have listed improvements in this chapter, those improvements are presented as an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

5.3.3 NMVOC emissions from manure management

5.3.3.1 Category description (NMVOC)

Cf. Chapter 5.3.1.

5.3.3.1.1 Methodological issues (NMVOC)

5.3.3.1.2 Methods (NMVOC)

IPCC (2006b) does not provide any method for calculating NMVOC emissions from manure management. EMEP/EEA (2023) provides methods and the relevant parameters. Germany calculates NMVOC emissions separately for each animal category. In the process, it uses the Tier 2 method for dairy cows and other cattle, and the Tier 1 method for other animals. With the simple Tier 1 method, the number of animals in each case is multiplied by an emission factor that is referenced to animal place. The Tier 2 method calculates animal-specific NMVOC emissions as the sum of emissions a) from silage storage, b) from feeding with silage, c) in housing, d) from manure management, e) from manure application and f) from grazing. To determine how these subfractions of emissions relate to one another, the method relies on ratios between corresponding fractions of NH_3 emissions. In the German Py-GAS-EM inventory model and for purposes of reporting under the CLRTAP (UNECE, 1979), these NH_3 emissions are calculated in a manner consistent with the way greenhouse gas emissions are calculated.

For further details on the NMVOC emissions calculations, cf. Chapter 4.3.3 in Vos et al. (2026). With regard to the equation set used in the Tier 2 method, we refer to EMEP (2023).

5.3.3.1.3 Emission factors (NMVOC)

For the Tier 1 method, different emission factors for feeding with and without silage are provided. For horses, the German inventory applies the relevant emission factors for feeding with silage; for other animals, for which a Tier 1 calculation is carried out, it uses the factors for feeding without silage. Table 275 presents a list of the emission factors used in the inventory. Due to missing emission factors or factors that did not correspond to the inventory animal categories, the following was specified for weaners, boars, sheep, horses and pullets, cf. Chapter 4.3.3.1 in Vos et al. (2026):

In a conservative approach, the emission factor for sows is used for boars, and the factor for fattening pigs is used for weaners.

The emission factor for sheep listed in EMEP (2023) has been interpreted as applying to mature sheep. The emission factor for lambs is set at 40% of the emission factor for mature sheep.

The emission factor for horses listed in EMEP (2023) has been interpreted as applying to heavy horses. For light horses and ponies, the emission factor given in EMEP (2023) for mules and asses has been used.

Due to the similarity in the applicable housing systems, the emission factor for broilers has been used for pullets.

Since EMEP (2023) gives no emission factor for ostriches, the emission factor for other poultry has been used.

Table 275: NMVOC: Tier 1 emission factors pursuant to EMEP (2023) used in the inventory, in [kg place^{-1} a^{-1}]

	Tier 1 EF_{NMVOC}
Sows, boars	1.704
Fattening pigs, weaners	0.551
Mature sheep	0.169
Lambs	0.068
Goats	0.542
Heavy horses	7.781
Light horses and ponies	3.018
Laying hens	0.165
Broilers, pullets	0.108
Geese, ducks and turkeys	0.489
Deer	0.045
Rabbits	0.059
Ostriches	0.489
Fur-bearing animals	1.941

Table 276 shows, for selected years, the calculated Tier 2 implied emission factors (IEFs) for dairy cows and other cattle.

Table 276: NMVOC: Tier 2 emission factors (IEFs) calculated in the inventory, in [kg place^{-1} a^{-1}]

	1990	2005	2024
Dairy cows	32.91	39.73	45.58
Other cattle	12.40	12.25	11.90

The increasing trend in the IEF for dairy cows since 1990 results directly from performance increases. In the calculation, it is taken into account through GE intake. The temporal development of the IEF for other cattle reflects the impacts of performance growth in fattening animals and the temporal variance in the composition of the population since the IEFs for the various subcategories of other cattle differ from one another.

5.3.3.1.4 Emissions (NMVOC)

Table 277 lists the NMVOC emissions from manure management that are to be reported under CR Table 3.

Table 277: NMVOC emissions from manure management, in [Gg]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Total	418.6	362.0	346.8	325.4	324.2	325.3	322.0	318.6	314.2	311.1	307.0	300.6	296.1	296.7	291.7
in % of 1990	100.0	86.5	82.8	77.7	77.4	77.7	76.9	76.1	75.0	74.3	73.3	71.8	70.7	70.9	69.7
Dairy cows	209.2	185.3	175.9	168.3	168.5	175.2	174.3	173.1	172.2	171.8	170.2	166.9	164.5	166.0	163.6
Other cattle	162.9	131.1	123.7	107.8	105.3	98.8	97.0	94.8	91.9	89.5	87.0	85.5	85.2	84.6	81.8
Swine	18.4	14.2	15.0	15.5	14.9	15.0	14.8	14.9	14.3	14.0	13.9	12.7	11.4	11.3	11.4
Sheep	0.4	0.4	0.4	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Goats	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Horses	8.9	11.3	9.2	9.3	8.4	8.2	8.1	8.1	8.2	8.3	8.3	8.5	8.7	8.9	9.1
Poultry	18.3	19.2	22.1	23.6	26.3	27.7	27.4	27.3	27.3	27.2	27.2	26.6	26.0	25.4	25.5
Deer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rabbits	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ostriches	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fur-bearing animals	0.3	0.3	0.3	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

As Table 278 shows, cattle husbandry is responsible for the vast majority of the emissions. The reduction in NMVOC emissions seen since 1990, therefore, is due almost exclusively to decreases in numbers of cattle (R^2 = 98.9%). The relative emissions contribution from poultry husbandry has increased sharply, with respect to 1990, as a result of increases in numbers of poultry. At the end of the time series, that contribution is considerably greater than the total contribution from other animals.

Table 278: Percentage contributions to NMVOC emissions from manure management

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Cattle	88.9	87.4	86.4	84.9	84.5	84.2	84.3	84.1	84.0	84.0	83.8	84.0	84.3	84.5	84.1
Poultry	4.4	5.3	6.4	7.3	8.1	8.5	8.5	8.6	8.7	8.7	8.8	8.8	8.8	8.6	8.7
Other animals	6.8	7.3	7.2	7.9	7.4	7.3	7.2	7.3	7.3	7.3	7.4	7.2	6.9	6.9	7.1

5.3.3.2 Uncertainties and time series consistency (NMVOC)

EMEP (2023) highlights the very large uncertainty of the emission factors, but does not provide any quantitative information. The German inventory assumes a 95% confidence interval of [-79%, +200%]; cf. in this regard Chapter 6.7 in Vos et al. (2026). With regard to the uncertainty for the activity data (numbers of animals), cf. Chapter 6.3 in Vos et al. (2026).

The emissions time series are consistent since they were calculated with the same method for every year covered by the report period, and since the input data are also consistent and complete.

5.3.3.3 Category-specific QA/QC and verification (NMVOC)

With regard to quality control and quality assurance, we refer to Chapter 5.1.7.

5.3.3.4 Category-specific recalculations (NMVOC)

Table 279 shows the different emissions data reported in the 2026 and 2025 submissions. The different emission factors are not included since the emissions are directly proportional to the emission factors. The differences concerning cattle are mainly due to changes in the underlying NH_3 emissions, which in dairy cows are mainly due to higher milk production and otherwise due to manure transport effects (cf. Chapter 5.1.7.3).

Table 279: Comparison of NMVOC emissions between the 2025 and 2026 submissions for dairy cows, other cattle and poultry, in [Gg]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023
Dairy cows, 2026	209.2	185.3	175.9	168.3	168.5	175.2	174.3	173.1	172.2	171.8	170.2	166.9	164.5	166.0
Dairy cows, 2025	205.8	180.7	171.4	163.9	164.4	172.0	170.8	169.6	168.8	168.3	166.6	163.3	161.3	161.2
Other cattle, 2026	162.9	131.1	123.7	107.8	105.3	98.8	97.0	94.8	91.9	89.5	87.0	85.5	85.2	84.6
Other cattle, 2025	162.8	131.1	123.7	107.8	105.6	99.4	97.5	95.2	92.3	89.9	87.4	85.9	85.5	84.9
Poultry, 2026	18.3	19.2	22.1	23.8	26.3	27.7	27.4	27.3	27.3	27.2	27.2	26.6	26.0	25.4
Poultry, 2025	18.3	19.2	22.1	23.8	26.3	27.7	27.4	27.3	27.3	27.2	27.2	26.6	26.0	25.4

5.3.3.5 Planned improvements (NMVOC)

No further improvements are planned at present.

Where previous reports have listed improvements in this chapter, those improvements are presented as an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

5.3.4 Direct N_2O and NO emissions from manure management (3.B, N_2O & NO)

5.3.4.1 Category description (3.B, N_2O_{direct} & NO)

Cf. Chapter 5.3.1.

5.3.4.2 Methodological issues (3.B, N_2O_{direct} & NO)

5.3.4.2.1 Method (3.B, N_2O_{direct} & NO)

The calculation of N_2O emissions from manure management is carried out separately for each animal category, taking into account the specific management systems in place (including manure digestion, cf. Chapter 5.1.3.6.5) and following a Tier 2 method:

Equation 21: Calculation of total N_2O emissions from manure management

$$E_{\text{N2O-N}} = \sum_{\text{i,j}} [(N_{\text{excr, } i} + N_{\text{straw, i, } j}) \cdot MS_{\text{i, } j}] \cdot EF_{\text{N2O-N, } j}$$

where:

- $E_{\text{N2O-N}}$ = Total N_2O-N emissions from manure management (kg a^{-1} N_2O-N)
- $N_{\text{excr, i}}$ = Total N excretions of animal category i (kg a^{-1} N)
- $N_{\text{straw, i, j}}$ = N input through bedding material for animal category i and manure management system j (kg a^{-1} N)
- $MS_{\text{i, j}}$ = Relative share of manure management system j of animal category i (place $place^{-1}$)
- $EF_{\text{N2O-N, j}}$ = N_2O-N emission factor for manure management system (kg kg^{-1} N_2O-N)

With regard to total N excretions and total N inputs through bedding material, cf. Chapters 5.1.3.4 and 5.1.3.6.2. With regard to the relative frequencies of manure management systems, cf. Chapters 5.1.3.6.1 and Annex 7.3.1.

NO emissions from manure management are calculated using a method similar to that used to calculate N_2O emissions.

N_2O and NO emissions from manure application and grazing are reported under 3.D.

5.3.4.2.2 Emission factors (3.B, N_2O_{direct} & NO)

For slurry storage, the default emission factors in IPCC (2019) are used. For this reason, since the 2025 submission, the same emission factor 0.005 kg N_2O-N (kg N)$^{-1}$has been used for all existing storage covers.

Manure management systems for solid manure are broken down into the categories tied systems/stables allowing free movement (with storage in heaps) and deep bedding (without storage in heaps). With regard to deep bedding, German agricultural techniques do not include active mixing of the bedding (expert judgement, Brigitte Eurich-Menden et al.; cf. Chapter 4.4.2 in Vos et al. (2026)). For deep bedding, therefore, the IPCC (2019) default value of 0.010 kg N_2O-N (kg N)$^{-1}$ is used. For storage of solid manure from tied systems/stables allowing free movement, and for storage of poultry manure, the respective IPCC (2019) default values of 0.010 and 0.001 kg N_2O-N (kg N)$^{-1}$ are used.

IPCC (2019) treats manure digestion, including storage of digestates, as a separate type of storage, one that produces no N_2O emissions (EF = 0 kg kg^{-1}). This IPCC default approach does

not take account of the fact that open systems for storage of digestates emit N_2O. The German inventory thus calculates N_2O emissions from manure digestion, broken down by different types of manure and digestates storage; cf. Chapter 5.1.3.6.5.

Table 280 shows the N_2O-N emission factors used.

Table 280: Emission factors for emissions of N_2O-N from manure management, not including digestion (in relation to total excreted N and straw bedding N) (3.B(b)), in [kg kg^{-1}]

Manure		Emission factor
Slurry	Open tank, without natural crust	0.000
	Solid cover	0.005
	Natural crust	0.005
	Floating cover (chaff)	0.005
	Floating cover (plastic film)	0.005
	Below slatted floor	0.002
Leachate [a]	Solid cover	0.005
Solid manure		0.010
Deep bedding		0.010
Poultry manure with or without litter		0.001

Source: IPCC (2019)

[a] Assumption: Comparable to solid-covered storage of slurry

IPCC (2019) does not give any emission factors for NO. The Tier 1 emission factors given in EMEP (2023) refer to animal places. They cannot be used in the Py-GAS-EM inventory model, since Py-GAS-EM, in the context of the N-flow concept (cf. Chapter 5.1.2.4), requires emission factors that refer to emissions-relevant N quantities. Comparative calculations have shown, however, that the German total NO emissions from Sector 3.B, as calculated with the Tier 1 emission factors, can be reproduced with the Py-GAS-EM N-flow concept if the NO-N emission factor oriented to N is smaller than the N_2O-N emission factor by an order of magnitude. For this reason, in the inventory, the NO-N emission factor has been set at a level of 10% of the N_2O-N emission factor. This approach yields NO emissions that are directly proportional to the relevant N_2O emissions.

Neither IPCC nor EMEP gives emission factors for N_2 (which must also be taken into account in the N-flow concept; cf. Chapter 5.1.2.4). Jarvis and Pain (1994) obtained 3:1 as the ratio of N_2 emissions to N_2O-N emissions. Therefore, for purposes of the inventory, it has been assumed that the N_2 emission factor is three times larger than the N_2O-N emission factor.

Table 281 shows the time series for the average N_2O-N emission factors for the four overarching categories of manure management systems of relevance for reporting. These categories are slurry-based (without digestion), straw-based (without deep bedding and without digestion), deep bedding (without digestion) and digestion (of manure). In the interest of clarity, we have used the unit g kg^{-1} instead of kg kg^{-1} (cf. Table 280), the unit typically used for emission factors. These emission factors are defined as the ratio of total N_2O-N emissions from a management system to the sum of animal N excretions in the same management system. Under this perspective, the total N_2O emissions of categories with bedding also include emissions fractions tied to bedding N. For this reason, the resulting emission factor for deep bedding that is listed in Table 281 is higher than the factor given in Table 280. The same is generally true for straw-

based systems without deep bedding and without digestion, although the effect is not perceived, because the relevant values in Table 281 also include the considerably lower emission factor for poultry (cf. Table 280). The N_2O-N emission factors for straw-based systems and systems with digestion show, throughout the entire time series, a pronounced negative trend. For straw-based systems, this results from decreases in N_2O contributions from solid manure systems in cattle and swine husbandry. Those decreases, in turn, result from changes in numbers of animals in the various housing systems. For digestion systems, the negative trend in the emission factors is due primarily to increasing use of gas-tight storage of digestates (cf. Chapter 5.1.3.6.5)

Table 281: Average N_2O-N emission factors, by manure management systems (3.B(b)), in [g/kg]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Slurry-based [a]	3.16	3.58	3.56	3.63	3.68	3.58	3.57	3.55	3.53	3.52	3.51	3.51	3.53	3.52	3.52
Straw-based [a]	8.88	8.75	8.34	8.20	8.15	8.02	7.95	7.89	7.81	7.75	7.80	7.81	7.99	8.00	7.97
Deep bedding [a]	10.90	11.18	11.05	10.94	10.58	10.55	10.59	10.63	10.68	10.74	10.74	10.74	10.75	10.74	10.73
Digestion	5.02	4.82	4.62	4.33	3.02	1.96	1.90	1.83	1.58	1.41	1.26	1.11	1.09	0.95	0.95

[a] Without digestion

[b] Without deep bedding and without digestion

5.3.4.2.3 Emissions (3.B, N_2O_{direct} & NO)

Table 282 shows the direct total N_2O emissions from manure management (including storage of digested manure) and breaks them down by system categories. The sharp emissions decrease in the first half of the 1990s is due primarily to reductions of livestock populations following German reunification. Additional influencing factors include shifts over time in the distributions of management systems (cf. Chapters 5.1.3.6.1 and Annex 7.3.1), and gradually increasing emissions reductions achieved through manure digestion (cf. Chapter 5.1.3.6.5).

Table 282: Direct N_2O emissions from manure management (MM), total and by system categories (3.B(b)), in [Gg]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Total	12.14	10.57	9.98	9.86	9.55	9.04	8.93	8.87	8.61	8.42	8.18	7.81	7.64	7.69	7.59
in % of 1990	100.0	87.1	82.3	81.3	78.7	74.5	73.6	73.1	70.9	69.4	67.4	64.4	62.9	63.3	62.6
Slurry-based [a]	4.54	4.88	4.68	4.33	3.64	3.35	3.35	3.35	3.29	3.26	3.14	2.90	2.77	2.86	2.82
Straw-based [a]	6.76	4.81	4.34	4.22	4.08	3.48	3.33	3.22	3.08	2.95	2.92	2.89	2.88	2.92	2.92
Deep bedding [a]	0.83	0.88	0.93	1.06	1.14	1.49	1.56	1.62	1.67	1.73	1.68	1.62	1.60	1.60	1.55
Digestion	0.00	0.00	0.04	0.25	0.69	0.72	0.70	0.68	0.56	0.49	0.44	0.40	0.39	0.31	0.30

[a] Without digestion

[b] Without deep bedding and without digestion

Table 283 shows the absolute and percentage reductions in N_2O emissions achieved through manure digestion compared to a situation with no digestion and storage of digestion residues. Positive values denote an emissions increase. The primary reason for the increase is that storage of digestates, if it is not gas-tight, generates higher N_2O emissions than conventional storage of manure. Furthermore, storage of digested poultry manure generally produces higher N_2O emissions than storage of undigested poultry manure. The fraction of storage systems with gas-tight storage has increased significantly over the years (cf. Chapter 5.1.3.6.5). It was not until

2006/2007 that the share of gas-tight storage, which had been increasing over the years, led to savings in N_2O emissions.

Table 283: Absolute and percentage changes in direct N_2O emissions as a result of manure digestion, in comparison to a situation with no digestion and storage of digestates (negative values: emission reduction)

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Gg	0.0001	0.0009	0.006	0.04	-0.17	-0.60	-0.61	-0.65	-0.71	-0.74	-0.81	-0.90	-0.89	-0.83	-0.83
[%]	0.001	0.009	0.00	0.0	-1.8	-6.3	-6.4	-6.8	-7.7	-8.1	-9.0	-10.3	-10.4	-9.7	-9.8

Table 284 shows the total NO emissions in category 3.B. Because the NO and N_2O emission factors are proportional to each other, the trends for NO are identical to those for N_2O.

Table 284: NO emissions from manure management, in [Gg]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Total	1.655	1.442	1.361	1.345	1.302	1.233	1.218	1.209	1.174	1.149	1.115	1.065	1.041	1.048	1.035

5.3.4.3 Uncertainties and time series consistency (3.B, N_2O_{direct} & NO)

Table 250 in Chapter 5.1.6 shows the uncertainties in activity data and emission factors that have been used in estimating the total uncertainty of the German GHG inventory.

The estimate of the uncertainty of the N_2O emission factors (95% confidence interval) is based on the default values in IPCC (2006b Vol 4, Table 10.21). See also in this regard Chapters 4.2.2.4 and 14.4.1 in Vos et al. (2026). With regard to the uncertainty for the activity data (numbers of animals), cf. Chapter 6.3 in Vos et al. (2026).

Due to a lack of data on the uncertainty of the NO emission factor, the uncertainty of the N_2O emission factor is used as that uncertainty.

The emissions time series are consistent since they were calculated with the same method for every year covered by the report period, and since the input data are also consistent and complete.

5.3.4.4 Category-specific QA/QC and verification (3.B, N_2O_{direct} & NO)

With regard to quality control and quality assurance, we refer to Chapter 5.1.7.

In the framework of verification and in an approach similar to that used in Chapter 5.2.4, the 2023 N excretions and N_2O emissions figures for manure management in Germany were compared with the corresponding figures of neighbouring countries including the UK; cf. Table 285 and Table 286.

Germany's value for N excretions of dairy cows is about 1% higher than the median, and in plausible proximity to the values of other countries. The German value for N excretions of other cattle is about 7% below the median. The German N excretions value for swine is the highest. These results bring up the question of how to define the average value for the entire swine population. Germany calculates the average value in conformance with the rules for an AAP place that is occupied 365 days of the year – cf. Chapter 1.1.2.2 in Vos et al. (2026). The lower N excretions values given by the other countries may be due in part to non-AAP-consistent inclusion of vacancy periods.

In the case of poultry, Germany also has the highest average N excretions figure. A lack of data on the compositions of the total populations in the various countries hampers direct comparisons, since the various types of poultry have widely differing excretion levels (cf. the range pursuant to EMEP (2023)).

Table 285: N excretions per animal place, for dairy cows, other cattle, swine and poultry of various countries, for the time series year 2023

	Dairy cows	Other cattle	Swine	Poultry
	[kg place^{-1} a^{-1}]	[kg place^{-1} a^{-1}]	[kg place^{-1} a^{-1}]	[kg place^{-1} a^{-1}]
Austria	107.04	51.76	10.95	0.42
Belgium	115.35	50.42	7.17	0.49
Czech Republic	119.30	59.22	10.76	0.50
Denmark	155.32	40.78	6.62	0.46
France	116.76	59.96	9.68	0.46
Germany	**118.58**	**44.19**	**12.19**	**0.66**
Netherlands [a]	77.20	37.86	7.59	0.60
Poland	122.42	51.60	11.15	0.61
Switzerland [a]	111.38	39.83	9.12	0.47
UK [b]	117.55	43.81	n/a	0.48
IPCC (2006b Vol 4, 10.59, 10.72, 10.78, 10.80-10.82):	105.1[c]	50.6[c]	9.3/30.4[c,d]	0.53[c, e]
EMEP/EEA (2023-3B-31)	105	41	12.1/34.5[d]	0.36 to 1.64

Source: Germany: 2026 submission; other countries: UNFCCC (2025)

[a] Netherlands and Switzerland, other cattle: Calculated from CRT data

[b] UK: Cattle data differentiate between dairy cows (dairy cows and dairy replacements, including calves selected to be dairy cows) and the remaining other cattle

c IPCC weights: Calculated pursuant to IPCC (2006b Vol 4), with the IPCC's standard values for weight and N excretions and, in the case of poultry, with the German animal counts in the various poultry subcategories (2022 submission)

d IPCC (2006b Vol 4) Sows and boars: 30.4, other: 9.3; EMEP/EEA (2023): Sows: 34.5, fattening pigs: 12.1

e Poultry: Assumptions for missing values: Weight of geese = 1/2 standard weight of turkeys IPCC (2006b Vol 4); N excretions of geese = standard N excretions of turkeys (IPCC (2006b Vol 4)); weight of pullets = 1/2 standard weight of laying hens IPCC (2006b Vol 4); N excretions of pullets = standard N excretions of laying hens IPCC (2006b Vol 4)

Table 286 shows a comparison of the IEFs for direct N_2O emissions from manure management for dairy cows, other cattle, swine and poultry. The data sets reported by the various countries all exhibit very wide ranges. The fluctuation ranges cannot be explained on the basis of the available data. Germany's value for dairy cows is almost exactly the median, while its value for other cattle is 13% above the median. With regard to swine, Germany's value is about 23% above the median; for poultry it is 6% above the median. The Czech Republic and the UK have IEFs that are a factor of 3 higher.

Table 286: N_2O emissions from manure management for dairy cows, other cattle, pigs and poultry – a comparison of Implied Emission Factors (IEF) in various countries for the time series year 2023

	Dairy cows	Other cattle	Swine	Poultry
	[kg place^{-1} a^{-1}]	[kg place^{-1} a^{-1}]	[kg place^{-1} a^{-1}]	[kg place^{-1} a^{-1}]
Austria	0.663	0.460	0.096	0.0006
Belgium	0.405	0.265	0.024	0.0008
Czech Republic	0.633	0.322	0.043	0.0037
Denmark	0.860	0.398	0.050	0.0007
France	0.680	0.295	0.010	0.0007
Germany	**0.670**	**0.373**	**0.057**	**0.0009**
Netherlands [a]	0.395	0.209	0.026	0.0009
Poland	0.877	0.339	0.084	0.0010
Switzerland [a]	0.309	0.125	0.022	0.0007
UK [b]	0.735	0.558	0.163	0.0038

Source: Germany: 2026 submission; other countries: UNFCCC (2025)

[a] Netherlands and Switzerland, other cattle: Calculated from CRT data

[b] UK: Cattle data differentiate between dairy cows (dairy cows and dairy replacements, including calves selected to be dairy cows) and the remaining other cattle

5.3.4.5 Category-specific recalculations (3.B, N_2O_{direct} & NO)

Table 287 shows the direct N_2O emissions from manure management in comparison to the corresponding results in the 2025 submission. The underlying N excretions data are shown in Table 288.

The N excretions are higher throughout in the 2026 submission until the year 2019. This is mainly due to the recalculation of N excretions for dairy cows and their higher milk yield. From 2020 onward, the effect of the higher milk yield is more than offset by the effect of the recalculated N excretions, resulting in lower overall N excretions. Other notable changes to N excretions occurred with sows (reduced N excretions due to the separation into gilts and old sows who have had at least one litter) and horses (increased N excretions from 2011 onwards because of altered feeding), cf. Chapter 5.1.7.3. However, the overall effect of these changes is still far outweighed by the changes observed in dairy cows. Direct N_2O emissions increase and decrease proportionally in a similar way to N excretions.

Table 287: Comparison of the total N_2O emissions, as reported in the 2025 and 2026 submissions, from manure management, in [Gg]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023
2026	12.136	10.573	9.983	9.860	9.551	9.043	8.929	8.869	8.609	8.425	8.176	7.812	7.636	7.688
2025	11.492	10.132	9.674	9.631	9.471	8.982	8.839	8.715	8.527	8.370	8.209	7.929	7.743	7.754

Table 288: Comparison of total N excretions as calculated in the 2025 and 2026 submissions (cf. Chapter 5.1.3.4), in [Gg]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023
2026	1688.2	1460.9	1398.0	1340.5	1309.8	1339.9	1330.7	1332.8	1308.7	1290.1	1262.7	1216.9	1182.9	1180.1
2025	1603.0	1398.1	1354.8	1309.3	1298.8	1330.3	1318.6	1310.6	1288.6	1276.2	1263.5	1230.0	1194.9	1195.2

The NO emissions, because they are directly proportional to N_2O emissions (cf. Chapter 5.3.4.2.2), have changed in the same manner that the N_2O emissions have changed; cf. Table 289.

Table 289: Comparison of the total NO emissions, as reported in the 2025 and 2026 submissions, from manure management, in [Gg]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023
2026	1.655	1.442	1.361	1.345	1.302	1.233	1.218	1.209	1.174	1.149	1.115	1.065	1.041	1.048
2025	1.567	1.382	1.319	1.313	1.291	1.225	1.205	1.188	1.163	1.141	1.119	1.081	1.056	1.057

5.3.4.6 Planned improvements (3.B, N_2O_{direct} & NO)

No further improvements are planned at present.

Where previous reports have listed improvements in this chapter, those improvements are presented as an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

5.3.5 Indirect N_2O emissions as a result of manure management (3.B)

5.3.5.1 Category description (3.B, N_2O_{direct})

Cf. Chapter 5.3.1.

5.3.5.2 Methodological issues (3.B, N_2O_{direct})

5.3.5.2.1 Methods (3.B, $N_2O_{indirect}$)

The indirect N_2O emissions resulting from deposition of NH_3 and NO from manure management (including storage of digestates of manure; not including application) are calculated in accordance with IPCC (2006b Vol 4, 11.21) in proportion to the N quantity deposited:

Equation 22: Indirect N_2O emissions as a result of manure management (deposition)

$$E_{\text{N2O indirect, MM, Dep}} = \frac{44}{28} \cdot (E_{\text{NH3-N, MM}} + E_{\text{NO-N, MM}}) \cdot EF_4$$

where:

- $E_{\text{N2O, indirect, MM, Dep}}$ = Indirect N2O emissions from deposition of NH_3-N and NO-N from manure management (kg a^{-1})
- $E_{\text{NH3-N, MM}}$ = Total NH_3 emissions from manure management (kg a^{-1})
- $E_{\text{NO-N, MM}}$ = Total NO-N emissions from manure management (kg a^{-1})
- EF_4 = N_2O-N emission factor, cf. Chapter 5.3.5.2.2

A general description of the method used to calculate NH_3 and NO emissions from housing systems and manure storage is provided, along with relevant animal-specific details, in Chapters 4.3.1 and 4.3.2 in Vos et al. (2026).

The indirect N_2O emissions from leaching from manure management are reported in proportion to the quantity of N in solid manure in field storage.

Leaching of nitrogen is reported only in connection with field storage of solid manure, since with all other types of storage the legal provisions applying to construction of storage facilities prevent leaching. Pursuant to the German Working Group on water issues of the Federal States and the Federal Government (LAWA, 2019), field storage sites have to be covered with a waterproof cover after four weeks at the latest. In a conservative approach, therefore, it is assumed that leaching of N occurs in the first four weeks of storage. The leached-out fraction of the stored N quantity ($Frac_{LEACHMS}$) is calculated with (IPCC, 2019) – cf. Chapter 4.4.3 in Vos et al. (2026) – and amounts to 0.00333 kg kg^{-1}.

Indirect N_2O emissions from leaching are calculated, using the Tier-1 method as described in IPCC (2006b Vol 4, 11.21), as the product of the N_2O-N conversion factor 44/28, the leached N quantity and the emission factor (0.011 kg N_2O-N (kg N)$^{-1}$), cf. IPCC (2006b Vol 4, 11.24, Table 11.3); (IPCC, 2019):

Equation 23: Indirect N_2O emissions as a result of manure management (leaching)

$$E_{\text{N2O indirect, MM, Leach}} = \frac{44}{28} \cdot N_{\text{leaching, MM}} \cdot EF_5$$

where:

- $E_{\text{N2O, indirect, MM, Leach}}$ = Indirect N_2O emissions from leaching of N from manure management (kg a^{-1})
- $N_{\text{leaching, MM}}$ = N quantity leached out during field storage (kg a^{-1})
- EF_5 = N_2O-N emission factor for leaching, cf. Chapter 5.3.5.2.2

A detailed description of the calculation of indirect N_2O emissions resulting from leaching and surface runoff is provided in Chapter 5.3.2.1 in Vos et al. (2026).

5.3.5.2.2 Emission factors (3.B and 3.D, $N_2O_{indirect}$)

Since the 2026 submission, the emission factor EF_4 for indirect N_2O emissions resulting from deposition of NH_3 and NO as a result of manure management and from soils is differentiated by climate. For a wet climate the value is 0.014 kg N_2O-N (kg N)$^{-1}$, while for a dry climate it is 0.005 kg N_2O-N (kg N)$^{-1}$; cf. see Table 11.3 in IPCC (2019). For each year, the quotient of precipitation and potential evapotranspiration is calculated on a 1 km × 1 km grid using data from the German Meteorological Service. If the quotient is greater than 1, the factor for wet climates is used as per (IPCC, 2019). If the quotient is less than 1, the factor for dry climates is applied. For each region and for every year a mean emission factor is calculated by combining the resulting wet and dry zones with the agricultural area of the NUTS-3 regions.

The emission factor EF_5 for indirect N_2O emissions due to leaching from manure management (only for field storage of solid manure) is 0.011 kg N_2O-N (kg N)$^{-1}$ (IPCC, 2019).

5.3.5.2.3 Emissions (3.B, $N_2O_{indirect}$)

Table 290 shows the indirect N_2O emissions resulting from deposition of reactive nitrogen from NH_3 and NO emissions from manure management – as reported in the present submission and, in anticipation of Chapter 5.3.5.5, as reported in last year's submission. Compared with the 2025 submission, in which only the EF for a wet climate was used, the emissions across the entire time series are markedly lower. In particular, exceptionally dry years such as 2018 or 2022 see emissions halved compared to the 2025 submission. In general, very high interannual fluctuations can occur.

Table 291 shows the resulting indirect N_2O emissions from leaching from manure management.

In contrast, the emissions resulting from leaching and surface runoff have only changed slightly compared with the 2025 submission. They largely follow the pattern of the direct N_2O emissions; cf. Chapter 5.3.4.2.3. The changes compared with the 2025 submission are thus largely due to changes in N excretions from dairy cows; cf. Chapter 5.1.7.3.

Table 290: Indirect N_2O emissions as a result of deposition of NH_3 and NO from manure management (2025 and 2026 submissions), in Gg

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023
2026	4.776	4.316	4.197	4.175	4.268	3.223	3.369	3.867	1.744	2.652	2.411	3.363	1.818	3.131
2025	5.464	4.582	4.514	4.521	4.399	4.324	4.250	4.210	4.087	4.005	3.934	3.783	3.596	3.572

Table 291: Indirect N_2O emissions as a result of leaching of NH_3 and NO from manure management (2025 and 2026 submissions), in Gg

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023
2026	0.0022	0.0012	0.0012	0.0012	0.0013	0.0009	0.0009	0.0008	0.0007	0.0007	0.0006	0.0006	0.0006	0.0006
2025	0.0021	0.0012	0.0011	0.0012	0.0013	0.0009	0.0009	0.0008	0.0007	0.0007	0.0006	0.0006	0.0006	0.0006

5.3.5.3 Uncertainties and time series consistency (3.B, $N_2O_{indirect}$)

Table 250 in Chapter 5.1.6 shows the uncertainties in activity data and emission factor that have been used in estimating the total uncertainty of the German GHG inventory.

The emission factor uncertainty (95% confidence interval) from the calculation of indirect N_2O emissions from agricultural soils (cf. Chapter 6.5 in Vos et al. (2026)) has been used here as well. With regard to estimation of the uncertainty of the activity data (available quantity of reactive nitrogen), cf. Chapter 6.3 in Vos et al. (2026).

The emissions time series are consistent since they were calculated with the same method for every year covered by the report period, and since the input data are also consistent and complete.

5.3.5.4 Category-specific QA/QC and verification (3.B, $N_2O_{indirect}$)

With regard to quality control and quality assurance, we refer to Chapter 5.1.7.

5.3.5.5 Category-specific recalculations (3.B, $N_2O_{indirect}$)

With regard to the category-specific recalculations, cf. Chapter 5.3.5.2.3.

5.3.5.6 Planned improvements (3.B, $N_2O_{indirect}$)

No further improvements are planned at present.

Where previous reports have listed improvements in this chapter, those improvements are presented as an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

5.4 Rice cultivation (3.C)

No rice is cultivated in Germany (not occurring – NO).

5.5 Agricultural soils (3.D)

5.5.1 Category description (3.D)

KC	Category	Activity	EM of	1990 (kt CO2-e.)	Fraction [%]	2024 (kt CO2-e.)	Fraction [%]	Trend [%] 1990-2024
L/T	3 D, Agricultural Soils		N_2O	20292.80	1.57	14473.14	2.05	-28.68

Gas	Method used	Source for the activity data	Emission factors used
N_2O	Tier 1/Tier 2/Tier 3	M/AS/RS/NS	D, CS
NO_X	Tier 1	RS/NS	D
NMVOC	Tier 1	RS/NS	D

The category agricultural soils is a key category for N_2O emissions in terms of emissions level and trend.

Microbial transformations of N compounds (nitrification and denitrification) lead to emissions of N_2O from soils. A distinction is made between direct and indirect N_2O emissions. The reported direct emissions in sector 3.D include N_2O emissions resulting from:

- application of mineral fertiliser
- application of manure (including manure digestates)
- application of sewage sludge
- application of other organic fertilisers (digestates of energy crops and waste; composts of biowaste and green waste; and imported manure)
- grazing
- crop residues
- mineralisation
- cultivation of organic soils

The indirect N_2O emissions in Sector 3.D result from deposition of reactive nitrogen and from leaching and surface runoff. A Tier 3 method is used for calculation of indirect N_2O emissions from leaching and surface runoff.

Table 292 shows the changes, over time, in emissions from use of agricultural soils since 1990. In addition, it shows, for the initial and final years of the time series, the emissions' shares of the relevant total emissions in the German agricultural sector.

Table 292: Percentage change in emissions from use of agricultural soils since 1990, and percentage shares of total agricultural sector emissions of N_2O and GHG

[%]	Change since 1990	Share of total agricultural emissions (N_2O, GHG)	
		1990	2024
N_2O_{soils}, direct	-17.6	62.8	69.2
N_2O_{soils}, indirect	-52.6	19.1	14.0
Total of N_2O_{soils}	-25.8	81.9	83.1
ditto, as GHG (in CO_{2eq})	-25.8	27.4	27.2

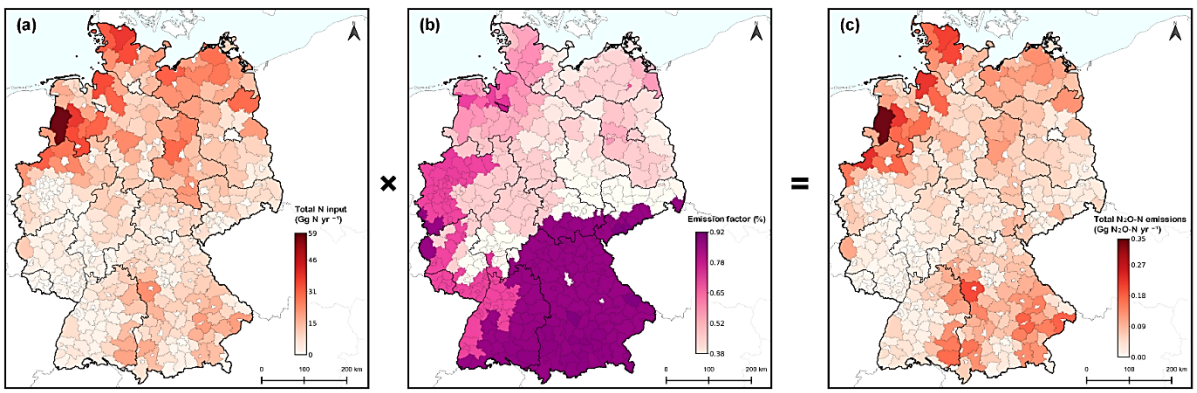
5.5.2 Methodological issues, and emissions (3.D)

5.5.2.1 Methods and emission factors (3.D)

5.5.2.1.1 Direct N_2O emissions (3.D.a)

Direct N_2O emissions resulting from application of N-containing substrates and from crop residues are calculated with a Tier 2 method at the NUTS-3 level, and with emission factors pursuant to Mathivanan et al. (2021) (cf. Chapter 5.1.5.1.1). The Tier 2 emission factors used for this purpose were derived in a meta analysis. The database for the analysis came from 71 studies, carried out in Germany, comprising a total of 676 field measurements of N_2O emissions carried out at 43 sites in Germany, over a period of at least 150 days. The emission factors were derived with the help of generalised Bayesian linear mixed models. The emission factors apply only to direct N_2O emissions. The indirect N_2O emissions resulting from application of mineral fertiliser, manure, compost (of biowaste and green waste), sewage sludge and digestates are calculated separately; cf. Chapters 5.5.2.1.2 and 5.5.2.1.3.

Figure 50: Depiction of the calculation of direct N_2O emissions from agricultural soils based on NUTS-3 regions.



Depiction: Figure from Mathivanan et al. (2021).

a) N inputs as a result of mineral fertiliser, manure, digestates, sewage sludge and crop residues, in Gg N yr^{-1};

b) N_2O emission factors in % based on NUTS-3 regions; and

c) annual direct N_2O emissions of NUTS-3 regions from application of N-containing substrates and crop residues

Separate emission factors for organic and mineral soils were determined. For classification as organic soil, the criterion used consisted of the threshold of at least 90 g kg^{-1} SOC, which is also used in the German LULUCF inventory. Emission factors for mineral soils were determined for four regions in Germany that were derived from the ecological zones pursuant to Metzger et al. (2005). For organic soils, it was only possible to derive an emission factor for Germany as a whole.

For derivation of emission factors, the nitrous oxide emissions are modelled as a linear function of N fertilisation; then, the emission factors correspond to the slope parameters of the model (Bouwman, 1996). The skewed distribution that nitrous oxide emissions typically exhibit was taken into account through the use of a generalised linear model with a gamma distribution and linear link function. Correlations within sites and measurement years were considered random effects. The model was optimised using a Bayesian approach for which the initial distribution was derived from the IPCC 2019 Refinement (IPCC, 2019) and earlier meta analyses carried out in Germany. Details on the various adjusted models are provided in Mathivanan et al. (2021).

The empirical modelling shows that separation into synthetic fertilisers and other nitrogen inputs, as set forth in the IPCC Refinement (Table 11.1 in (IPCC, 2019))), is not relevant for the German data. The environmental zones pursuant Metzger et al. (2005) do have a strong influence on the N_2O emissions, however. For this reason, emission factors for mineral soils were determined for four regions in Germany that were derived from those environmental zones. For organic soils, it was only possible to derive a national emission factor, due to the limited quantity of available data.

For purposes of inventory calculation, emission factors were calculated for all German NUTS-3 regions (cf. Figure 50). This was done by producing average emission factors for mineral and organic soils that are weighted according to the soil's relevant share of the agricultural area in the respective NUTS-3 region. The area data of the LULUCF inventory were used for this purpose. Since the area data of the LULUCF inventory for organic soils have changed from the 2025 submission (cf. Chapter 5.1.5.1.3), the emission factors for the 2025 submission have been recalculated. On average, they are marginally higher than in the 2024 submission due to the higher proportion of organic soils.

The emission factors for N inputs on mineral soils are listed in Table 293. Following the recalculation for the 2025 submission, the average emission factor, in Germany, for all soils and N inputs (synthetic fertilisers, manure, digestates, sewage sludge, compost, crop residues) is 0.0062 kg kg^{-1}, which is 38% lower than the IPCC Tier 1 emission factor. The confidence interval, 0.43%-0.85%, lies within the confidence interval of the IPCC Tier 1 emission factor (IPCC, 2019): 0.1% – 1.8%). Since the model used by Mathivanan et al. (2021) is purely empirical, like the models used to derive the IPCC emission factors, it is not possible to determine why the national implied emission factor is below the 1% global expected average value given by the IPCC. The possible reasons could include pedological and climatic factors and specifics of the agricultural practices involved. That said, it must be emphasised that there is no statistically significant difference between the Tier 1 emission factor and the German Tier 2 approach – primarily for the reason that the Tier 1 emission factor is subject to great uncertainty.

Table 293: N_2O-N emission factors for N inputs on soils, pursuant to (Mathivanan et al., 2021), in [kg kg^{-1}]

Soil	Region	Emission factor	Confidence interval
Mineral soils	Northwest Germany	0.0049	0.0026-0.0078
	Northeast Germany	0.0039	0.0017-0.0066
	Southwest Germany	0.0072	0.0037-0.0108
	Southeast Germany	0.0088	0.0038-0.0143
Organic soils	Germany	0.0101	0.0039-0.0165

The combined emission factors for the NUTS-3 regions (as weighted averages for mineral and organic soils) are between 0.0039 and 0.0092 kg N_2O-N per kg of applied nitrogen. The emission factors in NUTS-3 regions in southern Germany are generally higher than those in northern Germany. This is ascribed to the relevant differences in climate and soil characteristics (Dechow & Freibauer, 2011). With regard to the N-input quantities, the situation is roughly reversed, because the agricultural area's share of the NUTS-3 region tends to be higher, in general, in northern Germany, and because agriculture tends to be more intensive in northern Germany. The resulting N_2O emissions differ widely throughout Germany. In general, they are highest in areas in which the share of organic soils is high and large quantities of nitrogen are applied. The lowest N_2O emissions occur in urban regions in western Germany where N inputs are small.

Emissions from N excretions during grazing are calculated, pursuant to IPCC (2006b Vol 4, 11.7), in proportion to the N quantity excreted on pasture (cf. Chapter 5.1.5.1). From the 2026 submission on, the IPCC (2019) default emission factors, differentiated by climate, are used: For cattle, swine and poultry, 0.006 kg N_2O-N per kg of excreted nitrogen in wet climates and 0.002 kg N_2O-N per kg of excreted nitrogen in dry climates; for sheep, goats and horses, 0.003 kg N_2O-N per kg of excreted nitrogen (IPCC does not distinguish by climate here); cf. IPCC (2019) Vol. 4, Table 11.1. The derivation of the mean emission factor is carried out as per the description in Chapter 5.3.5.2.2. For swine, free-range management plays a negligible part in Germany (IE; cf. Chapter 5.1.3.6.4).

Direct N_2O emissions from mineralisation of organic soil substance in mineral agricultural soils are calculated using a Tier 1 method pursuant to IPCC (2006b Vol 4, 11.7) in proportion to the relevant released N quantities (cf. Chapter 5.1.5.1). Pursuant to IPCC (2019), from the 2025 submission, the relevant emission factor is 0.006 kg N_2O-N per kg of released nitrogen.

Direct N_2O emissions from mineralisation of organic soil substance on cultivated organic soils are calculated by multiplying the relevant area by an emission factor. This is done separately for cropland and grassland. With regard to the areas, cf. Chapter 5.1.5.1.3 A Germany-wide study, (Tiemeyer et al., 2020), has derived current N_2O-N emission factors for Germany: 11.1 kg ha^{-1} a^{-1} for cropland and 4.6 kg ha^{-1} a^{-1} for grassland. The data on which the previous emission factors were based have been re-evaluated by Tiemeyer et al. (2020) and supplemented with more recent data: overall, the updated emission factors for cropland and grassland are based on 206 year-round measurements for 25 different peatland areas in Germany. In the LULUCF sector, the updated emission factors were used to calculate the total N_2O emissions for cropland and grassland on organic soils, with those calculations taking account of the fact that subareas with a depth to water table < 10 cm do not emit any N_2O. Division of these emissions by the total areas given in Chapter 5.1.5.1.3 yields the following implied emission factors (IEFs): on average around 10.8 kg ha^{-1} a^{-1} for cropland and about 4.1 kg ha^{-1} a^{-1} for grassland. Table 294 shows the area-weighted average value derived from these factors, which varies over time, mainly due to the dependence on the weather variable climatic water balance (cf. Chapter 6.1.2.2.2) introduced in the 2025 submission, and only to a lesser extent because the ratio of cropland to grassland areas is not constant.

Table 294: Average N_2O-N emission factors for agricultural soils, in [kg kg^{-1}]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Mineral fertiliser	0.0063	0.0061	0.0062	0.0061	0.0061	0.0060	0.0061	0.0062	0.0063	0.0062	0.0062	0.0062	0.0061	0.0061	0.0062
Manure	0.0066	0.0067	0.0067	0.0067	0.0067	0.0066	0.0066	0.0066	0.0066	0.006	0.0066	0.0066	0.0066	0.0066	0.0066
Other organic fertilisers	0.0063	0.0063	0.0064	0.0065	0.0065	0.0064	0.0064	0.0064	0.0064	0.0064	0.0064	0.0064	0.0065	0.0064	0.0064
Sewage sludge	0.0063	0.0063	0.0062	0.0059	0.0056	0.0057	0.0057	0.0057	0.0056	0.0055	0.0055	0.0054	0.0056	0.0054	0.0054

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Crop residues	0.0062	0.0062	0.0062	0.0062	0.0061	0.0061	0.0061	0.0061	0.0062	0.0062	0.0061	0.0061	0.0061	0.0061	0.0061
Grazing	0.0051	0.0052	0.0051	0.0051	0.0054	0.0042	0.0044	0.0051	0.0026	0.0038	0.0036	0.0048	0.0033	0.0048	0.0047
Mineralisation	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060
Cultivated organic soils [kg ha^{-1}]	5.58	5.70	5.73	5.81	5.75	5.96	6.07	5.62	6.24	6.02	6.07	5.77	6.10	5.23	5.66

5.5.2.1.2 Indirect N_2O emissions from deposition of reactive nitrogen from use of agricultural soils (3.D)

Indirect N_2O emissions resulting from deposition of reactive nitrogen are calculated, pursuant to IPCC (2006b Vol 4, 11.21), in proportion to the N quantity deposited. The methodology corresponds to the approach described in Chapter 5.3.5.2.1. With regard to the emission factor, cf. Chapter 5.3.5.2.2 (0.014 kg N_2O-N (kg N)$^{-1}$ for wet climates and 0.005 kg N_2O-N (kg N)$^{-1}$ for dry climates) The total deposited N quantity of relevance for the calculations in Sector 3.D comprises the N quantities of the NH_3 and NO emissions (cf. Chapter 5.1.5.1.4) from:

- application of mineral fertiliser,
- application of manure (including manure digestates),
- application of sewage sludge,
- application of other organic fertilisers (digestates of energy crops and waste; composts of biowaste and green waste; and imported manure),
- grazing,
- crop residues remaining on the field.

A description of the calculation of indirect N_2O emissions from deposition of NH_3-N and NO-N is provided in Chapter 5.3.2.2 in Vos et al. (2026). The German inventory does not use the IPCC default values for $Frac_{GASM}$ and $Frac_{GASF}$. Instead, it calculates the NH_3 and NO emissions that lead to deposition of reactive nitrogen by multiplying the relevant applied N quantity/N excretions on pasture by the respective emission factors.

With regard to application of the various types of mineral fertiliser, cf. Chapters 5.2.1.2 and 5.2.2.2 in Vos et al. (2026). Grazing is described in chapters 5.2.1.1 and 5.2.2.1 in Vos et al. (2026). For the calculation of NH_3 and NO emissions from application of manure (including manure digestates), energy crop digestates, digestates of waste, compost of biowaste, compost of green waste, imported manure and sewage sludge, refer to Chapters 5.1, 5.2.1.2 and 5.2.2.2 in Vos et al. (2026). For the calculation of NH_3 emissions from crop residues, refer to Chapter 5.2.1.3 in Vos et al. (2026). As of 2020, application of urea fertiliser is subject to legal restrictions: “Since 1 February 2020, urea may be applied, as a fertiliser, only if a urease inhibitor is added to it, or if it is worked into the soil without delay, no later than four hours following its application.” (DüV, 2017 §6, Absatz 2). As of time series year 2020, therefore, an emission factor reduced by 70% is used for NH_3 from urea (Bittman et al., 2014, Chapter 8, Table 15) for cases in which the urea is worked into the soil, and an emission factor reduced by 60% is used for cases where the urea is inhibited using an inhibitor, see Schoof et al. (2025). Consequently, the indirect N_2O emissions drop considerably as of that year.

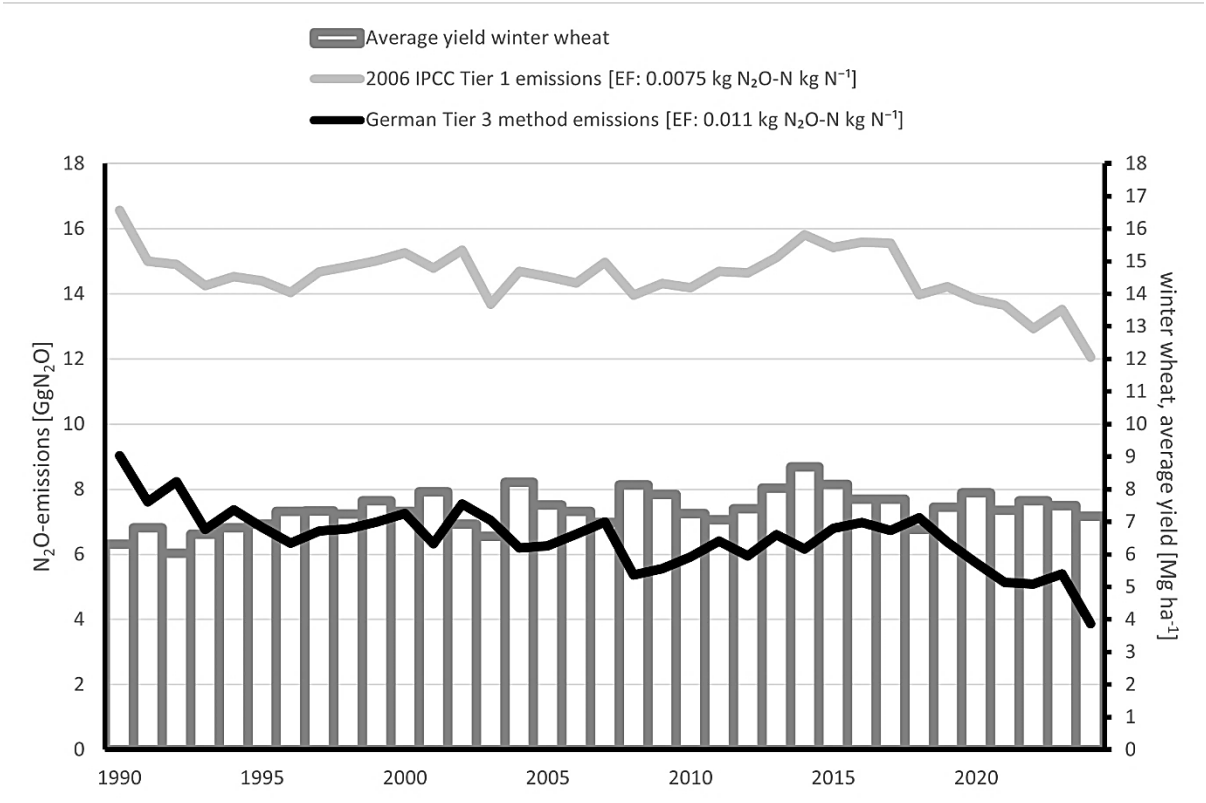
5.5.2.1.3 Indirect N2O emissions resulting from leaching and surface runoff (3.D)

As of the 2024 submission, the indirect N_2O emissions resulting from leaching and surface runoff are calculated using a Tier 3 method. The method is based on regionally specific calculation of

nitrogen surpluses, of which portions are leached out, as nitrate, or are transferred laterally, into receiving streams. The N surpluses are obtained as the sum of N inputs (consisting of mineral fertiliser, manure, crop residues, digestates, compost, sewage sludge and mineralisation), minus the N removals as a result of harvests, and minus the nitrogen that is emitted as NH_3 as a result of application of mineral and organic fertilisers. Eysholdt et al. (2022) developed a model that reveals the fraction of the N surplus that, at the NUTS-2 level, is leached out or flows off with surface runoff. That fraction is assumed to be constant throughout the entire time series. The relevant method is described in detail in Eysholdt et al. (2022) and Vos et al. (2026), Chapter 5.3.2. The indirect N_2O emissions are obtained by multiplying the N quantity that is leached out or runs off the surface by the N_2O-N conversion factor 44/28, and by the emission factor (0.011 kg N_2O-N (kg N)$^{-1}$; cf. IPCC (2019)). The IPCC (2006b) default value for $Frac_{LEACH}$ (0.3), which was used for calculating emissions until the 2023 submission, is no longer used; instead, an implied national $Frac_{LEACH}$ value is calculated after the fact (cf. Chapter 5.5.2.2).

As Figure 51 shows, the emissions as calculated with the new method are considerably lower than the emissions as calculated with the formerly used Tier 1 method and with constant $Frac_{LEACH}$.

Figure 51: Comparison of annual indirect N_2O emissions from leaching and surface runoff as calculated with the IPCC 2006 Tier 1 method and with the new Tier 3 method pursuant to Eysholdt et al. (2022)



Source: own illustration, Thünen-Institut

The average winter wheat yield, which correlates negatively with the national N surplus in crop cultivation, is plotted on the secondary axis. As of 2020, this correlation is obscured somewhat as a result of tightening of laws pertaining to fertilisation and of high fertiliser prices.

At the same time, the emissions as calculated with the new method vary more widely from year to year since the N surplus – and, thus, the resulting leaching – depend more strongly on the

environmental conditions prevailing in the relevant years. Consequently, in years with poor harvests and high N inputs (such as 2018), emissions are relatively high. $Frac_{LEACH}$, as calculated after the fact, attains values between 0.07 and 0.11, which means it lies within the uncertainty range given for the new $Frac_{LEACH-(H)}$ (0.24) in IPCC (2019) (0.01-0.73). The relative uncertainty range given by Eysholdt et al. (2022) for $Frac_{LEACH}$ (-100%, +200%) yields considerably smaller absolute confidence intervals than the uncertainty range for the Tier 1 method.

5.5.2.1.4 NO emissions

The method for calculating NO emissions is similar to that for calculating N_2O emissions (cf. Chapter 5.5.2.1.2). EMEP (2023) 3D Table 3.1 provides, for application of mineral fertiliser and manure, and for animal excretions on pasture, a unified NO emission factor of 0.04 kg NO_2 per kg of applied nitrogen (cf. in this regard also EMEP (2023) 3D-14. This emission factor has been rounded to two decimal places and is based on the emission factor of Stehfest and Bouwman (2006), which amounts to 0.012 kg kg^{-1} in NO-N units. The inventory uses the original emission factor of Stehfest and Bouwman (2006) and, within the meaning of EMEP/EEA (2023-3D, Table 3.1, p.13, Supplement A2.3), also uses it for N excretions during grazing and from application of sewage sludge and other organic fertilisers.

5.5.2.1.5 NMVOC emissions

IPCC (2006b) does not provide any method for calculating the NMVOC emissions from agricultural crops. Germany calculates the NMVOC emissions separately for each crop using a Tier 2 method pursuant to EMEP (2023) 3D-21f:

Equation 24: Calculation of annual NMVOC emissions from agricultural crops pursuant EMEP (2023)

$$E_{\text{NMVOC, cult, i}} = A_i \cdot m_{\text{FM,i}} \cdot x_{\text{DM,i}} \cdot t_i \cdot EF_{\text{NMVOC, cult, i}}$$

where

- $E_{\text{NMVOC, cult, i}}$ = NMVOC emissions from agricultural crop i (in kg a^{-1})
- A_i = Area under cultivation with crop i (in ha)
- $m_{\text{FM, i}}$ = Average fresh matter yield from crop i (in kg ha^{-1} a^{-1})
- $x_{\text{DM, i}}$ = Dry matter content of crop i (in kg kg^{-1})
- t_i = Fraction of the year during which crop i emits NMVOCs (in a a^{-1})
- $EF_{\text{NMVOC, cult, i}}$ = NMVOC emission factor for crop i (in kg kg^{-1})

With regard to areas under cultivation, fresh matter yields, dry matter content and relative duration of emissions, cf. Chapter 5.1.5.3. The emission factors for wheat, rye, rape and grass were obtained from EMEP (2023) 3D Table 3.4; cf. Table 295. For the crop categories grass clover ley, alfalfa, forage grass and pastures and meadows, the EMEP emission factor for grass has been used. For the remaining crops, the EMEP emission factor for wheat has been used.

Table 295: NMVOC emission factors for agricultural crops, in [kg kg^{-1} h^{-1}]

Crop	Emission factor
Wheat	2.60·10-8
Rye	1.41·10-7
Rape	2.02·10-7
Grass (15°C)	1.03·10-8

5.5.2.2 *Frac* values (3.D)

Germany reports $Frac_{leach}$, $Frac_{GASF}$ and $Frac_{GASM}$.

$Frac_{LEACH}$ describes the leached-out N quantity as a fraction of the N quantity that is applied and/or available from crop residues (cf. IPCC (2006b Vol 4, 11.21)). Since the 2024 submission, $Frac_{LEACH}$ is no longer input as such into calculations due to the use of the new Tier 3 method in the German inventory. For purposes of emissions reporting, the value is obtained after the fact, as the quotient of the available N quantity and the relevant emissions. $Frac_{LEACH}$ is not a constant since it depends on N surpluses, which vary from year to year; cf. Table 296.

Similarly, the quantities $Frac_{GASF}$ and $Frac_{GASM}$ are also determined after the fact, for reporting purposes, from the input and output data for the completed emission calculation.

Pursuant to IPCC (2006b Vol 4, 11.21, eq.11.9), $Frac_{GASF}$ denotes the fraction of the N quantity applied with mineral fertiliser that is emitted as NH_3-N and NO-N; cf. Table 296. In such emissions, NH_3 is the predominant influencing factor. Due to the different NH_3 emission factors used for different mineral fertiliser types, the $Frac_{GASF}$ value depends on the mineral fertiliser mix prevailing in the year in question. Because urea has a relatively high emission factor (EMEP, 2023), until 2019 $Frac_{GASF}$ correlates very well with the ratio of urea-N to total mineral fertiliser-N; cf. (Vos et al., 2026). As of the year 2020, the $Frac_{GASF}$ value is considerably lower than it was in previous years since the calculation is being carried out with an NH_3 emission factor for urea that has been reduced by 60% in cases in which the urea is inhibited using an inhibitor, or by 70% in cases in which the urea is worked into the soil (cf. Chapter 5.5.2.1.2).

Pursuant to IPCC (2006b Vol 4, 11.21, eq.11.9), $Frac_{GASM}$ denotes the fraction of the N quantity applied from manure (incl. manure digestates), sewage sludge, other organic fertilisers during grazing, or remaining on the area as above-ground crop residue that is emitted as NH_3-N and NO-N; cf. Table 296.

Table 296: Frac time series and averages throughout the entire time series (3.D), in [kg kg^{-1}]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	Mean
FracLEACH	0.111	0.097	0.097	0.088	0.085	0.090	0.092	0.088	0.104	0.092	0.085	0.077	0.081	0.082	0.066	0.091
FracGASF	0.058	0.059	0.063	0.066	0.073	0.075	0.076	0.074	0.070	0.066	0.046	0.046	0.047	0.047	0.046	0.064
FracGASM	0.168	0.155	0.145	0.137	0.138	0.132	0.131	0.128	0.132	0.127	0.124	0.122	0.124	0.123	0.122	0.181

5.5.2.3 Emissions (3.D)

Table 297 presents an overview of the contributions of the various individual subsources to overall N_2O emissions from agricultural soils.

Table 297: Overview of N2O emissions from agricultural soils (3.D), in [Gg]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Total emissions	76.6	67.0	69.9	66.4	65.6	67.6	69.6	69.5	62.7	63.3	60.7	60.8	56.8	59.1	54.6
Total direct emissions	58.7	52.5	55.0	52.9	51.7	54.7	56.0	55.2	52.0	52.2	51.0	50.0	48.3	48.3	45.4
Total indirect emissions	17.9	14.5	14.9	13.4	13.9	12.8	13.6	14.3	10.7	11.2	9.8	10.8	8.5	10.7	9.2
Mineral fertiliser	21.8	16.5	18.6	17.3	15.6	16.3	16.7	15.7	14.8	13.7	12.8	12.1	10.8	10.1	10.0
Manure	12.8	11.5	11.1	10.7	10.4	10.7	10.7	10.7	10.5	10.4	10.2	9.8	9.6	9.6	9.5
Other organic fertilisers	0.1	0.4	0.6	1.1	2.4	3.7	3.7	3.6	3.6	3.6	3.6	3.5	3.8	3.6	3.6
Sewage sludge	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Grazing	1.9	1.6	1.4	1.2	1.3	0.9	1.0	1.1	0.6	0.8	0.8	1.0	0.7	1.0	1.0
Crop residues	6.6	6.4	7.0	7.2	7.3	8.0	8.1	8.5	7.2	7.9	8.1	8.3	8.1	8.2	8.1
Mineralisation	2.8	3.1	3.4	2.5	2.1	2.1	2.6	3.3	1.8	2.7	2.4	2.9	2.3	4.6	1.1
Organic soils	12.3	12.6	12.6	12.7	12.5	12.9	13.1	12.1	13.4	12.9	13.0	12.3	13.0	11.1	12.0
Indirect, deposition	8.9	7.6	7.6	7.2	8.0	6.0	6.7	7.5	3.5	4.8	4.0	5.7	3.4	5.3	5.3
Indirect, leaching	9.0	6.8	7.3	6.3	5.9	6.8	7.0	6.7	7.1	6.4	5.7	5.1	5.1	5.4	3.9

The total N_2O emissions decreased in the first half of the 1990s. In subsequent years, until around 2016, no clear trend emerges. The lowest emissions during this period were in 2003, while the highest were in 2014. From 2016, the emissions decreased again markedly; in 2024, they are about 21.5% lower than they were in 2016.

The main cause of annual fluctuations in total emissions are the indirect emissions from deposition (due to the emission factor's dependency on climate). These fluctuations, however, are not sufficient to outweigh the downward emissions trend observed since around 2016. Emissions from organic soils, mineralisation and crop residues, and indirect emissions from leaching are further examples of sub-categories whose fluctuating emissions are highly influenced by meteorological factors. The reduction in total emissions from 2016 is primarily due to reductions in mineral fertiliser application. In addition, a drought in 2018 meant that the harvest of 2018 was smaller than that of 2017, with the result that crop residues in 2018 were smaller than they were in 2017 (cf. Chapter 5.1.5.1.2). This effect was only partially offset by higher indirect emissions from leaching. The emissions-reducing effect of the livestock population reductions occurring in recent years has been partly offset by the emissions-increasing effects of increases in performance. Also, since 2005, application of increasing quantities of digestates of manure and of energy crops has been having an impact in this regard.

The results of the NO emissions calculations are shown in Table 298. With regard to the sources, cf. Chapter 5.5.2.1.2. The trend regarding total emissions largely follows that of the N_2O emissions. (For purposes of reporting in CR Table 3, the NO values are converted into NO_2 by multiplying them by the molar ratio 46/30).

Table 298: NO emissions from agricultural soils (3.D), in [Gg]

1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
95.4	79.3	83.2	79.6	78.1	84.9	84.7	81.6	77.8	75.0	72.5	69.2	65.9	63.7	62.8

Table 299 shows the development of NMVOC emissions over time. The annual changes - and, thus, the increasing trend that continued until 2014 - are primarily tied to variations in harvest yields. The yields of 2014 were the largest seen to date.

Table 299: NMVOC emissions from agricultural soils, in [Gg]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
	7.69	8.19	8.79	9.17	9.53	9.91	9.69	9.74	7.82	8.56	9.16	9.44	8.91	9.23	8.87
in % of 1990	100.0	106.5	114.2	119.2	123.9	128.9	126.0	126.7	101.7	111.3	119.0	122.7	115.9	120.0	115.3

5.5.3 Category-specific QA/QC and verification (3.D)

With regard to quality control and quality assurance, refer to Chapter 5.1.7.

For purposes of verification, Table 300 and Table 301, in an approach similar to that used in Chapter 5.2.4, compare the German inventory's N_2O-N emission factors and Frac values $Frac_{GASF}$, $Frac_{GASM}$ and $Frac_{LEACH}$ with the corresponding data of neighbouring countries or countries whose agricultural practice in this regard is similar to that of Germany. For the reasons given in Chapter 5.2.4, the year chosen for the comparison is the time series year 2023.

Table 300: N_2O emissions from soils of different countries in comparison of the implicit N_2O-N emission factor for the time series year 2023

N_2O-N	Mineral fertiliser	Manure	Crop residues	Mineralisation	Organic soils	Grazing	Deposition	Leaching
	[kg kg^{-1}]	[kg kg^{-1}]	[kg kg^{-1}]	[kg kg^{-1}]	[kg ha^{-1}]	[kg kg^{-1}]	[kg kg^{-1}]	[kg kg^{-1}]
Austria	0.0100	0.0100	0.0100	0.0100	5.1242	0.0038	0.0102	0.0110
Belgium	0.0160	0.0060	0.0060	0.0060	8.0000	0.0058	0.0140	0.0110
Czech Republic	0.0103	0.0055	0.0055	NA	NO	0.0039	0.0094	0.0110
Denmark	0.0100	0.0100	0.0100	0.0100	6.7439	0.0037	0.0140	0.0088
France	0.0103	0.0057	0.0055	NO	4.6128	0.0045	0.0100	0.0110
Germany	**0.0061**	**0.0066**	**0.0061**	**0.0060**	**5.2275**	**0.0048**	**0.0123**	**0.0110**
Netherlands	0.0104	0.0085	0.0105	0.0100	4.4441	0.0308	0.0100	0.0075
Poland	0.0100	0.0100	0.0100	0.0100	8.0000	0.0195	0.0100	0.0075
Switzerland	0.0098	0.0100	0.0100	0.0100	10.6275	0.0056	0.0264	0.0110
United Kingdom	0.0064	0.0061	0.0100	0.0100	11.9452	0.0033	0.0140	0.0075
IPCC (2006b Vol 4, 11.11, 11.24), IPCC et al. (2014) [a]	0.0100	0.0100	0.0100	0.0100	8.00 (13/4.3/8.2/ 1.6)[a]	0.02 (cattle, swine, poultry); 0.01 (other animals)	0.0100	0.0075
(IPCC, 2019),Vol. 4, Tables 11.1 and 11.3), wet climates/dry climates	0.0160/0.005	0.0060	0.0060/0.005	0.0060/0.005		0.003 (cattle, swine, poultry); 0.003 (other animals)	0.014/0.005	0.011/0.011

Source: Germany: 2026 submission; other countries: UNFCCC (2025)

[a] IPCC et al. (2014) Wetlands Supplement, Table 2.5 (cropland, drained/grassland, drained, nutrient-poor/grassland, deep-drained, nutrient-rich/grassland, shallow-drained, nutrient-rich)

As of the 2022 submission, Germany uses regionalised emission factors, derived by (Mathivanan et al., 2021), for application of mineral fertiliser, manure, other organic fertilisers and sewage sludge, and for crop residues. While these factors are considerably smaller than the (IPCC,

2006a) default emission factor of 0.01 kg kg^{-1}, they are similar in magnitude to the (IPCC, 2019) default emission factor for N inputs in wet climates (apart from those from mineral fertiliser).

For application of mineral fertiliser, the average German emission factor is lower than the values of Switzerland, the Czech Republic, the Netherlands, the UK and France, countries which also do not use the (IPCC, 2006a) default emission factor. Belgium is the only listed country which uses the (IPCC, 2019) default emission factors for wet climates in the 2025 submission.

For manure application, the average German value is lower than the value of the Netherlands and somewhat higher than that of the UK, France, the Czech Republic and Belgium.

Except for Germany, the Netherlands, France, the Czech Republic and Belgium, the other compared countries use the (IPCC, 2006a) default emission factor of 0.01 kg kg^{-1} for emissions from crop residues. Also here, the Dutch emission factor is clearly higher than the German value, whereas the values for the other countries are slightly below the German value.

In the case of mineralisation, a total of six countries use the default IPCC (2006) emission factor of 0.01 kg kg^{-1}. France and the Czech Republic do not report emissions from mineralisation, and Belgium uses the default IPCC (2019) emission factor for wet climates.

For N_2O-N from organic soils, Belgium and Poland use the IPCC (2006b) default emission factor of 8 kg ha^{-1}. Two countries have factors that are higher than this default value, while five countries (including Germany) have lower factors. Of the latter group, two countries (the Netherlands and France) have factors that are considerably lower. The German value, which is based on national emission factors for cropland and grassland (cf. Chapter 5.5.2.1.1), is roughly on par with the value for Austria.

Most emission factors for N_2O-N from grazing are probably based on a combination of IPCC default values. Nevertheless, it seems clear that, apart from Poland and the Netherlands, they use the (IPCC, 2019a) values as a basis, as does Germany.

In the case of indirect N_2O-N emissions resulting from deposition of reactive nitrogen, Germany, the Czech Republic and possibly Austria also use the climate-differentiated IPCC (2019) default emission factors. Three other countries (Belgium, Denmark and the UK) appear to use only the IPCC (2019) default emission factor for wet climates, while a further three (France, the Netherlands and Poland) use the IPCC (2006) default emission factor. The emission factor used by Switzerland is about a factor of two larger than the factors used by the other countries.

In terms of indirect N_2O-N emissions arising from leaching and surface runoff, six countries (including Germany) use the IPCC (2019) default emission factor. Three further countries (the Netherlands, Poland and the UK) still use the IPCC (2006b) default value, whereas Denmark uses an emission factor that lies between these two default values.

Table 301: Comparison of Frac values in various countries for the time series year 2023

	$Frac_{GASF}$ [kg kg^{-1}]	$Frac_{GASM}$ [kg kg^{-1}]	$Frac_{LEACH}$ [kg kg^{-1}]
Austria	0.078	0.19	0.15
Belgium	0.075	0.18	0.24
Czech Republic	0.110	0.21	0.24
Denmark	0.060	0.09	0.24
France	0.095	0.11	0.14

	$Frac_{GASF}$	$Frac_{GASM}$	$Frac_{LEACH}$
Germany	**0.047**	**0.12**	**0.08**
Netherlands	0.049	0.10	0.13
Poland	0.100	0.20	0.30
Switzerland	0.074	0.22	0.18
United Kingdom	0.043	0.09	0.19
IPCC (2006b Vol 4, 11.24)	0.100	0.20	0.30
IPCC (2019)	0.110	0.21	0.24

Source: Germany: 2026 submission; other countries: UNFCCC (2025)

It appears that only the Czech Republic and Poland consistently use the IPCC default values for the Frac variables, although the Czech Republic uses the values from (IPCC, 2019), whereas Poland uses the values from (IPCC, 2006a). The scattering seen in the $Frac_{GASF}$ data can be attributed to the variation, among the neighbouring countries, seen in the relative shares of different fertiliser types (with their different NH_3 emission factors). The German value is around 30% below the median and is of a similar magnitude to the Dutch value. The German $Frac_{GASM}$ value is around 20% below the median, while the German $Frac_{LEACH}$ value is the lowest of all values of the countries compared. This is due to using a Tier 3 method to calculate indirect N_2O emissions from leaching and surface runoff as of the 2024 submission. The $Frac_{LEACH}$ value is chronologically and spatially variable. It does not enter into the calculation; instead, as with $Frac_{GASF}$ and $Frac_{GASM}$, it is calculated after the fact; cf. Chapter 5.5.2.2. The values at the end of the German time series are lower than at the beginning, reflecting the improvement of N use efficiency in arable production. On average over the time series, the value is 0.09 kg kg^{-1}, at the beginning it was 0.11 kg kg^{-1}, which is only slightly lower than the Dutch value.

5.5.4 Uncertainties and time series consistency (3.D)

The activity data and emission factor uncertainties for direct and indirect N_2O emissions that are used to estimate the total uncertainty of the German GHG inventory are listed in Table 250 in Chapter 5.1.6.

The emission-factor uncertainties for direct N_2O from mineral fertiliser, organic fertiliser (manure, digestates, compost, sewage sludge) and crop residues are uncertainties that (Mathivanan et al., 2021) has calculated for the respective emission factors. The emission factors for grazing are default values from IPCC (2019) Table 11.11. With regard to the uncertainty for the activity data (N quantities and $Frac_{LEACH}$), cf. Chapter 6.3 in Vos et al. (2026).

The activity data and emission factor uncertainties for direct N_2O emissions from drained organic soils have been derived from national data; cf. Chapters 6.3 and 6.5 in Vos et al. (2026). The same applies to mineralisation of organic soil substance; cf. Chapters 6.3 and 6.5 in Vos et al. (2026).

For the uncertainty of the emission factor for NO from application of mineral fertiliser, manure, sewage sludge and other organic fertilisers, and from N excretions on pasture, the German inventory uses a 95% confidence interval of -95% to +400%; cf. Vos et al. (2026), Chapter 6.5. With regard to the uncertainties for the activity data (N quantities), refer to the discussion on N_2O emissions above.

With regard to the uncertainties in connection with the indirect N_2O emissions, cf. Chapter 6.5 in Vos et al. (2026).

EMEP (2023) does not provide any uncertainty information with regard to the Tier 2 NMVOC emission factors. If one adopts the upper value-range boundary given in EMEP (2023) Table 3.1 for the Tier 1 emission factor and then fits a log normal distribution, this results in a 95% confidence interval of -89% to +300%; cf. Chapter 6.7 in Vos et al. (2026). The uncertainty of the activity data for crop residues is taken from the uncertainty figures for N_2O. The emissions time series are consistent since they were calculated with the same method for every year covered by the report period, and since the input data are also consistent and complete.

5.5.5 Category-specific recalculations (3.D)

Table 302 compares the N_2O emissions from agricultural soils as reported in the present submission and in last year's submission.

Table 302: Comparison of total N_2O emissions from agricultural soils as calculated in the 2025 and 2026 submissions, in [Gg]

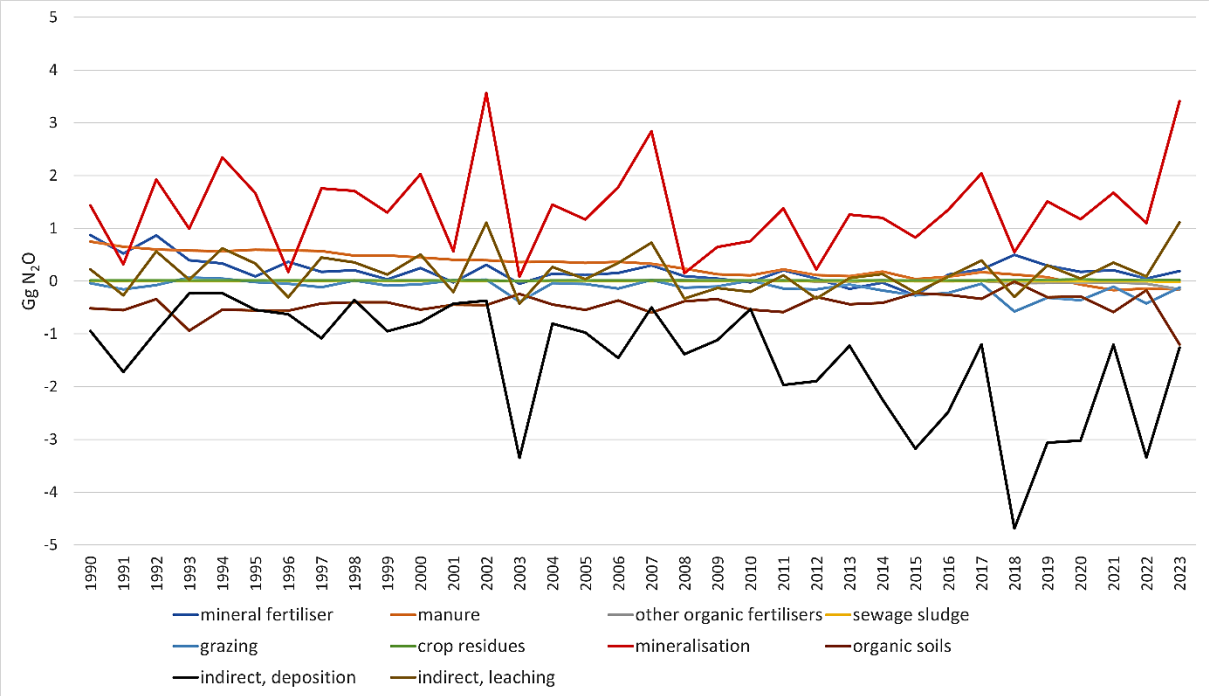
	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023
2026	75.6	65.5	67.9	65.6	65.5	67.1	68.3	67.3	62.4	61.9	59.7	59.3	55.7	55.6
2025	74.8	65.4	68.0	66.2	66.0	70.8	70.9	68.2	67.1	64.8	63.1	60.7	59.7	57.2

Table 303 and Figure 52 show the changes in N_2O emissions with respect to the figures given in last year's submission.

Table 303: Change in N_2O emissions from use of agricultural soils between the 2025 and 2026 submissions (negative values: reduction), in [Gg]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total	**1.794,**	**1.589,**	**1.856,**	**0.118,**	**-0.395,**	**-3.286,**	**-1.311,**	**1.265,**	**-4.416,**	**-1.510,**	**-2.333,**	**0.153,**	**-2.858,**	**1.826**
Mineral fertiliser	0.873,	0.090,	0.247,	0.113,	-0.022,	-0.275,	0.123,	0.224,	0.497,	0.292,	0.178,	0.205,	0.049,	0.191
Manure	0.748	0.596	0.447	0.344	0.111	0.040	0.086	0.169	0.126	0.076	-0.065	-0.171	-0.139	-0.156
Other organic fertilisers	0.002	0.006	0.005	0.012	0.006	-0.001	-0.003	0.004	-0.039	-0.032	-0.028	-0.025	-0.049	-0.157
Sewage sludge	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.017
Grazing	-0.038	-0.017	-0.060	-0.052	0.011	-0.269	-0.225	-0.047	-0.576	-0.314	-0.362	-0.107	-0.422	-0.118
Crop residues	0.013	0.012	0.012	0.012	0.012	0.011	0.013	0.013	0.018	0.021	0.035	0.016	0.023	0.022
Mineralisation	1.435	1.670	2.026	1.169	0.759	0.826	1.351	2.045	0.552	1.509	1.173	1.673	1.103	3.408
Organic soils	-0.515	-0.557	-0.541	-0.544	-0.541	-0.229	-0.261	-0.335	-0.005	-0.304	-0.288	-0.584	-0.173	-1.197
Indirect, deposition	-0.945	-0.545	-0.782	-0.972	-0.527	-3.173	-2.480	-1.201	-4.689	-3.060	-3.021	-1.207	-3.341	-1.262
Indirect, leaching	0.221	0.333	0.501	0.036	-0.203	-0.217	0.084	0.391	-0.299	0.301	0.046	0.352	0.091	1.111

Figure 52: Change in N_2O emissions from agricultural soils between the 2025 and 2026 submissions



Source: own illustration, Thünen-Institut

Total emissions reported in the 2026 submission are above the corresponding 2025 submission values in one half of the years and below them in the other half of the years. Prior to 2006, years with higher emissions predominate, while after that period, years with lower emissions predominate. The extreme values observed among these differences occur in the years 2002 (+4.6 Gg N_2O-N compared with the 2025 submission) and 2018 (-4.4 Gg N_2O-N compared with the 2025 submission). In the time series, 2002 is the wettest year and 2018 is the driest year.

In terms of magnitude, the largest changes are attributable to the sub-categories mineralisation and indirect emissions, deposition. Emissions from mineralisation are consistently higher than in the 2025 submission because, for the first time, they include mineralisation in grassland in addition to that in cropland. The strong interannual fluctuation of the change is ultimately due to the greater influence of weather as a result of using the RothC soil carbon model for the first time. The considerably lower emissions from the sub-category indirect emissions, deposition are also weather-related due to using climate-differentiated emission factors according to (IPCC, 2019) for the first time.

The weather effects of mineralisation also affect indirect emissions from leaching. Changes in grazing are mainly weather-related.

By contrast, the introduction of the transport module and the accompanying change to the previously static distribution of mineral fertiliser across NUTS-3 regions (cf. Chapter 5.1.2.5 and Chapter 5.1.7.3) results in only comparatively small changes. The generally higher emissions from mineral fertiliser application compared with the 2025 submission indicate that, in the model, it is now applied more in regions with a higher emission factor. The higher emissions from manure application at the start of the time series are mainly due to the recalculation of N excretions from dairy cows. For information about these changes, cf. Chapter 5.1.7.3.

Table 304 compares the total NO emissions with the corresponding data from last year's submission. In Table 305, the differences between the two submissions are broken down by

subsources. Since the NO emissions are generally calculated on the basis of their being proportional to the available N quantity, the non-zero differences reflect the changes affecting the N quantities as described in Chapter 5.1.7.3. The changes in 2023 for mineral fertiliser and sewage sludge are based on using the multiple-year moving average and on using data that are available for the first time for the year.

Table 304: Comparison of total NO emissions from agricultural soils as calculated in the 2025 and 2026 submissions, in [Gg]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023
2026	95.4	79.3	83.2	79.6	78.1	84.9	84.7	81.6	77.8	75.0	72.5	69.2	65.9	63.7
2025	93.1	77.7	82.1	78.7	77.6	84.4	84.1	80.8	77.1	74.5	72.3	69.2	66.0	63.8

Table 305: Change in NO emissions from use of agricultural soils between the 2025 and 2026 submissions (negative values: reduction), in [Gg]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total	**2.220**	**1.627**	**1.158**	**0.884**	**0.472**	**0.484**	**0.517**	**0.764**	**0.696**	**0.566**	**0.229**	**-0.047**	**-0.060**	**-0.115**
Mineral fertiliser	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.270
Manure	1.831	1.438	1.046	0.802	0.416	0.405	0.461	0.667	0.613	0.484	0.169	-0.083	-0.064	-0.140
Other organic fertilisers	0.000	0.000	0.000	0.000	0.019	0.031	0.000	0.015	0.000	0.012	0.010	0.009	-0.019	-0.220
Sewage sludge	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.043
Grazing	0.388	0.189	0.112	0.082	0.037	0.048	0.055	0.083	0.082	0.070	0.049	0.026	0.023	0.018

There was no change in NVMOC emissions with respect to last year's submission (cf. Table 306).

Table 306: Comparison of NMVOC emissions from agricultural soils as calculated in the 2025 and 2026 submissions, in [Gg]

[kt a^{-1}]	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023
2026	7.692	8.190	8.788	9.171	9.530	9.913	9.694	9.744	7.820	8.559	9.156	9.436	8.913	9.232
2025	7.692	8.190	8.788	9.171	9.530	9.913	9.694	9.744	7.820	8.559	9.156	9.436	8.913	9.232

5.5.6 Planned improvements (3.D)

No further improvements are planned at present.

Where previous reports have listed improvements in this chapter, those improvements are presented as an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

5.6 Prescribed burning of savannas (3.E)

Land clearance by prescribed burning is not practised in Germany (NO).

5.7 Field burning of agricultural residues (3.F)

Field burning of agricultural residues was already prohibited in Germany in 1990, at the beginning of the emissions-reporting period. Approvals for such burning are issued only in exceptional cases (for example, in cases of insect infestation), and only at the municipal level.

Since no official data on such cases are available, Germany reports no emissions (NO) under 3.F. For details, cf. Chapter 2.8.9 in Vos et al. (2026).

5.8 CO_2 from liming and urea application (3.G-I)

5.8.1 Category description (3.G-I)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
L/T	3 G, Liming		CO_2	2200.01	0.18	1906.50	0.27	-13.34
-/-	3 H, Urea Application		CO_2	480.00	0.04	330.20	0.05	-31.21
-/-	3 I, Other carbon-containing fertilisers		CO_2	510.45	0.04	144.75	0.03	-71.64

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1	NS	D

The category CO_2 from liming is a key category for CO_2 emissions in terms of emissions level and trend.

Liming, i.e. addition of carbonates to the soil, reduces the soil's acidity. It enhances plant growth, releasing CO_2 in the process. Lime fertilisers include all carbonates of calcium and magnesium, either as pure substances or as additives. The inventory differentiates between dolomite and limestone in order to take account of how the two groups differ in carbonate carbon content, as well as in their CO_2 emission factors. With regard to the latter group, application of calcium ammonium nitrate is considered separately. The resulting CO_2 emissions are reported under CRF 3.I (Other carbon-containing fertilisers), while the CO_2 emissions from application of limestone and dolomite are reported under CRF 3.G. In accordance with the requirements in IPCC (2006b Vol 4, 11.3 & CRF Table 3.G-I), the reported CO_2 emissions include both the emissions from the agricultural sector and from liming in the forestry sector.

Nitrogen fertilisation with urea leads to CO_2 emissions as a result of reactions involving urease and water. Germany reports these CO_2 emissions in Sector 3.H without deducting CO_2 bound through industrial production of urea fertiliser.

The CO_2 emissions from liming and urea application that are reported in this chapter represent 100% of the CO_2 emissions of the agricultural sector. Table 307, which complements the above table, shows the change over time in the sum of these CO_2 emissions since 1990, as well as the emissions' percentage shares of total GHG emissions from the German agricultural sector for the initial and final years of the time series.

Table 307: Percentage change in the sum of CO_2 emissions from liming and urea application since 1990, and percentage shares of total GHG emissions from the German agricultural sector

[%]	Change since 1990	Share of total agricultural GHG emissions	
		1990	2024
Total CO_2 from liming and urea application	-25.4	4.3	4.5

5.8.2 Methods and emissions (3.G-I)

The Tier 2 approach given in IPCC (2006b Vol 4, 11.27) is based on use of the Tier 1 equation (Equation 11.12 in IPCC (2006b Vol 4, 11.27)), which calls for multiplication of the fertiliser quantity by the emission factor. With regard to the fertiliser quantities, cf. Chapter 5.1.5.2. No specific German emission factors are available for dolomite and limestone; for this reason, the default emission factors given in IPCC (2006b Vol 4, 11.27) are used: 0.13 kg CO_2-C per kg dolomite ($CaMg(CO_3)_2$) and 0.12 kg CO_2-C per kg limestone ($CaCO_3$). In the case of calcium ammonium nitrate, CO_2 is produced from the $CaCO_3$ fraction, a process for which the limestone emission factor of 0.12 kg CO_2-C per kg $CaCO_3$ has been used. On that basis, an emission factor of 0.02748 kg CO_2-C per kg with respect to the total applicable mass of calcium ammonium nitrate can be derived; cf. Chapter 5.3.3 in Vos et al. (2026).

For purposes of entry into the CR tables, the so-calculated CO_2-C emissions are converted into CO_2 units by multiplying them by the molar ratio 44/12 (IPCC (2006b Vol 4, 11.27)). These CO_2 emissions may be seen as the highest emissions possible, since the aforementioned emission factors are based on the conservative assumption that all of the carbon contained in the fertilisers is converted into CO_2.

Table 308 shows the CO_2 emissions from liming over time, both as a sum total and broken down in accordance with the three reported lime fertiliser categories.

Table 308: CO_2 emissions from liming (3.G, 3.I), in [Gg]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Total	2710.5	1669.2	2062.0	1735.0	1806.2	2136.5	2107.5	2150.7	2250.1	2233.1	2195.2	2158.2	2152.1	2086.5	2051.3
in % of 1990	100.0	61.6	76.1	64.0	66.6	78.8	77.8	79.3	83.0	82.4	81.0	79.6	79.4	77.0	75.7
Limestone	1850.3	1071.8	1526.3	1329.4	1463.0	1828.8	1815.5	1878.4	1992.5	1991.0	1960.2	1935.0	1942.8	1896.3	1867.7
Dolomite	349.7	207.9	169.1	98.1	86.0	77.0	66.3	59.2	55.0	47.8	49.6	47.6	51.8	42.4	38.8
Calcium ammonium nitrate	510.4	389.5	366.6	307.5	257.2	230.7	225.7	213.0	202.7	194.2	185.5	175.5	157.5	147.8	144.8

The Tier 1 method for CO_2-C emissions from urea application (IPCC, 2006b Vol 4, 11.32) calculates the emissions in proportion to the quantity of urea applied (cf. Chapter 5.1.5.2). The proportionality factor used in the method is the CO_2-C emission factor to be derived stoichiometrically and is given as 0.2 kg CO_2-C per kg of urea (IPCC, 2006b Vol 4, 11.32). Conversion into units of CO_2, as required for the CR tables, is analogous to the conversion for CO_2 from liming; see above. Table 309 shows the resulting time series.

Table 309: CO_2 emissions from urea application (3H) in [Gg]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Total	480.0	458.5	593.1	641.1	710.8	791.5	815.1	719.6	605.3	497.7	433.3	397.3	367.0	347.5	330.2
in % of 1990	100.0	95.5	123.6	133.6	148.1	164.9	169.8	149.9	126.1	103.7	90.3	82.8	76.5	72.4	68.8

5.8.3 Category-specific QA/QC and verification (3.G-I)

With regard to quality control and quality assurance, refer to Chapter 5.1.7.

In the framework of verification, and in an approach similar to that used in Chapter 5.2.4, the 2022 CO_2 emissions from liming and urea application in Germany (current 2026 submission)

were compared with those of neighbouring countries and the UK (2025 submission), cf. Table 310.

Table 310: CO_2 emissions from liming and urea – a comparison of Implied Emission Factors (IEF) in various countries for the time series year 2023

	Limestone	Dolomite	Other lime-containing fertilisers	Urea application
	[kg CO_2-C per kg of fertiliser]	[kg CO_2-C per kg of fertiliser]	[kg CO_2-C per kg of fertiliser]	[kg CO_2-C per kg of fertiliser]
Austria	0.12	0.13	0.12500	0.20
Belgium	0.12	0.13	NO	0.20
Czech Republic	0.12	0.13	NO	0.20
Denmark	0.12	IE	0.02600	0.20
France	0.12	0.13	0.12500	0.20
Germany	**0.12**	**0.13**	**0.02748**	**0.20**
Netherlands	0.12	0.13	NO	0.43
Poland	0.12	0.13	0.12000	0.20
Switzerland	0.12	0.13	NO	0.20
United Kingdom	0.12	0.13	NO	0.20
IPCC (2006b): Vol. 4, 11.27	0.12	0.13		0.20

Source: Germany: 2026 submission; other countries: UNFCCC (2025)
IE, NO, n/a: No data available

With regard to emission factors, all of the countries considered use the default values given in IPCC (2006b) Vol. 4 for calculation of emissions from limestone, dolomite and urea (the Dutch emission factor for urea is most likely an error in the CR table). Use of other lime-containing fertilisers is reported by only a few countries. The German IEF is close to the Danish value.

5.8.4 Uncertainties and time series consistency (3.G-I)

Table 250 in Chapter 5.1.6 shows the uncertainties in activity data and emission factors for CO_2 from liming and urea application that have been used to estimate the total uncertainty of the German GHG inventory. For derivation of the uncertainties, cf. Chapters 6.3 and 6.9 in (Vos et al., 2026).

The uncertainty of the activity data does not include the uncertainty that results because a) normally, not all of the carbon applied is converted into CO_2, and b) the conversion rate cannot be quantified. In the context of the uncertainties listed in Table 250 in Chapter 5.1.6, the calculated emissions thus represent the maximum possible emissions.

The emissions time series are consistent since they were calculated with the same method for every year covered by the report period, and since the input data are also consistent and complete.

5.8.5 Category-specific recalculations (3.G-I)

Only in the last time series year 2023 do the emissions differ from those reported in the 2025 submission. This is a direct result of multiple-year averaging of activity data; cf. Chapter 5.1.5.2.

Table 311: CO_2 emissions from liming and urea application (3.G-I), in [kt a^{-1}]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023
2026 submission	2710.5	1669.2	2062.0	1735.0	1806.2	2136.5	2107.5	2150.7	2250.1	2233.1	2195.2	2158.2	2152.1	2086.5
2025 submission	2710.5	1669.2	2062.0	1735.0	1806.2	2136.5	2107.5	2150.7	2250.1	2233.1	2195.2	2158.2	2152.1	2103.8
Absolute change	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-17.3
Relative change	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.8%

5.8.6 Planned improvements (3.G-I)

No further improvements are planned at present.

Where previous reports have listed improvements in this chapter, those improvements are presented as an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

5.9 CH_4 and N_2O from digestion of energy crops (digesters and systems for storage of digestates) (3.J)

5.9.1 Category description (3.J)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
-/T	3 J, Other		CH_4	0.31	0.01	1445.31	0.21	460915.75
-/-	3 J, Other		N_2O	0.11	0.01	92.70	0.02	87107.90

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 2	Q/RS/NS	CS/D
N_2O direct	Tier 2	Q/RS/NS	CS/D
N_2O indirect	Tier 1	Q/RS/NS	D
NO_X	Tier 2	Q/RS/NS	CS

The category CH_4 and N_2O from digestion of energy crops (digesters and systems for storage of digestates) is a key category for CH_4 emissions in terms of trend.

Digestion of energy crops is carried out primarily for purposes of energy generation. The emissions occurring during digestion itself (digester) and through storage of digestates (CH_4, N_2O and NO; cf. Chapter 5.1.4.1) are reported as a separate category (CRF 3/J). The emissions resulting from use of digestates as fertiliser are reported in conjunction with reporting on emissions from application of other fertilisers, under 3.D.1.b.iii.

In a procedure analogous to that used for manure, the indirect N_2O emissions connected to storage of digestates of energy crops are calculated as a result of deposition of reactive nitrogen. In addition, no indirect N_2O emissions result from leaching/surface runoff from storage systems.

Table 312, which complements the table above, shows, for the first and last years of the time series, the percentage shares of emissions of CH_4, N_2O and GHG from digestion of energy crops (digesters and systems for storage of digestates) with respect to total agricultural emissions of CH_4, N_2O and GHG. Table 312 does not show percentage changes in emissions since 1990; because of the low prevalence of energy crop digestion in 1990, such data are of limited use, as

the table above shows. The emissions increase over time is a direct result of the growth in quantities of substrate.

Table 312: Percentage shares of emissions from digestion of energy crops (digesters and systems for storage of digestates) with respect to total agricultural emissions of CH_4, N_2O and GHG

[%]	Share of total agricultural emissions (CH_4, N_2O, GHG)	
	1990	2024
$CH_{4, EC}$	0.0	4.3
N_2O_{EC}	0.0	0.5
$CH_{4, EC}$ + N_2O_{EC} as GHG (in CO_{2eq})	0.0	2.9

5.9.2 Methodological issues (3.J)

The procedure for calculating CH4 emissions and direct N_2O emissions is analogous to that for calculation of emissions from manure digestion (cf. Chapter 5.1.3.6.5), with the exception that it does not take pre-storage into account.

As for manure (cf. Chapter 5.3.5), indirect N_2O emissions from storage of residues from digestion of energy crops are calculated as a result of deposition of reactive nitrogen. In the case of energy crops, such nitrogen originates in NH_3 and NO emissions from systems for storage of residues from digestion of energy crops. Like NO emissions from manure management, NO emissions from systems for storage of digestion residues are calculated using a procedure similar to that for calculation of N_2O emissions (cf. Chapter 5.3.4.2). With regard to calculation of NH_3 emissions from systems for storage of residues from digestion of energy crops, cf. Chapter 5.1 in (Vos et al., 2026).

5.9.3 CH_4 emission factors and emissions (3.J, CH_4)

Table 313 shows the temporal development for the CH_4 emission factor for digestion of energy crops (digesters and systems for storage of digestates) related to the dry matter quantities that are input into the digestion process along with energy crops (cf. Chapter 5.1.4.2). In the interest of clarity, we have used the unit g kg^{-1} instead of kg kg^{-1}, the unit typically used for emission factors. The decrease in the emission factor over time results from increasing use of gas-tight storage for digestates (cf. Chapter 5.1.4.2). For such storage, only the CH_4 leakage rate has to be taken into account instead of the higher emission factor for open storage.

Table 313: CH_4 emission factor for digestion of energy crops (digesters and systems for storage of digestates), related to the dry matter quantities input into digestion along with energy crops, in g [kg^{-1}]

1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
3.41	3.36	3.32	3.25	2.99	2.76	2.74	2.72	2.70	2.66	2.62	2.58	2.59	2.55	2.55

The CH_4 emissions from digestion of energy crops (digesters and systems for storage of digestion residues) are shown in Table 314. The increasing trend results from strong increases in the quantities of energy crops being digested, especially since 2005. It has been slowed by the increasing use of gas-tight storage of digestates. For details, cf. Chapter 5.1.4.2.

Table 314: CH_4 emissions from digestion of energy crops (digesters and systems for storage of digestion residues), in [Gg]

1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
0.01	0.14	1.21	10.04	33.36	55.45	54.77	53.52	52.37	51.64	52.00	50.25	54.09	51.66	51.62

5.9.4 N_2O emission factors and emissions (3.J, N_2O)

The emission factors for direct N_2O emissions from digestion of energy crops (systems for storage of digestion residues) are shown in Table 315. These data represent the average values for gas-tight and open storage. In their decreasing trend, they represent the increasing use of gas-tight storage, which emits no N_2O, that has occurred over the years. In the interest of clarity, we have used the unit g kg^{-1} instead of kg kg^{-1}, the unit typically used for emission factors. The emission factors in Table 315 are to be applied to the N quantities that are input, along with energy crops, into the digestion process (cf. Chapter 5.1.4.2).

Table 315: N_2O-N emission factor for direct N_2O emissions from digestion of energy crops (systems for storage of digestates), related to the N quantities input with energy crops, in [g kg^{-1}]

1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
5.00	4.77	4.53	4.21	2.89	1.73	1.63	1.54	1.45	1.26	1.07	0.87	0.90	0.71	0.71

As with manure, the IPCC (2019) emission factor differentiated by climate is used as the emission factor for indirect N_2O emissions as a result of deposition of NH_3 and NO from storage of digestates of energy crops. For a wet climate the value is 0.014 kg N_2O-N (kg N)$^{-1}$, while for a dry climate it is 0.005 kg N_2O-N (kg N)$^{-1}$; cf. see Table 11.3 in IPCC (2019).

The calculated direct and indirect N_2O emissions are presented in Table 316. The trend reflects the sharp increase that has occurred in digested quantities of energy crops (cf. Chapter 5.1.4), especially since 2005. The marked emissions decrease seen from 2011 to 2012 results from a disproportional increase in use of gas-tight storage; cf. Chapter 5.1.4.2.

Table 316: N_2O emissions from storage of digestates of energy crops, in [Gg]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Total	0.000	0.005	0.041	0.319	0.794	0.838	0.791	0.743	0.664	0.586	0.507	0.414	0.446	0.350	0.350
N_2O direct	0.000	0.005	0.038	0.298	0.741	0.798	0.749	0.697	0.644	0.559	0.485	0.388	0.430	0.329	0.329
N_2O indirect	0.000	0.000	0.003	0.020	0.053	0.040	0.042	0.047	0.020	0.026	0.022	0.025	0.016	0.021	0.021

5.9.5 NO emission factors and emissions (3.J, NO)

As for the case of manure (cf. Chapter 5.3.4.2.2), the relevant NO emissions are calculated in proportion to the direct N_2O emissions using the NO-N emission factor, which is to be applied to the input N quantity; that factor is set to 10% of the N_2O-N emission factor.

Table 317 shows the trend in NO emissions from digestion of energy crops (systems for storage of digestion residues).

Table 317: NO emissions from storage of digestates of energy crops, in [Gg]

1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
0.000	0.001	0.005	0.041	0.101	0.109	0.102	0.095	0.088	0.076	0.066	0.053	0.059	0.045	0.045

5.9.6 Category-specific QA/QC and verification (3.J)

With regard to quality control and quality assurance, refer to Chapter 5.1.7.

Verification cannot be carried out due to a lack of other German data sources. It is also not possible to carry out an international comparison as a substitute since other countries do not have comparable levels of use of digestion of energy crops.

5.9.7 Uncertainties and time series consistency (3.J)

Table 250 in Chapter 5.1.6 shows the activity data and emission factor uncertainties in connection with digestion of energy crops that have been used to estimate the total uncertainty of the German GHG inventory. For derivation of the uncertainties, cf. Chapter 6.3 and Vos et al. (2026).

The emissions time series are consistent since they were calculated with the same method for every year covered by the report period, and since the input data are also consistent and complete.

5.9.8 Category-specific recalculations (3.J)

Table 318 compares the results of the present submission with those of last year's submission. The deviations for the whole time series are mainly due to the first-time use of climate-differentiated (IPCC, 2019) emission factors to calculate indirect emissions from deposition (cf. Chapter 5.1.7.3) and, to a lesser extent, to the introduction of the transport module (cf. Chapter 5.1.2.5).

Table 318: Comparison of GHG emissions from digestion of energy crops (digesters and systems for storage of digestates), as reported in the 2025 and 2026 submissions, in [Gg CO_{2eq}]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023
Submission 2026	0.4	5.3	44.7	365.7	1144.5	1774.7	1743.0	1695.6	1642.3	1601.1	1590.3	1516.5	1632.7	1538.0
Submission 2025	0.4	5.3	44.8	366.0	1144.5	1779.2	1746.3	1696.4	1649.2	1604.9	1593.8	1517.2	1636.6	1636.6
Absolute change	0.0	0.0	-0.1	-0.3	0.0	-4.5	-3.3	-0.9	-6.8	-3.7	-3.5	-0.7	-3.9	-98.7
Relative change	-0.2%	-0.1%	-0.1%	-0.1%	0.0%	-0.3%	-0.2%	-0.1%	-0.4%	-0.2%	-0.2%	0.0%	-0.2%	-6.0%

5.9.9 Planned improvements (3.J)

No further improvements are planned at present.

Where previous reports have listed improvements in this chapter, those improvements are presented as an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter.

6 Land Use, Land-use Change and Forestry (CRF Sector 4)

6.1 Overview (CRF Sector 4)

6.1.1 Categories and total emissions and sinks, 1990-2024

In the LULUCF sector (Common Reporting Table 4), Germany reports on positive (source) and negative (sink) CO_2 emissions from the pools[77]

- above-ground and below-ground biomass
- dead wood, litter (dead organic matter),
- organic and mineral soils,
- artificial water bodies,
- and harvested wood products (4.G),

for the land-use categories

- Forest Land (4.A.1)
- Cropland (4.B.1)
- Grassland (4.C.1)
- Wetlands (4.D.1)
- Settlements (4.E.1)

as well as the relevant land-use changes between these categories (CRF 4.A.2 - 4.E.2). In the category *Other Land* (4.F), no anthropogenic emissions occur since the relevant land areas are not used. No land-use changes to *Other Land* occur since, by definition, land cannot be reassigned to the category unused land once it is in use.

The following are also inventoried:

- CO_2 emissions from
  - industrial peat extraction (4.D.1)
  - peat fires (4. (IV))
- N_2O emissions from
  - organic soils in land-use categories 4.A, 4.C (only woody grassland and hedges), 4.D, 4.E (emissions from the categories 4.B Cropland and 4.C Grassland in the strict sense) are reported under Agriculture in CRF 3.D.1.f)
  - direct (CRF 4. (III)) and indirect (CRF 4.(III)) emissions from humus mineralisation in mineral soils as a result of land-use changes and/or land management (emissions from 4.B.1 and 4.C.1 Grassland in the strict sense are reported under CRF 3.D.1.e)

[77] CO_2 emissions from wildfires are taken into account implicitly using carbon-stock changes in Forest Land.

- industrial peat extraction (4. (II))
- wildfires (4. (IV))

► CH_4 emissions from

- organic soils (4. (II))
- drainage ditches of organic soil areas (4.(II))
- drainage ditches of mineral soil areas (4.(II))
- standing artificial water bodies (reservoirs, ponds) (4.(II))
- artificial water bodies used for navigation (canals for shipping, harbour basins)
- industrial peat extraction (4. (II))
- wildfires (4. (IV))
- peat fires (4. (IV))

When reporting on emissions/removals of greenhouse gases in each land-use category, a distinction is made between areas which, during the reporting period,

► undergo no land-use changes, and thus remain in unchanged form in the land-use category they are in (remaining categories 4.A.1 - 4.F.1)

► undergo land-use changes: From the time of conversion onward, these areas are reported in the category to which they were converted. In these land-use categories, the converted areas are then reported in conversion categories (4.A.2 - 4.F.2) for a total of 20 years. After 20 years in a conversion category, the areas are reported in the remaining categories. If land use changes occur again before the end of the 20-year conversion period, the relevant areas are immediately assigned to the new conversion category from the date of the change in use. A new 20-year period (the effective conversion period) then begins for these areas.

Table 319 presents an overview of the German LULUCF reporting system with all of the relevant land-use categories, subcategories, pools, possible conversion categories and GHG emissions summarised in a table.

Table 319: Overview of the German LULUCF reporting system: Land-use categories, subcategories and pools, and possible transitions and their related greenhouse gas emissions

Category[1]	Land use/land-use change (areas)[2]			Pools (emissions)[2]					
	Remaining in	from	to	Biomass	Soil		Water bodies	Wildfire	DOM
					mineral	organic			
forl	x			CO_2 [$EF_{Biomass_forest_management}$]	CO_2, N_2O_{dir}, N_2O_{indir} [EF_{BZE} + Yasso model]	CO_2+DOC, N_2O, $CH_{4_org_soil}$+$CH_{4_ditch\ org_soil}$ [EF_{org_soil}IPCC default values_Forest]	/	CH_4, N_2O [$AD_{Officialstatistics}$, $EF_{Forestfire}$]	CO_2 [$EF_{DOM_forest_management}$]
forl		to crox, cros, crot, gra3, wett, set1		CO_2 [$EF_{Biomass_deforestation}$]	CO_2, N_2O_{dir}, N_2O_{indir} [EF+Yasso]	CO_2+DOC, N_2O, $CH_{4_org_soil}$+$CH_{4_ditch\ org_soil}$, [3]	/	/	CO_2 [$EF_{DOM_deforestation}$]
forl			from crot, gra2, gra3, wett, set1 (only dumping grounds, open-pit mines and landfills to forest land are possible), othl	CO_2 [$EF_{Biomass_afforestation}$]	CO_2, N_2O_{dir}, N_2O_{indir} [EF+Yasso]	CO_2+DOC, N_2O, $CH_{4_org_soil}$+$CH_{4_ditch\ org_soil}$ [EF_{org_soil}IPCC default values_Forest]	/	/	CO_2 [$EF_{DOM_afforestation}$]
cro1	x			/	/	CO_2+DOC, $CH_{4_org_soil}$+$CH_{4_ditch\ org_soil}$[5]	/	/	/
cro1		to all LUC, except forl, wetl, wetr, wetb, wetd, wets, set2, set3, othl		CO_2 [EF $cropland_{annual}$]	CO_2, N_2O [8]	CO_2+DOC, $CH_{4_org_soil}$+$CH_{4_ditch\ org_soil}$ N_2O [3]	/	/	CO_2, only to forl
cro1			from all LUC, except forl, wetl, wetr, wetb, wetd, wets, set2, set3	CO_2 [EF $cropland_{annual}$]	CO_2, N_2O [4]	CO_2+DOC, $CH_{4_org_soil}$+$CH_{4_ditch\ org_soil}$[5]	/	/	CO_2, only from forl
croh	x			/	/	CO_2+DOC, $CH_{4_org_soil}$+$CH_{4_ditch\ org_soil}$[5]	/	/	/
croh		to all LUC, except forl, wetl, wetr, wetb, wetd, wets, set2, set3, othl		CO_2 [EF croh]	CO_2, N_2O [8]	CO_2+DOC, $CH_{4_org_soil}$+$CH_{4_ditch\ org_soil}$, N_2O[3]	/	/	CO_2, only to forl
croh			from all LUC, except forl, wetl, wetr, wetb, wetd, wets, set2, set3	CO_2 [EF croh]	CO_2, N_2O [4]	CO_2+DOC, $CH_{4_org_soil}$+$CH_{4_ditch\ org_soil}$[5]	/	/	CO_2, only from forl
croo	x			CO_2 [Fruit model]	/	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$[5]	/	/	/
croo		to all LUC, except wetl, wetr, wetb, wetd, wets, set2, set3, othl		CO_2 [Fruit model]	CO_2, N_2O [8]	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$, N_2O[3]	/	/	CO_2, only to forl
croo			from all LUC, except forl, wetl, wetr, wetb, wetd, wets, set2, set3	CO_2 [Fruit model]	CO_2, N_2O [4]	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$[5]	/	/	CO_2, only from forl

Category[1]	Land use/land-use change (areas)[2]			Pools (emissions)[2]					
	Remaining in	from	to	Biomass	Soil		Water bodies	Wildfire	DOM
					mineral	organic			
cros	x			CO_2 [SRP model]	/	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$[5]	/	/	/
cros		to all LUC, except wetl, wetr, wetb, wetd, wets, set2, set3, othl		CO_2 [SRP model]	CO_2, N_2O [8]	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$, N_2O[3]	/	/	CO_2, only to forl
cros			from all LUC, except forl, wetl, wetr, wetb, wetd, wets, set2, set3	CO_2 [SRP model]	CO_2, N_2O [4]	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$[5]	/	/	CO_2, only from forl
crot	x			CO_2 [Tree nursery model]	/	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$[5]	/	/	/
crot		to all LUC, except forl, wetl, wetr, wetb, wetd, wets, othl		CO_2 [Tree nursery model]	CO_2, N_2O [8]	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$, N_2O[3]	/	/	CO_2, only to forl
crot			from all LUC, except forl, wetl, wetr, wetb, wetd, wets, set2	CO_2 [Tree nursery model]	CO_2, N_2O [4]	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$[5]	/	/	CO_2, only from forl
crow	x			CO_2 [Wine model]	/	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$[5]	/	/	/
crow		to all LUC, except forl, wetl, wetr, wetb, wetd, wets, set2, set3, othl		CO_2 [Wine model]	CO_2, N_2O [8]	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$, N_2O[3]	/	/	to forl, CO2
crow			from all LUC, except forl, wetl, wetr, wetb, wetd, wets, set2, set3,	CO_2 [Wine model]	CO_2, N_2O [4]	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$[5]	/	/	from forl, CO2
crox	x			CO_2 [Christmas tree model]	/	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$[5]	/	/	/
crox		to all LUC, except forl, wetl, wetr, wetb, wetd, wets, set2, set3, othl		CO_2 [Christmas tree model]	CO_2, N_2O [8]	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$, N_2O[3]	/	/	CO_2, only to forl
crox			from all LUC, except forl, wetl, wetr, wetb, wetd, wets, set2, set3	CO_2 [Christmas tree model]	CO_2, N_2O [4]	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$ [5]	/	/	CO_2, only from forl
gra1	x			/	/	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$[5]	/	/	/
gra1		to all LUC, except forl, wetl, wetr, wetb, wetd, wets, set2, set3, othl		CO_2 [EF $grassland_{annual}$]	CO_2, N_2O_{dir}, $N2O_{indir}$	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$, N_2O [3]	/	/	CO_2, only to forl
gra1			from all LUC, except forl, wetl, wetr, wetb, wetd, wets, set2, set3	CO_2 [EF $grassland_{annual}$]	CO_2, N_2O_{dir}, $N2O_{indir}$	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$[5]	/	/	CO_2, only from forl
gra2	x			CO_2 [Hedges/woody grassland model]	/	CO_2+DOC, $CH_{4_org_soil}$+$CH_{4_ditch\ org_soil}$, N_2O	/	/	/

Category[1]	Land use/land-use change (areas)[2]			Pools (emissions)[2]					
	Remaining in	from	to	Biomass	Soil		Water bodies	Wildfire	DOM
					mineral	organic			
						[EF_{org_soil}IPCC default values]			
gra2		to all LUC, except forl, wetl, wetr, wetb, wetd, wets, set2, set3, othl		CO_2 [Hedges/woody grassland model] [6]	CO_2, N_2O_{dir}, N_2O_{indir}	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$, N_2O [3]	/	/	CO_2, only to forl
gra2			from all LUC, except forl, wetl, wetr, wetb, wetd, wets, set2, set3	CO_2 [Hedges/woody grassland model]	CO_2, N_2O_{dir}, N_2O_{indir}	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$, N_2O [EF_{org_soil}IPCC default values_Forest]	/	/	CO_2, only from forl
gra3	x			CO_2 [Hedges/woody grassland model]	/	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$, N_2O	/	/	/
gra3		to all LUC, except wetl, wetr, wetb, wetd, wets, set2, set3, othl		CO_2 [Hedges/woody grassland model] [6]	CO_2, N_2O_{dir}, N_2O_{indir}	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$, N_2O 3)	/	/	CO_2, only to forl
gra3			from all LUC, except forl, wetl, wetr, wetb, wetd, wets, set2, set3	CO_2 [Hedges/woody grassland model]	CO_2, N_2O_{dir}, N_2O_{indir}	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$, N_2O	/	/	CO_2, only from forl
wett	x			CO_2 [Terrestrial wetlands model]	/	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$, N_2O	/	/	/
wett		to all LUC, except wetl, wetr, wetb, wetd, wets, set2, set3, othl		CO_2 [Terrestrial wetlands model]	CO_2, N_2O_{dir}, N_2O_{indir}	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$, N_2O [3]	/	/	CO_2, only to forl
wett			from all LUC, except forl, wetl, wetr, wetb, wetd, wets, set2, set3	CO_2 [Terrestrial wetlands model]	CO_2, N_2O_{dir}, N_2O_{indir}	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$, N_2O	/	/	CO_2, only from forl
wetl/wetr	x			/	/	/	/	/	/
wetp	x	to all LUC, except wetl, wetr, wetb, wetd, wets, set2, set3, othl		/	/	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$, N_2O [on-site emissions]	/	/	/
wetp			from all LUC, except wetl, wetr, wetb, wetd, wets, set2, set3	CO_2 [$EF_{peat_extraction}$]	/	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$, N_2O [3]	CH_4 [EF $wetb_{org_soil}$] [7]	/	CO_2, only to forl
wetp		/	/	CO_2 [$EF_{peat_extraction}$]	/	CO_2, CH_4, N_2O [on-site emissions]	/	/	CO_2, only from forl
wetp				/	/	CO_2 [off-site emissions]	/	/	/
wetb	x	to all LUC, except wetl, wetr, wetd, wets, set2, set3, othl		/	/	/	CH_4 [EF $wetb_{org_soil}$] + CH_4 [EF $wetb_{min_soil}$]	/	/
wetb			from all LUC, except wetl, wetr, wetd, wets, set2, set3	/	/	/	/	/	/

Category[1]	Land use/land-use change (areas)[2]			Pools (emissions)[2]					
	Remaining in	from	to	Biomass	Soil		Water bodies	Wildfire	DOM
					mineral	organic			
wetb				/	/	/	CH_4 [EF $wetb_{org_soil}$]	/	/
wetd	x	/	/	/	/	/	CH_4 [EF wetd]	/	/
wets	x	/	/	/	/	/	CH4 [EF wetd]	/	/
set1	x			CO_2 [Settlement model]	/	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$, N_2O	/	CH_4, N_2O [Peat fire]	/
set1		to all LUC, except wetl, wetr, wetb, wetd, wets, set2, set3, othl		CO_2 [Settlement model]	CO_2, N_2O_{dir}, N_2O_{indir}	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$, N_2O [3]	/	/	to forl, CO_2
set1			from all LUC, except wetl, wetr, wetb, wetd, wets, set2, set3	CO_2 [Settlement model]	CO_2, N_2O_{dir}, N_2O_{indir}	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$, N_2O	/	/	from forl, CO_2
set2	x	/	/	/	/	/	/	/	/
set3	x	/	/	/	/	/	/	/	/
setp	x								
setp		to all LUC, except forl, wetl, wetr, wetb, wetd, wets, set2, set3		CO_2 [EF $grassland_{annual}$]	CO_2, N_2O_{dir}, N_2O_{indir}	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$, N_2O	/	/	/
setp			from all LUC, except forl, wetl, wetr, wetb, wetd, wets, set2, set3	CO_2 [EF $grassland_{annual}$]	CO_2, N_2O_{dir}, N_2O_{indir}	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$, N_2O	/	/	/
othl	x			/	/	/	/	/	/
othl		to all LUC, except wetl, wetr, wetb, wetd, wets, set2, set3		/	CO_2, N_2O_{dir}, N_2O_{indir}	CO_2+DOC, $CH_{4_org_soil}$+ $CH_{4_ditch\ org_soil}$, N_2O [3]	/	/	CO_2, only to forl
othl			/	/	/	/	/	/	/

1) For definitions, cf. Table 335, Chapter 6.1.2

2) For all pools and land-use categories, identification of areas and emissions calculation are carried out at the federal state level

3) N_2O, CRF 3.D.1.f, in the case of LUC leading to gra1 and other cropland categories (cro*)

4) N_2O, CRF 3.D.1.e, in the case of LUC from other cropland categories (cro*)

5) N_2O, CRF 3.D.1.f

6) In the case of LUC to forl, only 50% biomass loss

7) Only in the case of LUC to wet4

8) N_2O, CRF 3.D.1.e, in the case of LUC to other cropland categories (cro*)

9) Exceptions: Heap/open-pit mine/landfill to forest land are all possible

Figure 54, Figure 55 and Figure 56 provide an overview, for the present 2026 submission, of the development over time of greenhouse gas emissions (sum of CO_2, CH_4 and N_2O emissions, as CO_2 equivalents) in categories 4.A-4.E, differentiated by subcategories, pools and greenhouse gases. The x axis consists of all the years covered by the report, while the y axis consists of a scale for emissions (positive values) and removals (negative values) expressed in kilotonnes of CO_2 equivalents (kt CO_2-eq.)

The considerable emissions changes in the years 1990, 2002, 2008 and especially 2018 result from use of forest biomass emission factors that have been highly modified to account for wood use. During the inventory period 1991 to 2001, wood use decreased sharply relative to its level in 1990 (harvest increased in 1990 due to work to clean up storm damage). From 2002 to 2008, wood use increased again, and then a slight decrease occurred in 2008 (cf. Chapter 6.4.2.2.1). The dramatic decline in forest biomass in 2018 and the subsequent years is the result of forest damage tied to the severe drought that occurred in these report years. These substantial changes to forest biomass were recorded during the latest National Forest Inventory (2022) and verified by a quantified evaluation of the survey. As a result of these calamities, the LULUCF sector provided a veritable source of greenhouse gases in 2024, with net emissions of approx. 57.8 Mt CO_2-eq. Combined with the emissions from mineral forest soils, this leads to markedly greater amplitudes in the curve of the net sectoral sum when compared with the previous submissions. Across the entire reporting period, the LULUCF sector mainly acted as a source of greenhouse gases with, particularly in recent years, a clearly increasing trend (cf. Figure 54 and Figure 54).

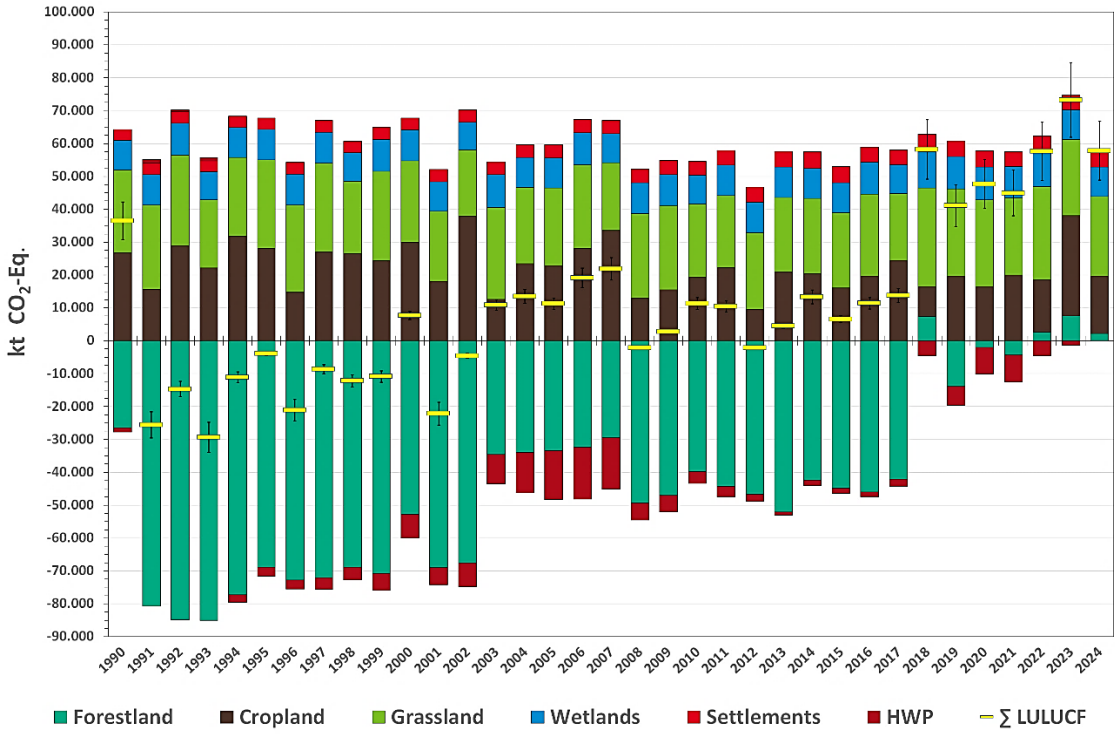
The time series reflect the changes in forest biomass and the trends in land-use changes (cf. Chapter 6.3.1.5). The land-use changes were determined on the basis of data sets for the reference years 1990, 1995, 2000, 2005, 2010, 2015, 2020 and 2024 (cf. Chapter 6.3.1). Between the reference years, the land-use changes were interpolated on a linear basis, resulting in constant average land-use changes between the reference years (cf. Table 347). Land use before the year 2010 was determined by extrapolation using stochastic methods (cf. Chapter 6.3.1.2.2).

The course of net emissions shows that the LULUCF sector functioned as a net source of greenhouse gases in most of the years in the period 1990 to 2024, mostly since the year 2000. The main sources are emissions from agriculturally used areas in the land-use categories Cropland and Grassland. These two categories exhibit consistently high emissions over the years from drained organic soils, and in net terms, to a lesser extent, from mineral soils. The land-use category Wetlands contributes – not inconsiderably – to the total sum of GHG emissions, primarily by way of industrial peat extraction and methane emissions from artificial water bodies. The forest C pools play an ambivalent role over time. With their mostly significantly negative emissions, the pools dead organic matter (dead wood and litter), just like timber products, counteract the pool's source function by increasing this carbon storage medium. Nonetheless, the path of the LULUCF emission curve is essentially determined by the biomass pool and, in particular, the forest land and cropland use categories (Figure 54 and Figure 55).

Also in net terms, the predominating greenhouse gas in this sector is carbon dioxide (CO_2). Emissions of this gas from Germany's biogeosphere are more than offset by retention of it over time in the same biogeosphere. As a result, the LULUCF sector often served as a net sink for this greenhouse gas. The recent forest damage dramatically altered this situation (Figure 55). Emissions of methane (CH_4) and nitrous oxide (N_2O), as percentages of the total sum of GHG, are significant only in net terms, with methane emissions having a significantly greater impact on the climate than nitrous oxide emissions. The reason for this is that methane emissions from artificial water bodies continue to be at high levels. Detailed descriptions of the emissions and

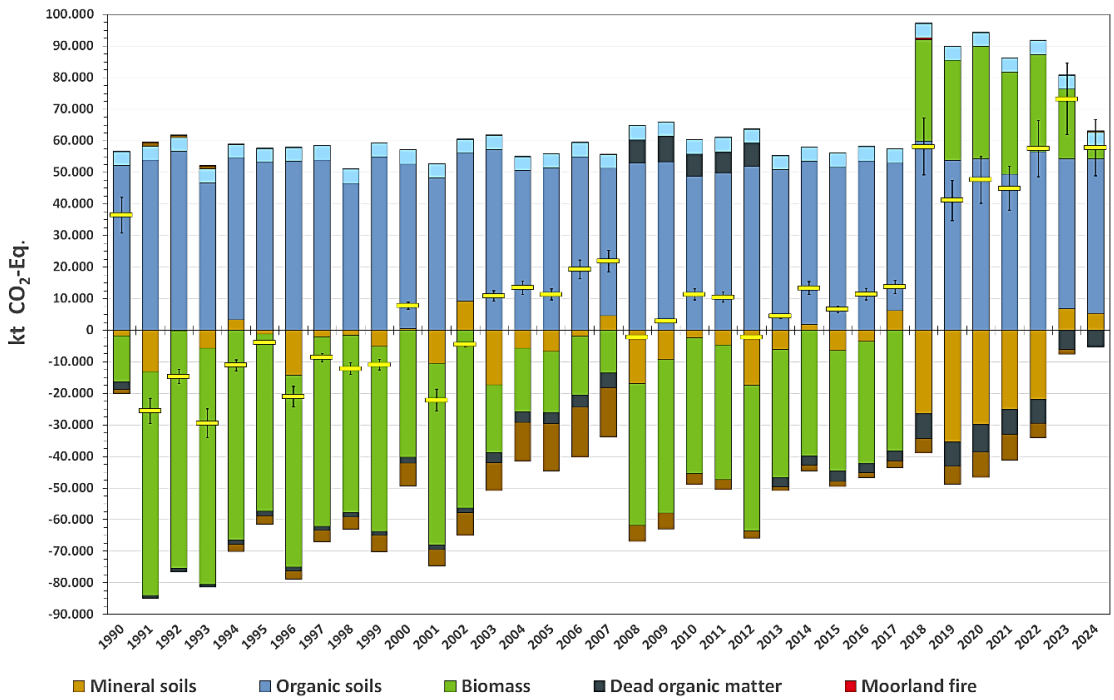
their time series are presented in the relevant chapters for the land-use categories (Chapter 6.4.1, Chapter 6.5.1, Chapter 6.6.1, Chapter 6.7.1, Chapter 6.8.1, and Chapter 6.10.1).

Figure 53: Time series for GHG emissions and removals (sum of CO_2, CH_4 and N_2O) [kt CO_2-eq.] in the LULUCF sector since 1990, by subcategories



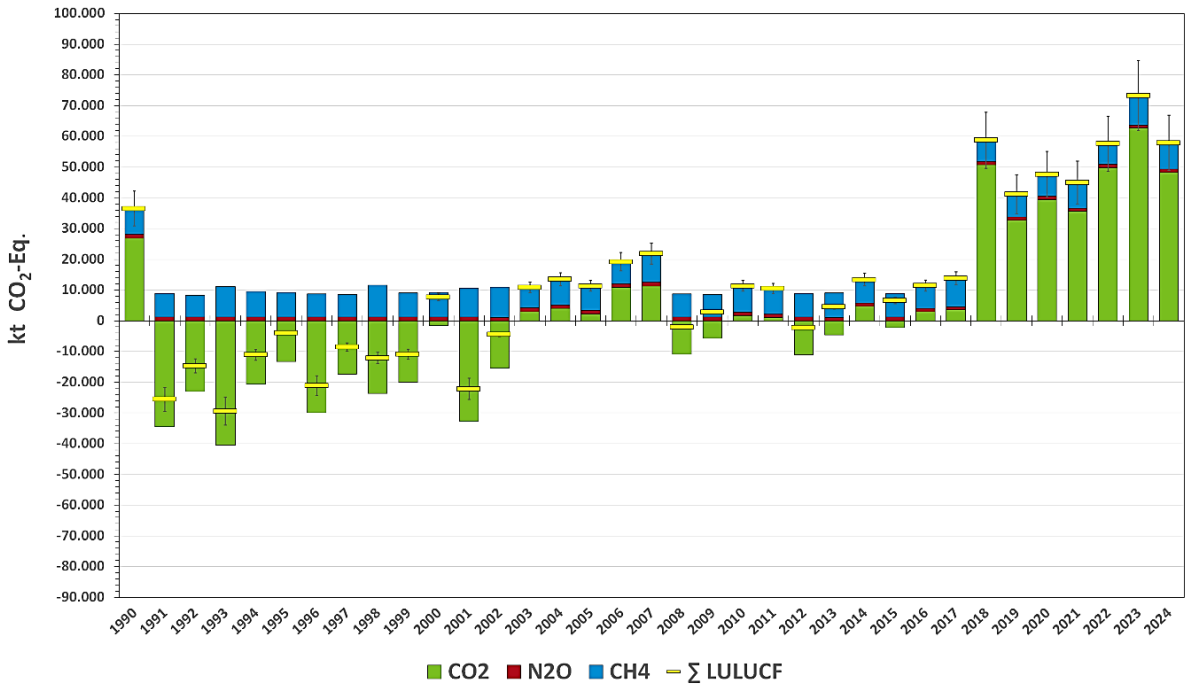
Source: own illustration, Thünen-Institut

Figure 54: Time series for GHG emissions and removals (sum of CO_2, CH_4 and N_2O) [kt CO_2-eq.] in the LULUCF sector since 1990, by pools



Source: own illustration, Thünen-Institut

Figure 55: Time series for GHG emissions and removals (sum of CO_2, CH_4 and N_2O) [kt CO_2-eq.] in the LULUCF sector since 1990, by greenhouse gases (GHG)



Source: own illustration, Thünen-Institut

The total uncertainty of the German LULUCF inventory (not including harvested wood products) is 11.2%. The relevant details are presented in the relevant chapters for the individual land-use categories and in Chapter 6.1.2.10.

6.1.2 Methodological basis

Germany adopted the land-use-system scheme that the 2006 IPCC Guidelines require for CRF Sector 4. The implementation is outlined in Table 320, and further explanations can be found in Chapter 6.2 (cf. also Chapter 6.3).

Table 320: Correlation of the German reporting categories with the IPCC land-use categories

IPCC category	German land-use category or subcategory		
	Abbreviation	Full description	Description
4.A Forest Land	forl	Forest Land	Deciduous, coniferous and mixed forest land
4.B Cropland	Cropland	Total consisting of $cropland_{annual}$, hops cultivation areas, vineyards, orchards, tree nurseries, Christmas tree plantations, short-rotation plantations	
	cro1	$Cropland_{annual}$	Areas for cultivation of crops and vegetables
	croh	Hops	Refers to agricultural areas that are equipped with special fixtures for hops cultivation
	crow	Vineyards	Vineyards are agricultural areas that are equipped with special fixtures for planting grapevines
	croo	Orchards	Orchards are areas used primarily for intensive fruit cultivation and contain fruit trees and shrubs. Orchards differ from meadow orchards in that they are monocultures and uniformly and densely planted.
	crot	Tree nurseries	Tree nurseries are areas on which woody plants are grown from seeds, shoots and cuttings, and are transplanted multiple times in the process.
	crox	Christmas tree plantations	Christmas tree plantations are agricultural areas that are planted primarily with Christmas trees.
	cros	Short-rotation plantations	Short-rotation plantations are areas on which trees are planted with the aim of producing a wood harvest in the near term; stocks in these plantations have rotation periods no longer than 20 years.

IPCC category	German land-use category or subcategory		
	Abbreviation	**Full description**	**Description**
4.C Grassland	Grassland	Total of grassland in the strict sense, woody grassland and hedges	
	gra1	Grassland in the strict sense	Grassland in the strict sense (meadows, pastures, mowed pastures, wet grassland, rough pastures, etc.)
	gra2	Woody grassland	Areas that contain scattered trees, groups of trees, bushes and shrubs and that do not fall under the definition of Forest Land or Grassland in the strict sense.
	gra3	Hedges	Hedges consist of shrubs (and trees, in some cases) growing in dense linear formations (with either one or multiple rows)
4.D Wetlands	Wetlands	Total of terrestrial wetlands, natural water bodies, peat extraction, standing and flowing artificial water bodies and water bodies used for navigation	
	wett	Terrestrial wetlands	Terrestrial wetlands that do not fall into one of the other land-use categories (such as semi-natural peatlands)
	wetl,wtr	Natural water bodies	Natural water areas (wetl) and watercourses (wetr)
	wetp	Peat extraction	Areas located on organic soils that are used for peat extraction
	wetb	Standing artificial water bodies	Artificial standing water bodies (water areas), such as reservoirs, quarry ponds and other types of ponds, lakes formed from open-pit mines, and artificial freshwater pools of all kinds (exception: wastewater treatment facilities)
	wetd	Flowing artificial water bodies	artificial, flowing water bodies (watercourses), such as drainage ditches for water management (exception: drainage ditches on organic soils)
	wets	Artificial water bodies used for navigation	Harbour basins along inland waterways, and canals for shipping
4.E Settlements	Settlements	Total comprising settlements and roads	
	set1	Buildings and open areas	Areas used for residential, production and traffic purposes, and urban green areas and other areas used for rest and recreation
	set2	Roads	Traffic routes for road vehicles and pedestrians
	set3	Railway track beds	Areas required for railway transports
	setp	Ground-mounted photovoltaic plants	Areas on which photovoltaic plants were erected
4.F Other Land	othl	Other Land	Vegetation-free, unmanaged areas

Basic elements of the LULUCF inventory, and the steps required to prepare it

1. Land-use matrix$_{annual}$ [Area$_{_ann}$]: Annual calculation of the total areas for the subcategories land use remaining and land-use change, in each of the categories *Forest Land, Cropland$_{annual}$, Hops, Vineyards, Orchards, Tree nurseries, Christmas tree plantations, Short-rotation plantations, Grassland (in the strict sense), Woody grassland, Hedges, Terrestrial wetlands, Natural water bodies, artificial flowing water bodies, artificial standing water bodies, artificial water bodies used for navigation, Peat extraction, Buildings and open areas, Roads, Railway track beds, Ground-mounted photovoltaic plants and Other land*, and differentiated by mineral and organic soils for all time series. The relevant land uses, and the specific areas assigned to them, were explicitly determined for the years 2010, 2015, 2020 and 2024. The areas applying to the periods between these years were obtained by linearly interpolating the calculated areas in accordance with the IPCC Guidelines 2006 IPCC Guidelines IPCC (2006a), Vol. 4 Chapter 3 Figure 3.1) (cf. Chapter 6.3.1). For the years before 2010, information from 2010 and 2015 is used to extrapolate back to 1970. First, the transition probabilities are determined for each land-use change. The transition probabilities are then used to select points in the inventory model stochastically at five-year intervals, to which the corresponding land-use change is then assigned (cf. Chapter 6.3.1.2.2).

2. Emission factors for carbon stocks, nitrous oxide and methane emissions in the year of a land-use change [EF$_{ann}$]: The emission factors for the various pools are calculated

individually for each survey point, and separately for each land-use category (Chapter 6.1.2 ff). The carbon stocks, nitrous oxide emissions and methane emissions per area unit are not constant over time.

3. Carbon-stock changes for the annual land-use changes [E_{ann}] are calculated using the formula

Equation 25:

$$E_{ann}\ [\text{e.g. t C}] = EF_{ann}\ [\text{e.g. t C/ha}] * Area_{ann}\ [\text{ha}]$$

under the assumption that, in each case, the entire carbon-stock change occurs in the year of the land-use change.

4. Introduction of a maximum twenty-year conversion period [$Area_{20y}$] (effective conversion period): The land-use matrix calculation is referenced to the year 1970 to make it possible to determine land-use change areas for years prior to the actual reporting period (cf. Chapter 6.3.1). Identified conversion areas are assigned to the corresponding land-use-change category in the year in which the land-use change takes place, and they remain in that category for a maximum of 20 years. At the end of the 20-year period, the areas are assigned to the remaining category within the final use category. Consequently, as of the second report year, the areas in the remaining categories are smaller, and those in the conversion categories larger than the corresponding areas in an annual land-use matrix. The relevant areas are shown in the CR tables and in Table 338 and Table 339. When areas undergoing a 20-year conversion period again undergo land-use changes within that period, the areas are assigned – with immediate effect as of the time of the land-use change – to the new conversion category and they enter a new 20-year conversion period.

5. Emission factors [EFs] and implied emission factors [IEFs] for the twenty-year conversion period [IEF_{20y}]: These factors are listed in the CRF tables. Annual emission factors are converted into emission factors and implied emission factors that are appropriate for the land-use matrix areas with 20-year conversion periods. After accounting for the mineral and organic soil areas for emissions from pools, the conversion of EF_{ann} to IEF_{20y} results in adjusted, i.e. implicit, IEFs. Even though the absolute emissions remain unchanged, the IEFs are affected by the areas' annual net changes and the various IEF_{20y} of the mineral soils in the conversion categories due to new land-use changes within the 20-year conversion period. In the process, the following equations are used:

   a. Mineral soils: The total carbon-stock change resulting from the land-use change is spread linearly over the 20 year conversion period using the formula

Equation 26:

$$IEF_{20y} = EF_{ann} / 20$$

, i.e. only one-twentieth of the total emissions is applied annually. As a result of the introduction of the effective conversion period, the carbon stocks in mineral soils have to be recorded at every survey point, since these stocks, in combination with the relevant new final value, serve as the basis for calculating the new EF_{ann} in the case of new land-use changes within the 20-year conversion period (cf. Chapter 6.1.2.1.1).

b. Organic soils I: In the land-use category Forest Land, the same quantities of CO_2, CH_4 and N_2O are emitted each year; this applies both to the conversion categories and to the remaining category of the new land use. This also applies for the N_2O emissions of all other land-use categories; $IEF_{20y} = EF_{ann}$.

c. Organic soils II: For organic soils areas under Cropland (including all subcategories), Grassland (including all subcategories), Wetlands (including all subcategories) and Settlements, CO_2 and CH_4 emissions are calculated annually with response functions and as a function of the groundwater level (cf. Chapters 6.1.2.2 ff).

d. Net carbon-stock changes and carbon-stock increases and decreases in the biomass of annual herbaceous plants and dead organic matter ($Cropland_{annual}$, Hops, Grassland (in the strict sense), Water bodies, Peat extraction): All emissions are completely accounted for in the year of the land-use change according to the equation

Equation 27:

$$IEF_{20y} = E_{ann} / [Area_{20y}]$$

e. Net carbon-stock changes and carbon-stock increases in biomass and dead organic matter and in connection with land-use changes to Forest Land; Vineyards and Orchards; Christmas tree plantations, tree nurseries, and short-rotation plantations; Woody Grassland; Wetlands; and Settlements: The total carbon-stock change resulting from a land-use change is determined with the equation $IEF_{20y} = EF_{ann}$, i.e. the carbon sink is allocated to the entire land-use change area each year.

f. N_2O from loss of organic matter in mineral soils as a result of land-use changes to Cropland: The method used is the same as the one used for calculation of carbon-stock losses in mineral soils. The entire carbon-stock change resulting from land-use change is distributed linearly throughout the 20-year conversion period in accordance with the formula

Equation 28:

$$IEF_{20y} = E_{ann} / Area_{20y}$$

In other words, only one-twentieth of the total emissions is applied each year. The same procedure is used in the case of new land-use changes within the 20-year period.

6. The total carbon-stock changes for areas with twenty-year conversion periods are calculated in accordance with the formula

Equation 29:

$$E_{20y}\ [kt\ C] = IEF_{20y}\ [t\ C/ha] * Area_{20y}\ [kha]$$

7. Calculation of CO_2 emissions on the basis of carbon-stock values by multiplying carbon-stock changes by the factor -44/12.

8. Calculation of N_2O emissions from nitrogen values by multiplying the nitrogen-stock changes by the factor -44/28; the N_2O values are converted into CO_2 equivalents using the factor 265 (GWP 100 pursuant to IPCC AR5).

9. The CH_4 emissions are converted into CO_2 equivalents using the factor 28 (GWP 100 pursuant to IPCC AR5).

The 2025 submission was compiled in accordance with the following provisions:

- 2006 IPCC Guidelines (IPCC, 2006a)
- 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (IPCC, 2014)
- 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands (IPCC et al., 2014)
- 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2019)

The key inventory improvement measures that were carried out for the present submission and that led to recalculations are shown in Table 21 in Chapter 6.1.3.4.2 .

Apart from these changes, the methods, data sources and emission factors used in the previous submission were again used.

Implementation of the inventory model

The calculations for determination of all emissions and inventory-relevant values for Germany's LULUCF sector are carried out completely automatically using a digital program system together with a combined geoinformation/database system. The inventory model LULUCFmod (Version 1.4.0) is implemented as a package in R (The R Core Team, 2025) and relies heavily on the R packages data.table (Barrett et al., 2025) and Rcpp (Eddelbuettel & François, 2011) to ensure sufficient performance. The R packages DBI[78] (Wickham, Müller, et al., 2025) and RPostgres(Wickham, Ooms, et al., 2025) serve as the interface for the LULUCF database. The software is administrated in an internal version control environment[79] and continually improved in line with the requirements from reviews and the inventory plan.

6.1.2.1 Carbon emissions from mineral soils (4.A to 4.F)

6.1.2.1.1 Overview of methods used

The area of the mineral soils in the transfer categories was calculated as the difference between the relevant total areas and the areas covered by organic soils (Chapter 6.1.2.1.9).

Changes in mineral soil carbon stocks due to changes in land use

Changes in carbon and nitrogen stocks in mineral soils are calculated, pursuant to Equation 2.25 in the 2006 IPCC Guidelines (IPCC, 2006a), as the difference between the stocks prior to relevant land-use changes and the stocks after the changes. The emission factors are country-specific. For the land-use categories Forest Land, $Cropland_{annual}$ and Grassland, they were taken from maps of the carbon and nitrogen stocks of Germany's mineral soils. The maps are based on the results of soil inventories for forest land and agricultural land that, with the help of various computer-based methods, were regionalised and georeferenced using a complete coverage approach that takes account of numerous site factors (such as climate, topography, geology, pedology, land use) (cf. Chapter 6.4.2.5.3 and Chapters 6.1.2.1.4 and 6.1.2.1.5).

[78] DBI https://dbi.r-dbi.org/

[79] GitLab https://about.gitlab.com/

Based on data from the German Agricultural Soil inventory, carbon stocks of mineral soils were determined to a depth of 30 cm for the land-use categories Other Land and Terrestrial Wetlands (cf. Chapter 6.1.2.1.7). For the subcategory Buildings and Open Areas in the category Settlements, country-specific carbon stocks based on the results of the Forest Soil and Agricultural Soil inventories were derived as a function of the direction of the land-use change, the previous use and the degree of soil sealing on the areas concerned. As a result, the reporting on mineral soils applies a Tier 2 or Tier 3 method.

In the category Wetlands (4.D), mineral soils occur in the subcategories Terrestrial Wetlands and Water bodies. In the case of land-use changes to *water bodies*, no carbon-stock changes are assumed. For land-use changes from Water bodies to other land-use forms, the difference between the previous use as Water bodies and the final use is applied, if it is known. If it is not known, no changes are assumed.

For each conversion category, the carbon-stock changes in mineral soils resulting from land-use changes are calculated as the difference between the carbon stocks of the final land-use category and the carbon stocks of the initial land-use category. For Forest Land, $Cropland_{annual}$ and Grassland, the final values are taken from the relevant maps, which are updated annually. Pursuant to IPCC Default (IPCC, 2006a), the total changes are distributed on a linear basis over a period of 20 years. The sum of all carbon-stock changes from land-use changes in Germany's mineral soils is calculated for a 20-year period as follows:

Equation 30:

$$\Delta C = C_{final} - C_{initial}$$

- ΔC: Change in carbon stocks as a result of land-use changes in mineral soils of a conversion category [t C $(20*a)^{-1}$]
- C_{final}: Mineral soil carbon stocks [t C] in the final category
- $C_{initial}$: Mineral soil carbon stocks [t C] in the initial category

Land-use changes leading to Settlements are an exception in this regard. In these cases, in a one-time step and only in the year of use changes, 11% of the carbon stocks in the mineral soils of the previous use are applied as an emission (Chapter 6.1.2.1.6).

To take account of the 20-year conversion period, the total stock change for each conversion category in question (EF_ann) is divided by 20. This yields the implied emission factors for the conversion categories for land-use changes leading out of a remaining category (IEF_20y).

Equation 31:

$$\Delta C_i = \frac{(C_{final,i} - C_{initial,i})}{20}, i = 0$$

- ΔC_i: Change in mineral soil carbon stocks in year i following a land-use change [t C a^{-1}]
- $C_{final,\,i}$: Final soil organic carbon stocks in the final category in year i following the land-use change [t C]
- $C_{initial,\,i}$: Current soil organic carbon stocks in the initial category [t C] in year i following the land-use change

- i: Year following the land-use change (0-19)

The new soil organic carbon stocks are then obtained as the sum of a) the current soil organic carbon stocks applying to the initial use and b) the calculated stock change ($\Delta C_i + C_{initial,\,i}$).

Areas affected by land-use changes remain in a conversion category for at least 20 years. They then attained the final category's carbon-stock level and are assigned to the relevant remaining category. As a result of the introduction of the effective conversion time concept, an area affected by a land-use change is assigned to its relevant new conversion category right at the time use changed. This is done regardless of how long the area has already been in a conversion category. Since the carbon-stock changes pursuant to the above equation depend, in each case, on the initial and final stocks involved, the carbon stocks of mineral soils have to be known for all grid points and for all relevant times. While final stocks (C_{final}) are given by the relevant soil map, initial stocks are variable. In each case, they represent the value reached until the next land-use change in the previous conversion category. Carbon-stock changes for areas undergoing early removal from conversion categories are also calculated using the above algorithms, although $C_{initial}$ then represents the current mineral soil carbon stocks attained in the previous conversion category up to the time of the next land-use change, as measured at the relevant detection point. The carbon-stock changes calculated using this method are distributed over 20 years: $\Delta C/20$ thus yields the annual rate of change that is added to the current initial soil organic carbon stocks until the time of the next land-use change or until the area transitions into the relevant remaining category. Ultimately, each implied emission factor is the mean of all IEF_20y for a conversion category in a given report year.

Changes in mineral soil carbon stocks due to land use

In the remaining categories of the land-use categories *Forest Land*, *Cropland* and *Grassland*, the changes in carbon and nitrogen stocks in the topsoil (0-30 cm) of mineral soils is calculated using process models,

- in the Forest Land category on an annual basis as of 2009, using the Yasso model. The resulting soil characteristics maps are updated on an annual, complete coverage basis (Chapters 6.4.2.5 ff).
- in *Cropland* and *Grassland* using the RothC model (Coleman & Jenkinson, 1999) (see below for a description of the model and method); the calculations are made for the entire time series, including ongoing adjustment of the maps of soil carbon stocks.

For mineral soils with no use change in land-use categories 4.D, 4.E and 4.F, it is assumed that the carbon inputs into the soil and carbon extractions from the soil are of equal size, i.e. that the systems are in equilibrium. In the subcategory *Terrestrial Wetlands and Water bodies*, this is due to the fact that these areas are not managed for production purposes; areas of the land-use category *Other Land* are not managed by definition. Regarding settlement areas, the reasons are provided in Chapter 6.1.2.1.6. In the CRF tables, the corresponding spaces are marked with "NA" (in accordance with the requirements of ERT 2021).

Calculation of the changes in carbon stocks in mineral soils beneath Cropland and Grassland using the RothC process model

For the calculation of the changes in soil carbon stocks in the topsoil (0-30 cm) of German cropland and grassland areas as affected by land use/farming, soil properties and local weather conditions, the RothC model (Coleman & Jenkinson, 1999) with calibrated partitioning coefficients pursuant to (Dechow et al., 2019) is used. These coefficients describe the

partitioning of carbon inputs into the pools DPM (decomposable plant material), RPM (resistant plant material) and HUM (humified organic material), thereby allowing the effects of carbon inputs from above- and below-ground harvest residues and various types of organic fertilisers to be specifically taken into account and the degradability of carbon inputs to be recorded. The model is implemented in the sorcering R package (Scherstjanoi & Dechow, 2025) within the R software environment (v.4.5.1, R Core Team 2025) having been evaluated in long-term experiments and long-term soil monitoring areas (Dechow et al., 2019),(Riggers et al., 2019).

The basis for the modelling is the soil map of organic carbon stocks of German cropland and grassland areas (Sakhaee et al., 2022) using data from the first German Agricultural Soil Inventory ((Jacobs et al., 2018); (Poeplau et al., 2020); cf. Chapter 6.1.2.1.4 and Chapter 6.1.2.1.5). The assignment of soils and land use was carried out for the period 1990-2024 on the 100 × 100 m grid of the land-use matrix for emissions reporting. The same applies to the point-based modelling of changes in soil carbon of the permanent cropland soils.

Starting from the original soil map, which represents the SOC stocks of cropland (Chapter 6.1.2.1.4; Figure 66) and grassland soils (Chapter 6.1.2.1.5; Figure 67) in 2014, an initial carbon stock for the year 1970 was derived for each point through inverse modelling with RothC. The inverse derivation of the initial soil carbon stocks was carried out taking into account weather conditions, texture information, carbon inputs from crop residues and organic fertilisers, as well as the assumption that the conceptual pools of RothC were in equilibrium in 1970. Based on the SOC stocks derived for 1970, annual values for the period 1990-2024 were calculated by applying the model in forward mode.

As input, the RothC model needs

1. Weather data: Precipitation, air temperature and potential evapotranspiration

    a. These data are extracted on a monthly basis from grid maps of the German Meteorological Service (DWD Climate Data Center, 2020a, 2020b, 2020c, 2020d) for the sites from the first German Agricultural Soil Inventory.

2. Soil data: Initial soil carbon stocks, clay content and inert soil carbon pool

    a. These originate from the first German Agricultural Soil Inventory (BZE-LW I) (Poeplau et al., 2020). The inert soil carbon pool was calculated in line with (Falloon & Smith, 2000).

3. Management data: Crop rotations, cover crops, C inputs from harvest residues and organic fertilisation

    a. Crop rotations of main crops were derived from InVekoS data, remote-sensing data (Schwieder et al., 2024); (Tetteh et al., 2024), and agricultural statistics (Statistisches Bundesamt, FS 3, R 3) using a Bayesian approach. Here, agricultural statistics at administrative district level were used to obtain the annual shares of crop types, with probabilities derived from InVekoS and remote-sensing products (Schwieder et al., 2024); (Tetteh et al., 2024) to define the crop distribution. In addition, data from InVekoS and remote-sensing products (Tetteh et al., 2024); (Schwieder et al., 2024) were used to define the annual and point-specific occurrence probabilities of certain crop types.

    b. The crop-specific shares of retained or removed crop residues were determined for each federal state, based on crop residue management data from the first German Agricultural

Soil Inventory. These shares are then used to randomly distribute the removal or integration of crop residues in each administrative district.

c. The definition of crop-specific growth periods of agricultural crops is based on monthly observations by the German Meteorological Service across Germany (reference phenology) (DWD, 2024b).

d. The C inputs from crop residues were quantified using allometric functions(Franko et al., 2011), which were complemented by an approach that distinguishes between above- and below-ground inputs (Dechow et al., 2019) using crop yields as the input.

e. The share of cover crop categories at administrative district level was quantified using agricultural statistics. Depending on the derived main crop rotations, the cover crops were randomly allocated to locations with suitable time frames for their cultivation. The cover crop types reported in the two soil inventories were matched to the cover crop categories used in the agricultural statistics. Crop-specific information on residue management of cover crop types from the German soil inventory was used to define the distribution of residue management practices. The carbon input from cover crop residues was quantified using national average values of the above- and below-ground biomass of cover crop species (Entrup et al., 2018).

f. The amount of organic fertiliser calculated at administrative district level using the Py-GASEM model (Vos et al., 2026) was distributed onto agricultural land using the data on fertiliser application determined at municipal level. The distribution of organic fertiliser application rates onto cropland and grassland was adjusted based on the reported fertiliser application rates in the first German Agricultural Soil Inventory and the resampling of the Agricultural Soil Inventory.

g. Given that no cultivation data were available for the periods 1970-1990 and 2024-2025, the annual C inputs were estimated by assuming the average carbon inputs for 1990-2024 and 2020-2024, respectively.

h. In the case of grassland, the C inputs were calculated based on grassland category crop residues (in meadows, pastures, mowed pastures), the number of cuts and the period and intensity of grazing (Jacobs et al., 2020).

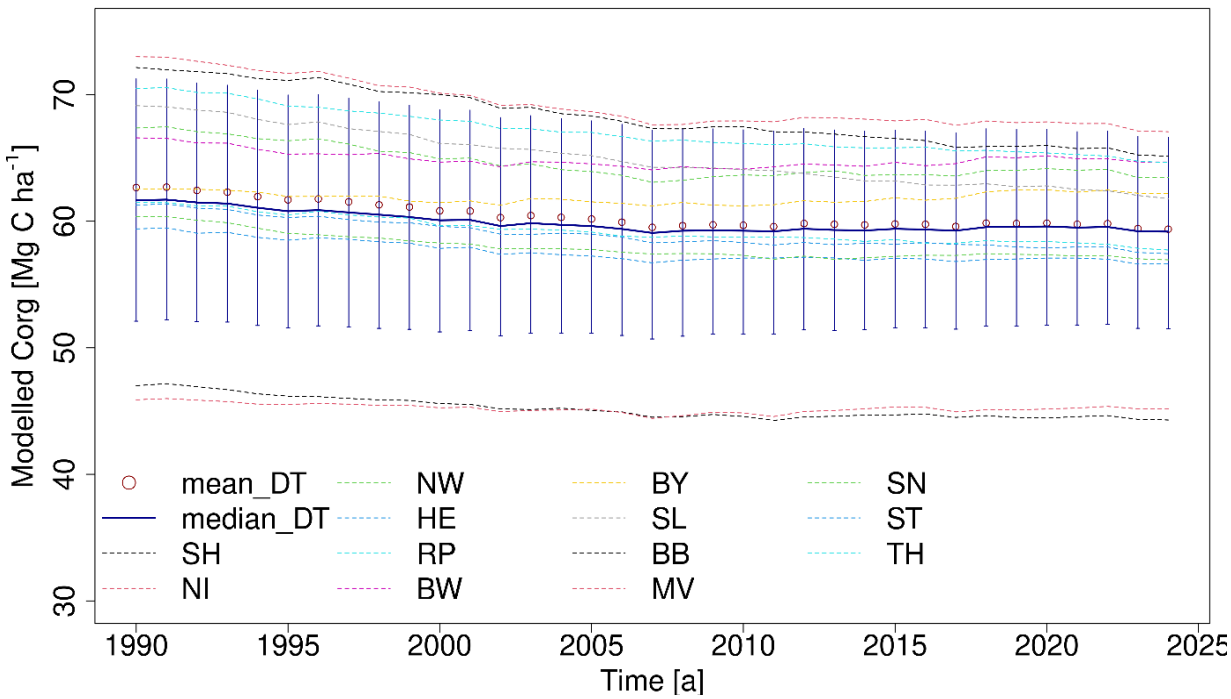
Estimation of carbon-stock change in mineral soils under cropland.

Based on a RothC simulation, C_{org} stocks decline between 1990 and 2024 under permanent cropland use at an average rate of 0.1 Mg C ha^{-1} a^{-1} from (Table 321). The time series of modelled C_{org} stocks show higher losses at the start of the simulation period (Figure 56); they weaken between 2005 and 2010, after which they largely remain at a constant level (Table 321; Figure 56). However, this trend is not uniform and varies markedly between individual federal states.

Table 321 **Average carbon stocks of mineral soils under cropland [t C ha^{-1}] and their change over time, together with the resulting rates of change [t C ha^{-1} a^{-1}] and the number of points under cropland used in the calculation.**

	Average soil carbon stocks [t C ha^{-1}]			N ≙ ∑area [ha]	Average change rate of carbon stocks (ΔC t^{-1}) [t C ha^{-1} a^{-1}]		
	1990	2015	2024		1990-2024	1990-2015	2015-2024
SH	72.71	66.68	65.24	566,593	-0.22	-0.25	-0.16
NI	73.48	68.07	67.14	1,648,589	-0.19	-0.23	-0.1
NW	67.74	63.62	63.45	986,336	-0.13	-0.17	-0.02
HE	59.54	56.92	56.62	464,115	-0.09	-0.11	-0.03
RP	61.7	58.41	57.86	338,271	-0.11	-0.14	-0.06
BW	66.87	64.34	64.68	780,518	-0.06	-0.11	0.04
BY	62.64	61.56	62.21	1,768,074	-0.01	-0.04	0.07
SL	69.47	63.17	62.04	27,427	-0.22	-0.26	-0.13
BB	47.14	44.68	44.35	922,081	-0.08	-0.1	-0.04
MV	46.05	45.18	45.17	928,535	-0.03	-0.04	0
SN	60.39	57.11	57.03	612,092	-0.1	-0.14	-0.01
ST	61.42	58.26	57.53	940,414	-0.11	-0.13	-0.08
TH	70.65	65.8	64.74	577,116	-0.17	-0.2	-0.12
DT	**62.9**	**59.71**	**59.42**	**10,560,161**	**-0.1**	**-0.13**	**-0.03**

Figure 56: **Time series of modelled C_{org} stocks [t C ha^{-1}] for Germany (DT) and the individual federal states**

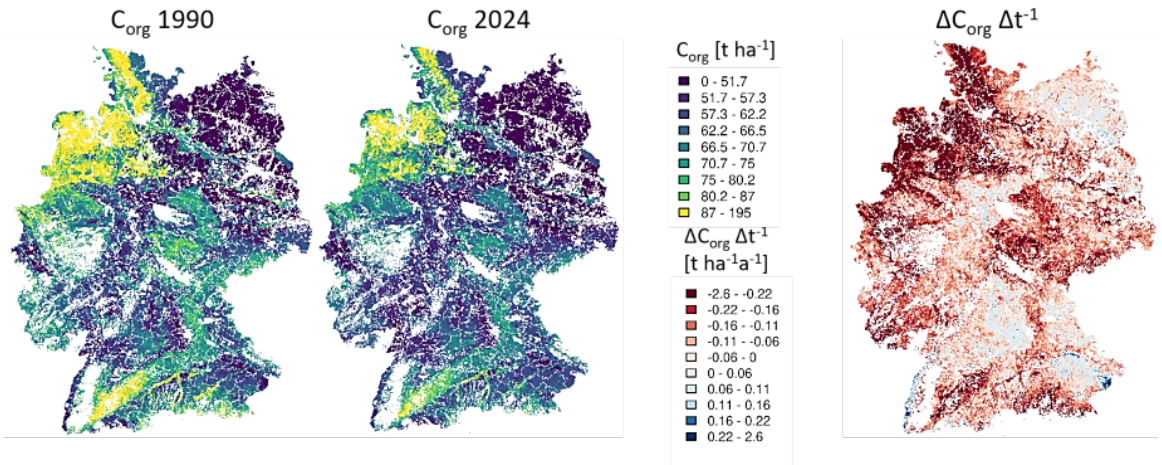


Source: own illustration, Thünen-Institut

There are several reasons for the curve shape:

- An imbalance between the SOC stocks of the basic SOC map for cropland (Sakhaee et al., 2022) and the quantified carbon inputs. Through inverse modelling, therefore, a higher, original SOC stock for most sites is estimated for the year 1970, which accounts for the general C_{org} loss between 1990 and 2014. Since the modelled C_{org} changes correlate with the regionalised C_{org} values of the 2014 map, areas with comparable high or low C_{org} stocks exhibit similar loss or gain rates (Figure 57).

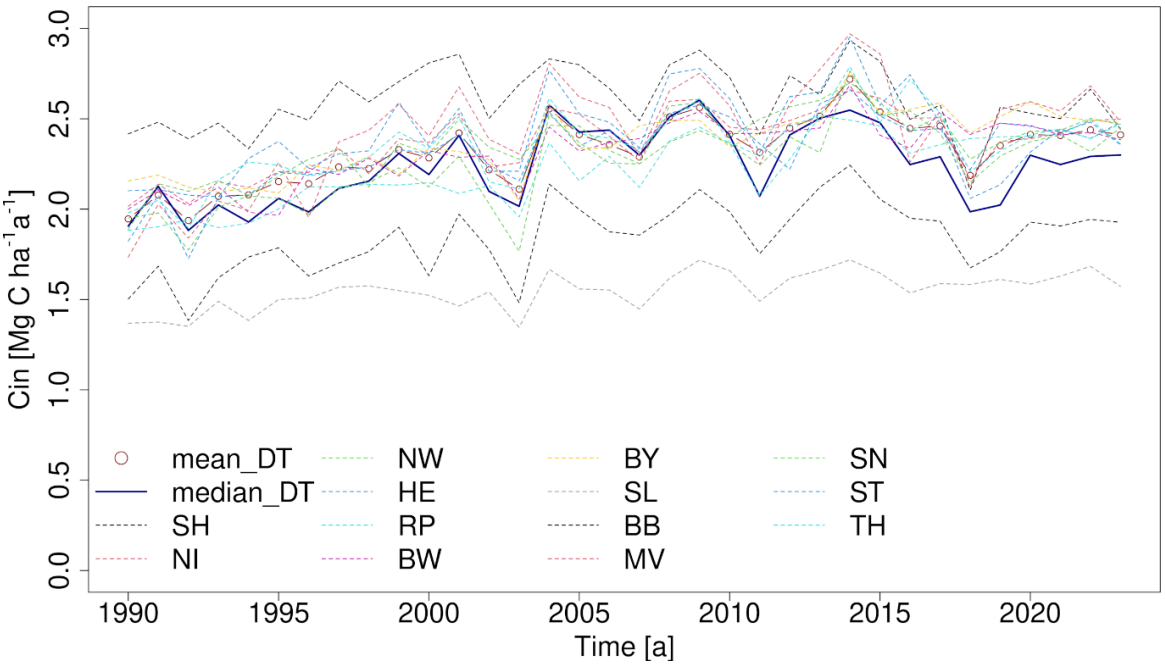
Figure 57: Modelled C_{org} stock for 1990 and 2024 [t C ha^{-1}] and rates of change between these years [t C ha^{-1} a^{-1}].



Source: own illustration, Thünen-Institut

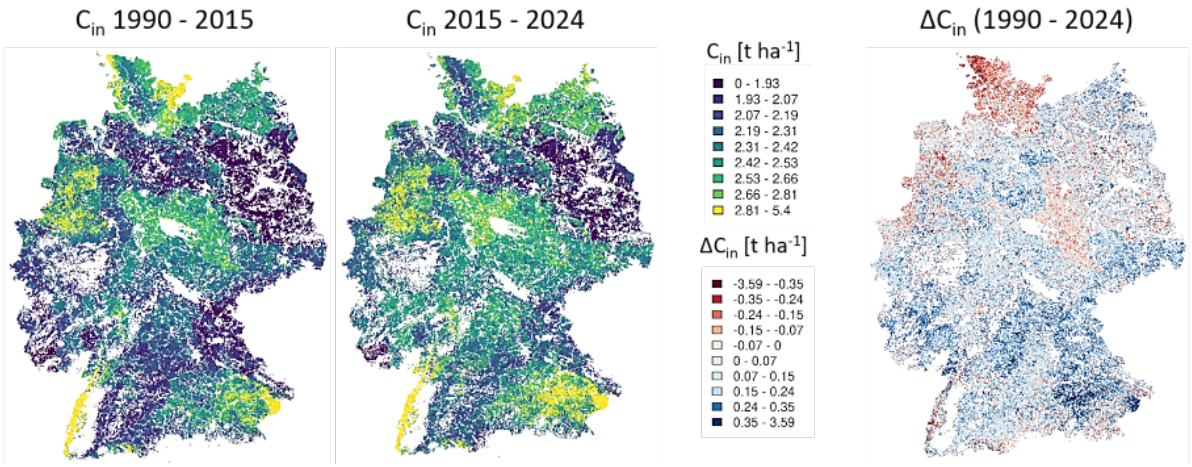
- Carbon inputs from crop residues of the main crops increase from 1990 to 2005, after which they vary strongly while remaining at a similar level (Figure 58;Figure 59).

Figure 58: Estimated carbon input from main crops [Mg C ha^{-1} a^{-1}] for Germany (DT) and the federal states



Source: own illustration, Thünen-Institut

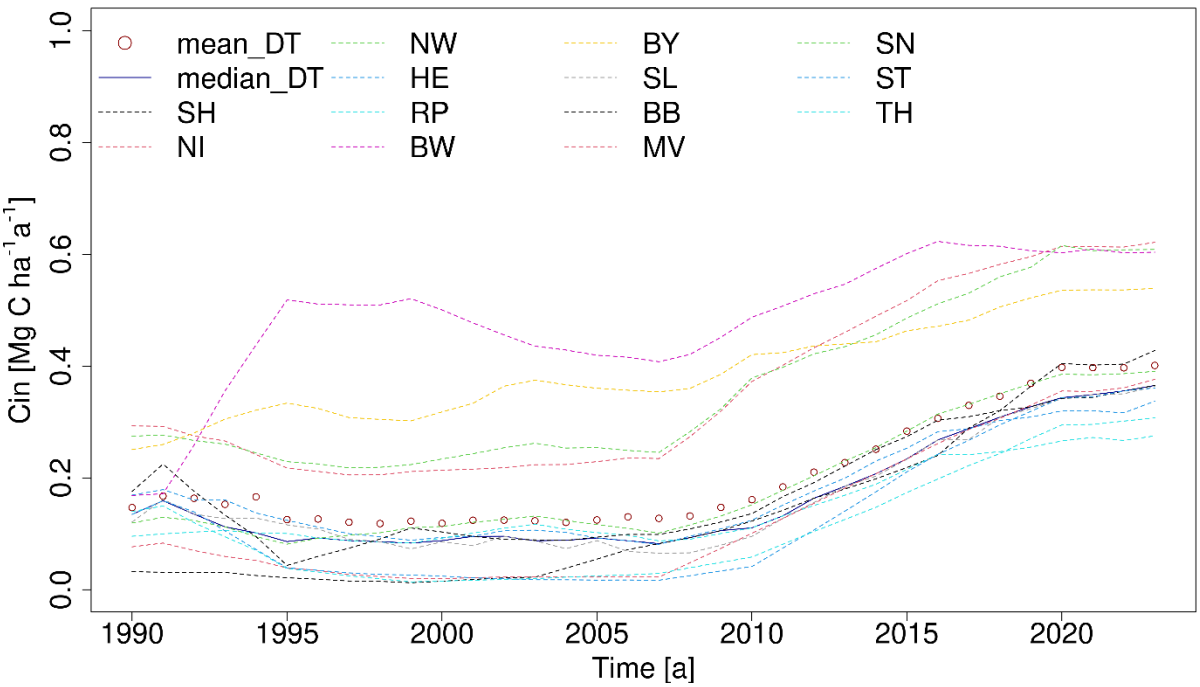
Figure 59: Estimated average carbon input from main crops [t C ha^{-1} a^{-1}] before and after 2014



Source: own illustration, Thünen-Institut

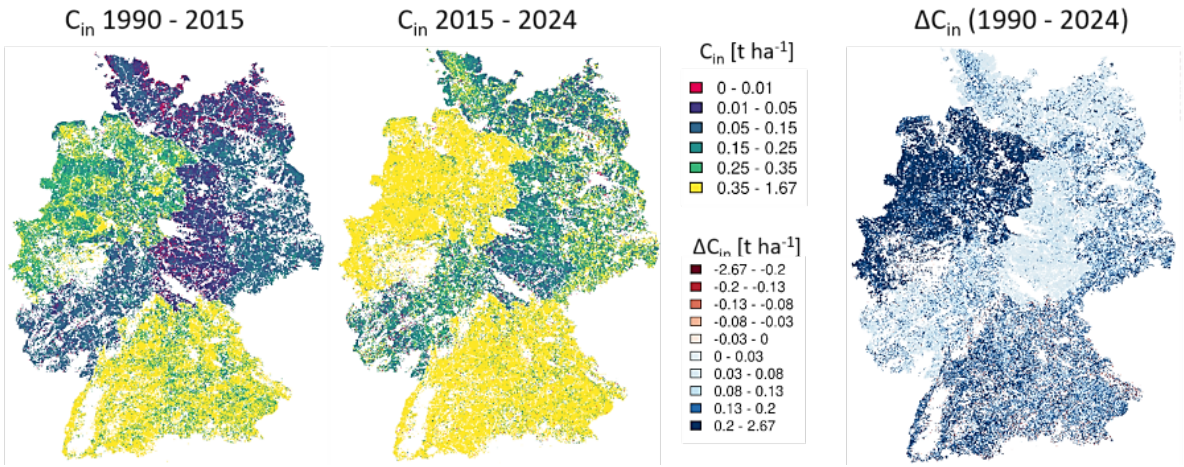
- Clear increase in carbon inputs from cover crop cultivation since 2007 after an initial period (1990-2007) of largely constant values (Figure 60; Figure 61). In RothC the increase in cover crop cultivation also affects the soil carbon mineralisation rate because the cover crop extends the period of soil cover. For these reasons the modelled time series of soil organic carbon stocks in some federal states show a sharp increase from 2007 (Fig. 1). This is also the main cause of the development of soil carbon stocks over the period (Figure 56).

Figure 60: Estimated average carbon input from main crops [Mg C ha^{-1} a^{-1}] for Germany (DT) and the federal states



Source: own illustration, Thünen-Institut

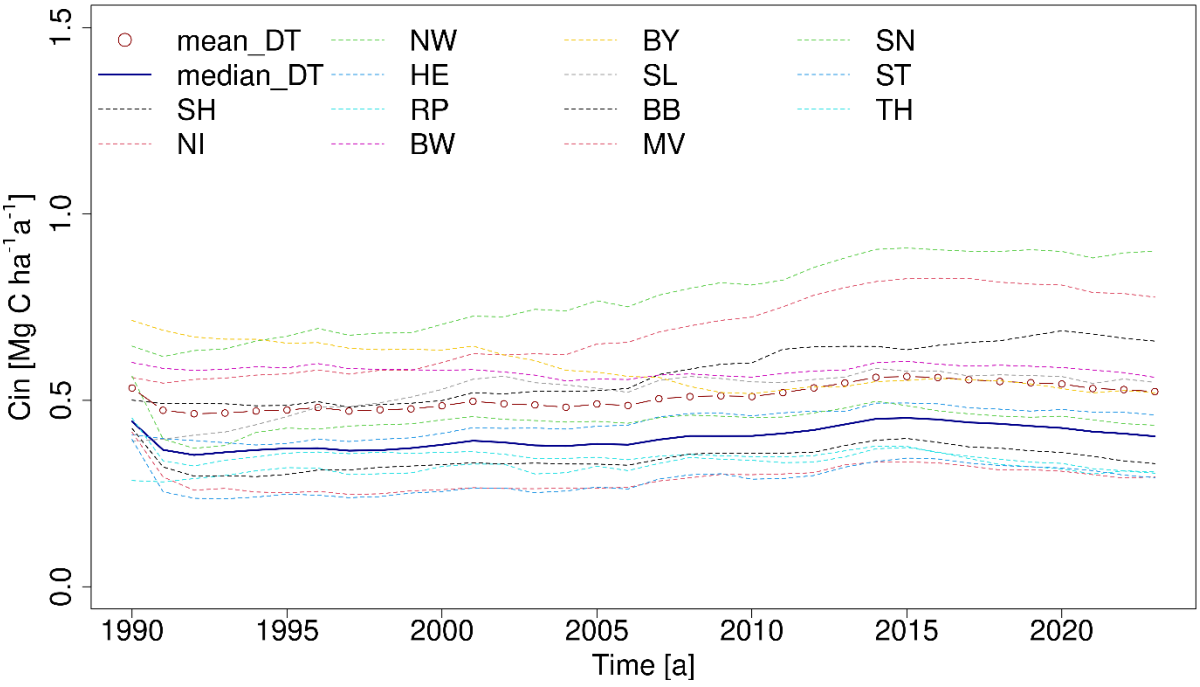
Figure 61: Estimated carbon input from cover-crop cultivation [t C ha^{-1}]



Source: own illustration, Thünen-Institut

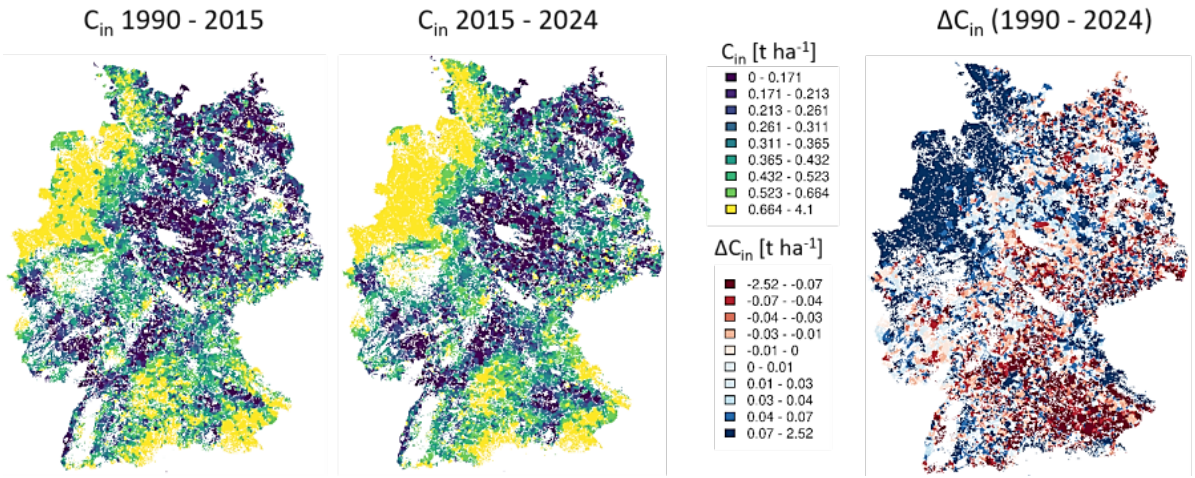
- Carbon inputs from organic fertilisers exhibit a short-term decline at the beginning of the reporting period (collapse of livestock farming in eastern Germany after reunification), followed by a gentle increase on average (increasing quantities of applied digestates from biogas plants) (Figure 62;Figure 63).

Figure 62: Time series of the average carbon input [Mg C ha^{-1}] from organic fertilisers in mineral agricultural soils in Germany (DT) and its federal states



Source: own illustration, Thünen-Institut

Figure 63: Estimated average carbon input from organic fertilisation [t C ha^{-1}]



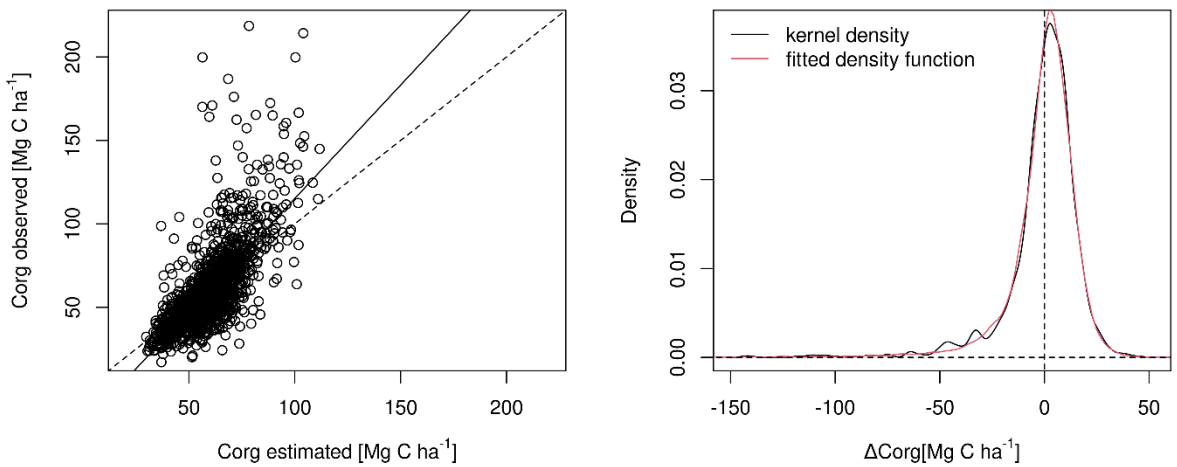
Source: own illustration, Thünen-Institut

Assessment of the data of the model used and quantification of uncertainty

Uncertainty of the soil carbon stock of mineral soils under cultivation

The regionalised map of C_{org} stocks of soils under cropland that was used during modelling as the basis for 2014 was compared with the observed C_{org} stocks from nearby soil inventory points under cropland use. The regionalised SOC stocks and the observations align well. However, there is a tendency to overestimate low SOC stocks and underestimate high SOC stocks (cf. Figure 64). This leads to a distorted density distribution of the regionalisation errors. The simulation showed that, in particular, soils with high C_{org} stocks tend to lose C_{org}.

Figure 64: Left: Regionalised C_{org} stocks [Mg C ha^{-1}] compared with observed C_{org} stocks [Mg C ha^{-1}] from soil inventory sampling points. Right: Kernel density and adjusted density function of the differences between observed and estimated C_{org} stocks [Mg C ha^{-1}]

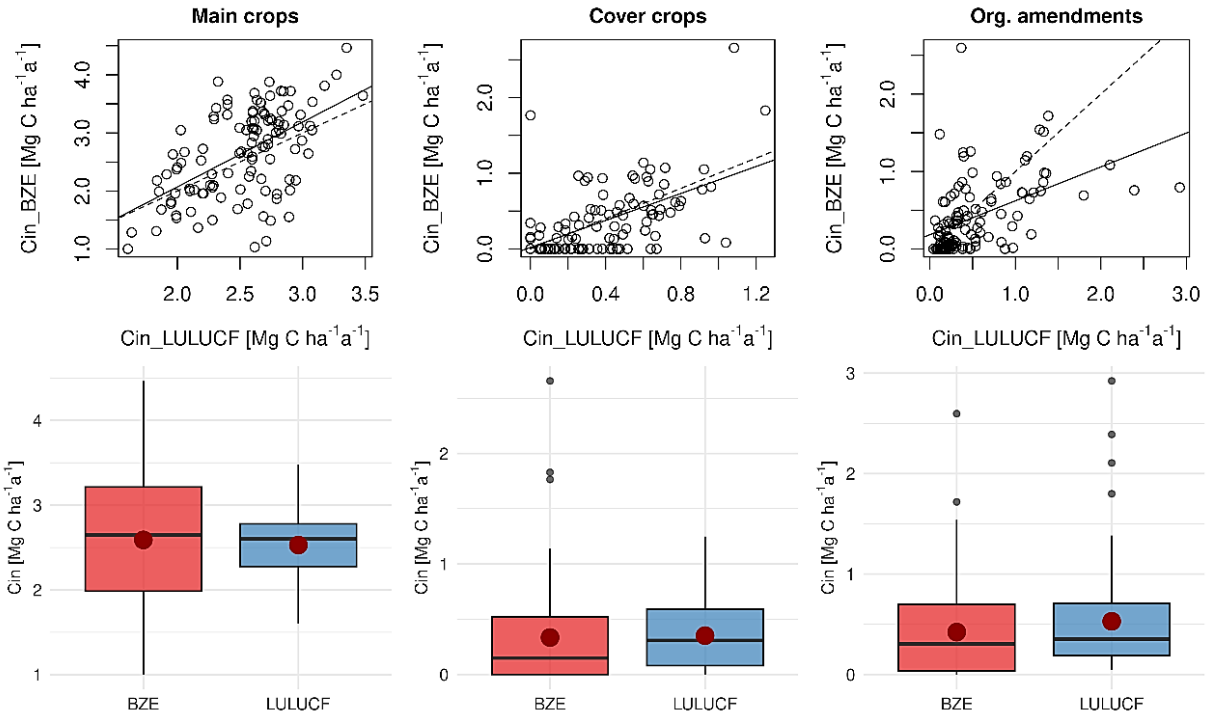


Uncertainty of the model input data

The carbon inputs quantified using the aforementioned methods were compared with carbon inputs from a data set of 124 cropland sites in the Agricultural Soil Inventory which had been sampled twice before (at an interval of at least 10 years). In addition, a complete set of management data was available for each site. The management data were collected using

questionnaires and included crop rotations, yields, information on crop residue management and details of timing, type and quantity of organic fertilisers, over the entire sampling period, beginning at least six years before the first sampling. The derived carbon inputs correlate with those of the Agricultural Soil Inventory and the sample averages align (Figure 65). However, the derived, site specific carbon inputs exhibit lower variability than those determined for the sites in the Agricultural Soil Inventory.

Figure 65: Comparison of carbon inputs derived by downscaling (LULUCF) and carbon inputs derived at soil inventory sites (BZE) from site-specific management information



Source: own illustration, Thünen-Institut

Uncertainty of the model and change to soil carbon stock changes

To quantify the overall uncertainty of the soil carbon stock changes estimated using the model, uncertainties in the model inputs and in the model approach were taken into account using a Monte-Carlo analysis. This comprised the following steps:

1. The uncertainty of the model approach, comprising the RothC model, calibrated distribution coefficients (Dechow et al., 2019) and allometric functions (Franko et al., 2011), was described using a model ensemble with parameter uncertainties. In essence, this is an ensemble whose members differ only by the chosen parameters for the same model. These kinds of approaches have already been used to estimate the prediction uncertainties of climate models (Murphy et al., 2007) and harvest models (Tao et al., 2018). The parameter chosen for the uncertainty description modulates the decomposition rate of the RothC model. Its uncertainty distribution was determined using a data set consisting of Swedish long-term experiments (7 sites and 32 variants per site, cf. (Dechow et al., 2019)), such that the observed trends in soil carbon development were covered by the intervals of the modelled trends of the ensemble in 95% of cases.

2. The uncertainty of the model inputs– soil carbon stock in 2014, soil carbon input and modifiers of decomposition rates – was described using probability functions created from

the difference between regionalised data and data collected in the Agricultural Soil Inventory. The simulation uncertainty was quantified based on Monte Carlo simulations for a subset of 0.5% of the permanent croplands distributed across Germany. These Monte Carlo simulations accounted for the effects of the uncertainty in the model inputs and the uncertainty of the model used.

These investigations into model uncertainty resulted in a 95% confidence interval for soil carbon change of -0.46 t C ha^{-1} a^{-1} to 0.14 Mg C ha^{-1} a^{-1}, with an average change rate of -0.1 t C ha^{-1} a^{-1} (cf. Table 321). The results show that the choice of model has a more pronounced effect on the modelled C_{org} stocks and changes than the error of the spatially aggregated model inputs; at federal state level, errors in the model inputs have a marginal effect on the spatially aggregated model output. This aligns with the findings of (Grosz et al., 2017) where a model comparison study for the federal state of North Rhine-Westphalia produced similar results (for uncertainties of the soil carbon stocks and the soil map, cf. Table 322 in Chapter 6.1.2.1.4).

Estimation of carbon stock change in mineral soils under grassland

While the changes in carbon stocks from mineral soils under cropland are calculated and reported for each individual site, this is currently not possible for mineral soils under grassland due to a considerably smaller pool of available data. Consequently, only a land-use-specific trend with regard to the change in carbon stocks in mineral soils due to grassland use and management was modelled for grassland soils. Only those sites from the Agricultural Soil Inventory (BZE-LW I) were included, for which adequate management data for a period of at least six years were available. This meant that it was only possible to apply the RothC model to 387 grassland sites of the 724 sites of the Agricultural Soil Inventory (BZE-LW I) (Poeplau et al., 2020). The land-use-specific trend in carbon stocks changes in mineral soils at depths of 0-30 cm is then derived for all sites in a land-use category from the average of the differences in the modelled soil carbon stocks, minus those measured in the context of the Agricultural Soil Inventory (BZE-LW I) over a ten-year period (cf. Equation 32:).

Equation 32:

$$\Delta C_{LUC} = \frac{\left(\frac{\sum_{i_{LUC}=1}^{i_{LUC}x} (C_{iLUC}t2 - C_{iLUC}t1)}{10} \right)}{n_{iLUC}}$$

- ΔC_{LUC}: Average of the annual change in carbon stocks [t C ha^{-1} a^{-1}] at a soil depth of 0-30 cm of all mineral soil sites of a specific land use in the Agricultural Soil Inventory (BZE-LW I)
- i_{LUC}: Site with specific land use (cropland or grassland)
- $C_{iLUC}t1$: Carbon stocks [t C ha^{-1}] measured in mineral soils at time (t1) of the sampling as part of the Agricultural Soil Inventory (BZE-LW I)
- $C_{iLUC}t2$: Carbon stocks [t C ha^{-1}] in mineral soil of a site with specific land use modelled for the time t1 + 10 a
- n_{iLUC}: Number of sites of a specific land use

Based on the selected sites from the Agricultural Soil Inventory, the modelling showed an average trend of -0.02 (-0.28 to -0.25) t C ha^{-1} a^{-1} for German grasslands, which was applied to the entire time series.

6.1.2.1.2 Data basis

The basis for determining the nationwide, representative mean carbon stocks in mineral soils, as a function of land use, consists of the following data sources:

- Results of the Forest Soil Inventories I and II (BZE-Wald I and BZE-Wald II; Wellbrock et al. (2016))
- Results of the German Agricultural Soil Inventory (BZE-LW; Jacobs et al. (2018); (Poeplau et al., 2020)
- Maps of the C and N stocks as well as the C/N ratios of Germany's mineral soils under agricultural use (Sakhaee et al., 2022).
- Soil map at a scale of 1:1,000,000 (BÜK 1,000; BGR 1995 & 1997, Düwel et al. (2007))
- Updated overview of organic soils in Germany (Wittnebel et al., 2023)
- Maps from the LUCAS survey
  - Nitrogen, pH (Ballabio et al., 2016)
  - Clay content, available water capacity (Ballabio et al., 2016)
- Geomorphographic map of Germany (Geomorphografische Karte Deutschlands) (BGR, 2007)
- Hydrogeological map of Germany (Hydrogeologische Karte Deutschlands) (BGR & SDG, 2019)
- Map of net soil erosion and deposition rates in Europe (Karte der Netto-Bodenerosion und der Ablagerungsraten in Europa) (Borrelli et al., 2018)
- Digital elevation model of Europe (Digitales Höhenmodell Europas) (EU-DEM; European Union Copernicus Land Monitoring Service and EEA, 2016)
- Data of the German Meteorological Service (Deutscher Wetterdienst) (DWD, various years)
- Data sets of the Digital Basic Landscape Model (Basis-Digitales Landschaftsmodell; B-DLM) of the Official topographic-cartographic information system (Amtliches Topographisch-Kartographisches Informationssystem (ATKIS®), for the years 2000, 2005, 2010, 2015, 2020 and 2022 (AdV 2000; 2005; 2010; 2015; 2020; 2022)
- Corine Land Cover
- The INSPIRE standard grid, newly scanned, with a resolution of 100 m[80]
- IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Agriculture, Forestry and Other Land Use (IPCC, 2006a)

Given that the various land-use categories differ in terms of their data availability, site specific mineral soil carbon and nitrogen stocks were determined separately for each land use category. The values for *Forest Land*, *Cropland*$_{annual}$ and the *Grassland* categories are obtained from maps of the carbon and nitrogen stocks of Germany's mineral soils, which were developed from the

[80] Eurostat Grid Generation Tool for ArcGIS, https://www.efgs.info/information-base/best-practices/tools/eurostat -grid-generation-tool-arcgis/; last accessed: 10 December 2020

results of the Forest Soil Inventories (BZE-Wald I and BZE-Wald II; (Wellbrock et al., 2016)) and of the Agricultural Soil Inventory (JACOBS et al. 2018) and are being used for the first time in this submission. These land-use categories currently comprise about 85% of Germany's area, thus representing the main land uses to consider. The various models used to prepare the maps are described in Chapter 6.1.2.1.3 for the forest, in Chapter 6.1.2.1.4 and 6.1.2.1.5 6.1.2.1.5 for *Cropland*$_{annual}$ and *Grassland*.

For the perennial Cropland subcategories *Hops*, *Orchards*, *Vineyards*, *Christmas tree plantations*, *Tree nurseries* and *Short-rotation plantations* (Chapter 6.1.2.1.4), and for *Terrestrial Wetlands* and *Other Land* (Chapter 6.1.2.1.7), area-weighted, use-specific and soil-specific average carbon and nitrogen stocks were determined for mineral soils using data from the Agricultural Soil Inventory. The mineral soil carbon stocks for Settlement soils were derived from the results of both soil inventories (cf. Chapter 6.1.2.1.6).

6.1.2.1.3 Forest Land

Two different methods are used to report GHG emissions from mineral soils on forest land for two different periods.

- For the period 1990-2008, changes in carbon and nitrogen stocks in mineral soils were determined using the stock-difference method (Chapter 6.4.2.5.3).
- For the period as of 2008, the results are based on the Yasso15 model (Järvenpää et al., 2018; Tuomi et al., 2009). The division into two time periods was necessary because sufficient input data sets enabling the correct calculation of organic carbon stocks in mineral soils with Yasso15 have only been available since 2008.
- The two approaches were combined using the overlap method (IPCC, 2006a). The relevant methods are described in detail in Chapters 6.4.2.5.3 and 6.4.2.5.4.

The results of the soil inventories (Grueneberg et al. (2014)) regarding the carbon and nitrogen stocks of mineral soils on Forest Land were regionalised.

Based on the results of the Forest Soil Inventory, the legend units of the BÜK 1000 soil overview map and using Yasso15, Forest Land regions with the same carbon and nitrogen stocks were identified, taking account their pedological, geological and climatic conditions. The results are presented annually in the form of chronologically dynamic, georeferenced maps (cf. Chapter 6.4.2.5.3). The carbon and nitrogen stocks shown in the maps serve as the basis for all calculations in connection with mineral forest soils.

6.1.2.1.4 Cropland

The carbon stocks of mineral soils on cropland with annual crops, on areas used for cultivation of hops, vineyards and orchards, and on areas used for tree nurseries, Christmas tree plantations and short-rotation plantations, were derived from the results of the German Agricultural Soil Inventory (Jacobs et al., 2018); (Poeplau et al., 2020). The German Agricultural Soil Inventory is a sample survey with systematic sample distribution. The inventory systematically describes, samples and analyses all of Germany's agricultural soils to a soil depth of 1 m throughout a complete coverage grid array of 8 x 8 km cells. The results of the Agricultural Soil Inventory are representative with regard to the distribution of soil characteristics and soil parameters and current agricultural land use in Germany.

Cropland with annual crops

For the land-use category *Cropland*$_{annual}$, complete-coverage grid maps (100 x 100 m grids) of soil carbon stocks and C/N ratios for Germany's mineral soil areas were prepared by

regionalising the results of the German Agricultural Soil Inventory. They were determined using ensemble learning methods. This entailed application of machine learning algorithms to decision-tree ensembles generated with independent partial data sets. The basis for this work consisted of data of the Agricultural Soil Inventory and numerous covariates from the following areas:

- Soil, geology, geomorphology, hydrology
- Climate
- Organic and vegetation indices
- Topography, relief

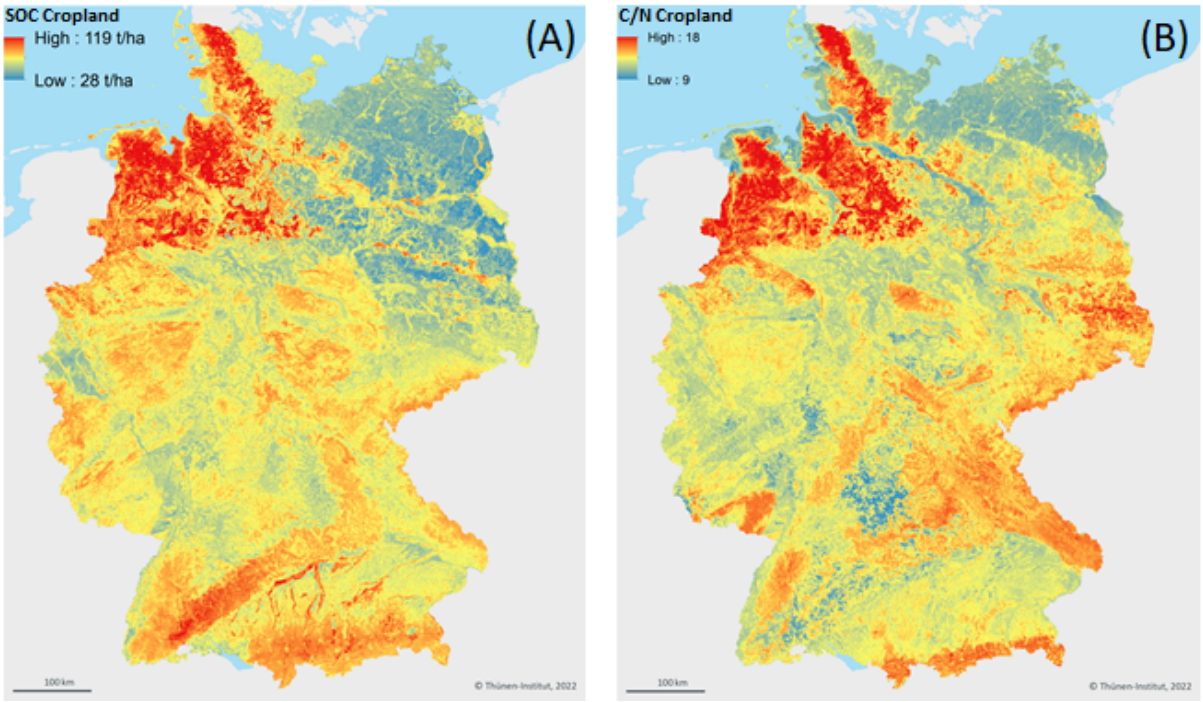
In order to reduce the model's multi-collinearity, strongly correlating covariates (R > 0.9) were removed from the ensemble; ultimately, 34 parameters entered into the model calculations. Detailed explanations of the procedure and the covariates involved are provided in (Sakhaee et al., 2022) and (Gebauer et al., 2022).

In the C/N model, the algorithms *Random Forest* and *Support Vector Machine for Regression* were used as base learners. The predictions of the base learners were then averaged in order to obtain the final prediction. In most instances of ensemble learning, each base learner is tuned independently. However, in the ensemble approach used, the hyperparameter tuning was part of training/learning programme(Shahhosseini et al., 2022).

The SOC model was prepared with a new method known as *Regressor Chaining* (Spyromitros-Xioufis et al., 2016). By using intercorrelated parameters, this method can improve predictions of soil characteristics (Santana et al., 2021). First, a *regressor chaining* model was developed that can predict C/N ratios, using *Random Forest*. The predicted C/N ratios were then used in an ensemble approach (*Random Forest* and *Support Vector Machine for Regression*) for SOC prediction. Like the ensemble approach, which was used for creation of the C/N model, the hyperparameter tuning of the *Regressor Chaining* approach was part of training/learning. Further details and explanations about the *Regressor Chaining* method are provided in Spyromitros-Xioufis et al. (2016). For all models, the hyperparameter tuning was carried out with the *Differential Evolution (DE) algorithm* (Sakhaee et al., 2022).

The robustness of the models, in connection with the combination of hyperparameter tuning and model evaluation, was checked using stratified, hierarchical/nested cross-validation (Sakhaee et al., 2022).

Figure 66: Map of (A) SOC stocks [t C ha^{-1} 30 cm^{-1}] and (B) C/N ratios in Germany's mineral soils that are managed as cropland with annual crops (*Cropland$_{annual}$*)



Source: own illustration, Thünen-Institut

Figure 66 shows the resulting grid maps. The measured (Agricultural Soil Inventory; Bodenzustandserhebung auf landwirtschaftlichen Böden in Deutschland) (BZE-LW; Jacobs et al. (2018)) and predicted average values and medians of the C/N ratios and soil carbon stocks (cf. Figure 66), and the necessary statistical variables to evaluate the model are shown in Table 322. The original grid map shows the values of the soil parameters in 2014. The grid maps are updated annually on the basis of the cropland trends modelled using RothC (Chapter 6.1.2.1.1).

Table 322: Average values and medians of the measured and predicted C/N ratios and soil organic carbon stocks [t C ha^{-1} 30 cm^{-1}] in mineral soils under annual cropland (*Cropland$_{annual}$*)

Cropland$_{annual}$		Average	Median	Statistical indicators of model quality				
				RMSE	MAE	MAPE [%]	Bias [%]	Number
C/N	measured	11.10	10.43	1.5	0.98	8.39	-0.02	2204
	predicted	11.12	10.57					
SOC [t C ha^{-1} 30 cm^{-1}]	measured	61.18	55.58	20.92	13.84	23.24	-0.05	2204
	predicted	59.04	57.11					

With regard to the uncertainty maps, cf. Chapter 6.1.2.1.1.

Cropland with perennial crops

In the Agricultural Soil Inventory (BZE-LW), only a small number of soil profiles on sites with special crops and/or perennial biomass (orchards, vineyards, hops, tree nurseries, Christmas tree plantations and short-rotation plantations) were studied. For this reason, it was not possible to regionalise the results in a map.

For the subcategories hops, tree nurseries, Christmas tree plantations and short-rotation plantations, the number of sites studied was even too small for derivation of specific average mineral soil carbon stocks for the relevant crops since it was not possible to prove or calculate statistically significant differences between these subcategories. For this reason, the average value of all special crop areas is assumed to apply to these areas. Nonetheless, the areas with hops, tree nurseries, Christmas tree plantations and short-rotation plantations are listed separately.

Due to their higher prevalence compared to other special crops, specific mineral soil carbon stocks were identified for vineyards and orchard areas, which differ significantly from all other special crops and from each other. Germany's wine-growing regions are mainly located in the same climate zone, which is why further stratification of the soils based on climate influence is unnecessary. In contrast, Germany's two main fruit-growing regions in the north ("Altes Land" region) and the extreme south (Lake Constance region) lie in different climate zones. While a comparison of the mineral soil carbon stocks of fruit-growing areas in the northern part of the country and the mineral soil carbon stocks of relevant areas in the southern part of the country shows considerable differences with regard to average soil organic carbon stocks (80 t C/ha as opposed to 66 t C/ha), these differences are not statistically significant due to the absolute number of samples involved and the very large range that results (93 t C/ha in the north and 60 t C/ha in the south). For this reason, a uniform value for orchards is applied nationwide.

The mean carbon stocks for mineral soils in the various individual cropland subcategories are shown in Table 323. The carbon stocks are updated annually based on the grassland trend modelled using RothC (Chapter 6.1.2.1.1). This is due to the fact that most of the sites with special crops are covered by herbaceous plants, usually grasses.

Table 323: Mean area-based mineral soil carbon stocks to a soil depth of 30 cm [t C ha^{-1} $30cm^{1}$] and their uncertainties [%] for croplands with annual and perennial crops

Mineral soils	Carbon stocks [t C ha^{-1}]	Uncertainty [%]
Hops	62.89	7.84
Vineyards	49.30	11.36
Orchards	71.69	8.87
Tree nurseries	62.89	7.84
Christmas tree plantations	62.89	7.84
Short-rotation plantations	62.89	7.84

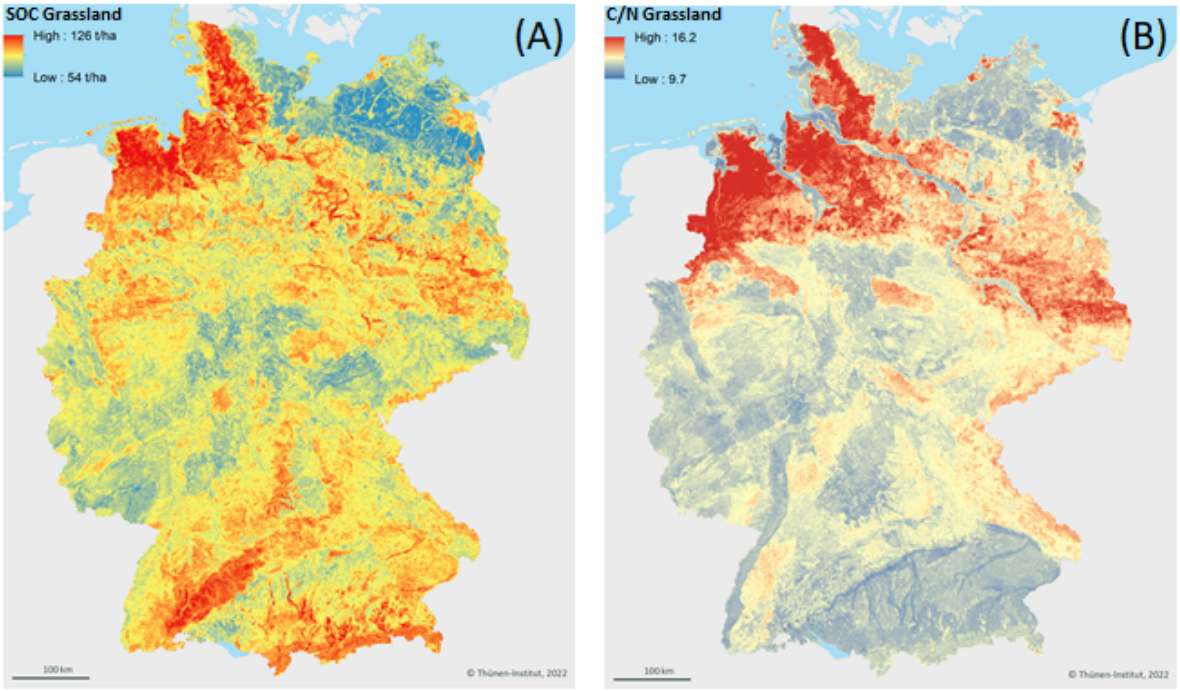
6.1.2.1.5 Grassland

The land-use category *Grassland* comprises the subcategories *Grassland in the strict sense*, *Woody Grassland* and *Hedges* (cf. Chapter 6.2.3). With regard to the characteristics of the mineral soils in these subcategories, it is assumed that they do not differ significantly by location in terms of their carbon and nitrogen stocks. Comparative studies of soils under *Grassland in the strict sense* and *Hedges* confirmed this assumption (DREXLER et al. 2021). For this reason, for all three subcategories, the mineral soils' carbon and nitrogen stocks were derived in a consistent manner from the Agricultural Soil Inventory's results for grassland (Jacobs et al., 2018).

As with $Cropland_{annual}$, a complete-coverage map of the C stocks and C/N ratios of Germany's grassland soils was prepared based on the results of the Agricultural Soil Inventory and a large number of covariates. A short description of the approach used is provided in Chapter 6.1.2.1.4. A detailed description of the underlying method is provided by (Sakhaee et al.). The grid maps

are shown in Figure 67, and the measured and predicted average values and medians of C/N and SOC along with several statistical indicators for assessment of the quality of the predictive model are presented in Table 324. The grid maps are updated annually on the basis of the grassland trend modelled using RothC (Chapter 6.1.2.1.1).

Figure 67: Map of (A) SOC stocks [t C ha^{-1} 30 cm^{-1}] and (B) C/N ratios in Germany's mineral soils under grassland



Source: own illustration, Thünen-Institut

Table 324: Average values and medians of the measured and predicted C/N ratios and soil organic carbon stocks [t C ha^{-1} 30 cm^{-1}] in mineral soils under *grassland*

Cropland$_{annual}$		Average	Median	Statistical indicators of the model quality				
				RMSE	MAE	MAPE [%]	Bias [%]	Number
C/N	measured	11.13	10.52	1.75	1.08	8.97	-0.01	740
	predicted	11.09	10.68					
SOC [t C ha^{-1} 30 cm^{-1}]	measured	88.09	83.21	30.48	21.42	27.57	-0.1	740
	predicted	86.45	84.84					

6.1.2.1.6 Settlements

The remarks in the following section refer only to the land-use subcategories Buildings and open areas as well as Areas with photovoltaic plants since the introduction of the subcategories Roads and Railway track beds was initially only on a static basis (cf. Chapter 6.1.1).

Emissions resulting from active construction measures

In the case of land-use changes leading to Settlements, the humus-rich topsoil layer (30 cm soil depth), which is relevant for reporting purposes, is completely removed on the affected area. German law mandates special protection for topsoil (Section 202 Bundesanzeiger Verlag (2015)) and, in the case of construction work, must be stored unmixed, protected and preserved; in the case of sealing, it must be transported laterally, uncontaminated and unmixed

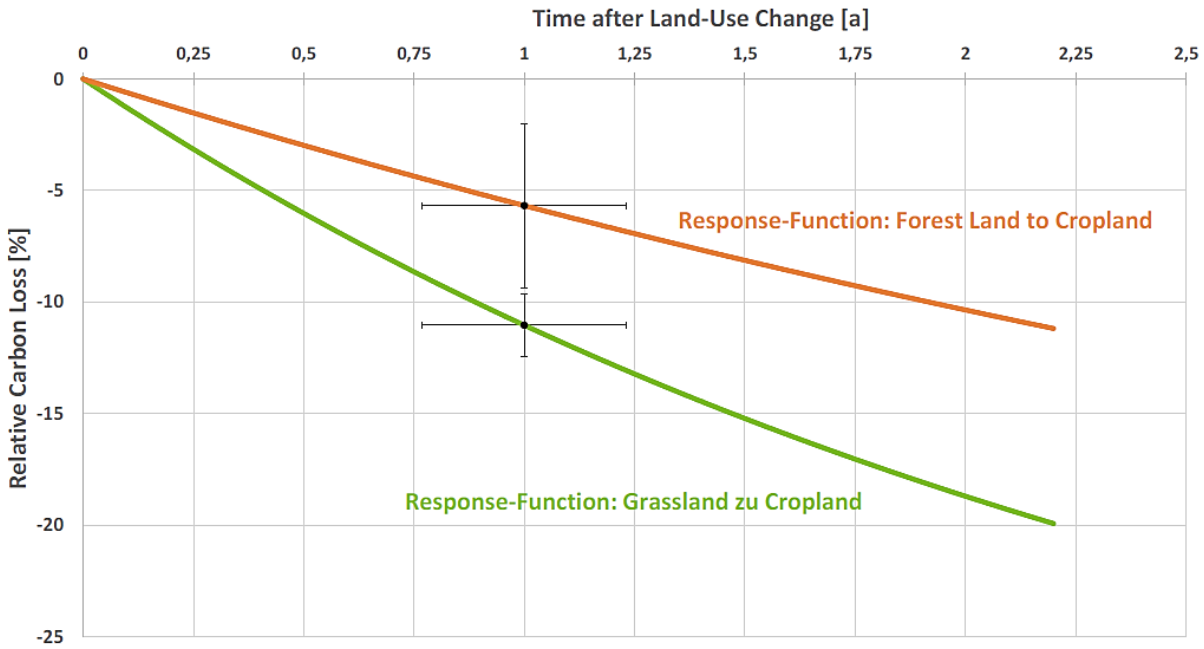
(BMJ & BfJ, 1998a; KrWG, 2012); and 16 construction codes of the federal states). Normally, topsoil sections of sealed areas are applied to unsealed areas (if possible, on the building site involved or on neighbouring land), so that little or no carbon is lost. Only lateral translocation occurs. The overall balance with respect to the carbon remains nearly the same. The 2006 IPCC Guidelines explicitly refer to this case. Pursuant to the Guidelines, it is good practice to reduce potential carbon losses by the amount of carbon contained in laterally translocated soil (IPCC (2006a), Chapter 8.3.3.1). Nevertheless, the soil on the areas concerned is disturbed (excavated, transported, reapplied; possibly stored properly in stockpiles for several months), which disrupts its structure and increases aeration, at least in the short term. This usually leads to increased conversion of organic soil substances by microorganisms. The quantities of CO_2 released this way have to be determined and included in the carbon balance. These carbon losses are quantified on the basis of the assumptions outlined below.

- No specifically collected scientific data are available on the carbon losses from organic matter in the topsoil as a result of construction measures; for this reason, these losses have to be estimated. The losses are estimated by response functions that describe the carbon losses from organic matter in mineral soils that result from conversion of Grassland or Forest Land to Cropland ((Poeplau et al., 2011)) (cf. Figure 68). These land-use changes result in enormous, lasting disruptions of the topsoil, including intensified aeration of the topsoil.
- Grassland converted to Cropland: ΔC_{SOC}_Ini_prev = 36.11*[1-exp(-t/2.74)]
- Forest Land converted to Cropland: ΔC_{SOC}_Ini_prev = 32.19*[1-exp(-t/5.15)]
- ΔC_{SOC} _Ini_prev: Relative carbon-stock change [%]
- t: Time following the disruption [a]
- Construction projects in Germany normally take 6-25 months, depending on the project (Schulz, 2012). By applying statistical data, i.e. the mean values of the time series for the numbers of relevant completed construction projects since 2010 (Statistisches Bundesamt, 2020), a weighted mean was calculated for the duration of construction periods in Germany. The value obtained is 11.9 months. In a conservative approach, a period of 12 months is assumed (t = 1 in the response functions).

Applying the calculated mean construction period in the response functions results in the following relative carbon losses with respect to the initial stocks:

- Function Grassland converted to Cropland: -11.0%
- Function Forest Land converted to Cropland: -5.7%

Figure 68: Relative carbon loss ([%]; uncertainties: 95% confidence interval [%]) from humus-rich topsoil as a result of construction-related disruptions, derived from response functions for Grassland/Forest Land converted to Cropland (Poeplau et al., 2011) and assuming an average construction period of 12 months



Source: own illustration, Thünen-Institut

In a conservative approach, in light of the fact that land-use changes from Grassland to Settlements take place 4-5 times as frequently as land-use changes from Forest Land to Settlements, the carbon losses from humus-rich topsoil layers as a result of construction-related disruptions are estimated using the response function for land converted from Grassland to Cropland. For an average construction period of 12 months, the calculation yields carbon losses of -11 ± 1.4% C (uncertainty$_{relative}$: 12.7%) (cf. Figure 68) from the current mineral soil carbon stocks of affected areas at the time of the land-use change. In the inventory, the carbon losses determined this way are applied only once, and only in the year of the land-use change.

Carbon stocks in settlement soils

Facts and assumptions

Unsealed soils within cities sometimes contain carbon stocks comparable to those found in forest and grassland soils outside of settlement areas (Klingenfuß et al. (2020); Cambou et al. (2018); Edelmann (2013); Raciti et al. (2012); Pouyat et al. (2009)). In particular, residential gardens, parks and green areas, allotment gardens and other areas with trees and shrubs have topsoils with carbon stocks that can considerably exceed those of comparable soils outside of settlement areas, regardless of how they are used (Klingenfuß et al. (2020); Cambou et al. (2018); Edmondson et al. (2012); Edelmann (2013); Pouyat et al. (2009)). This is due to the addition of extra humus soil, the gradual degradation of agricultural land (Edmondson et al., 2014) and the intensive cultivation of urban green spaces (input, irrigation) (Edmondson et al., 2014); Pouyat et al. (2009)). Vasenev et al. (2013) showed that this assessment applied to urban soils of the greater Moscow region with respect to carbon contents in topsoil and, especially, in subsoil horizons. They refer to these layers as cultural layers, meaning that they have been affected by human activities. These carbon stock differences between urban and neighbouring soils outside of cities were quantified in all of the aforementioned studies. Nonetheless, these

data do not support derivation of generally valid relative rates of change that would make it possible to estimate the carbon stocks in unsealed settlement soils (i.e. following land-use changes) on the basis of the soil carbon stocks during the previous uses.

- This is because the differences between the two sets of carbon stocks cover an extremely wide range, with a variation that depends on site characteristics, land use and management. Edmondson et al. (2014) investigated soils of urban green areas in the city of Leicester (UK) where they found that carbon stocks were 21-89% higher than in neighbouring agriculturally used grassland soils (86 t ha^{-1} 21 cm^{-1}; cropland: 73 t ha^{-1} 21 cm^{-1}). For the city of Paris, Cambou et al. (2018) found that the carbon-stock differences between urban soils and comparable soils throughout the region (forest land > agricultural areas) varied by 30-110% depending on how the former soils were used (parks > gardens ≥ areas with trees and shrubs).
- The various forms of use exhibit no consistent trends (Klingenfuß et al., 2020)

For these reasons, we assume, in a conservative approach, that unsealed, urban soils have carbon stocks similar to those of the soils from which they develop following a land-use change, less the 11% loss from construction-related disruption.

In addition, we assume that any land on which buildings are located has undergone deep excavation during construction and thus contains either no carbon or negligible quantities. During construction and in accordance with the law, the humus-rich topsoils on this land are shifted laterally on the building site or onto neighbouring parcels. Consequently, the carbon stock on the affected area was corrected by a sealing factor. This results in soil carbon losses due to construction-related disruptions to the topsoil on the unsealed areas being almost fully offset, although this is not reflected in changes in carbon stocks because they are only reported up to a soil depth of 30 cm. The 2025 ESD review by TERT criticised this unbalanced mass balance on the converted area in question because, when the area is re-used, it leads to an overestimation of the sink function. As a result, the SOC stock of the mineral soil, after accounting for the 11% loss due to the construction disruption, is no longer subsequently corrected by a sealing factor. It remains virtual over the entire land-use change area to maintain the mass balance. In view of all these circumstances, it is therefore also assumed that the mineral soils in the conversion and remaining categories in Buildings and open areas are in equilibrium, i.e. no emissions are reported. TERT accepted this approach ((EEA, 2025); Reference: No 3502/B2025/EEA.60384).

Estimation of emissions from mineral soils in connection with land-use changes to settlements.

The procedure is carried out in accordance with the assumptions and explanations set forth in the aforementioned sections of the chapter: A quantity of 11% of the soil carbon stocks from the previous use is deducted from (SOC_{Ini_prev}) and then listed as a one-time emission in the year of the land-use change:

Equation 33:

$$Emission_{\mathrm{LUC_{Set}}} = SOC_{Ini_{prev}} * A_{set1} * -0{,}11$$

- SOC_{Ini_prev} = Carbon stock of the area under the previous land use [t C ha^{-1} 30 cm^{-1} a^{-1}]
- A_{set1} = Area affected by the land-use change [ha]
- -0.11 = Relative loss (11%) of soil carbon due to construction

The stocks determined this way are used as a basis for all other calculations with urban soils at the relevant point. These stocks are assigned directly to the point in the year of the land-use change and with no conversion period. Apart from the emissions caused by the construction work, no further losses from mineral soils occur (see above).

For all settlement areas whose previous use is not known (i.e. all areas that have been listed in the remaining category since 1990), average carbon stocks regionalised at federal state level and weighted by area and the previous use in each case, are assumed for mineral soils. To this end, for each conversion category, the average value of the category's share of the total land-use changes leading to settlements was determined for the period 1990-2024. For the relevant previous land-use category, that share was then multiplied by the typical soil organic carbon stock of 1971. The sum of the resulting values, less 11% for the loss from construction, yields the SOC_{Ini_prev} for mineral soils on settlement areas in the relevant German federal states. The uncertainty for the area allocation estimations is assumed to be 10%. Consequently, for Buildings and open areas whose previous use is not known, the carbon and nitrogen stocks listed in Table 325 are obtained for mineral soils in individual German federal states. The stocks determined this way are used as a basis for all other calculations with urban soils at the relevant points.

Table 325: Average carbon [t C ha^{-1} 30 cm^{-1}] and nitrogen stocks [t N ha^{-1} 30 cm^{-1}] of mineral soils on settlement areas (subcategory Buildings and open areas) and the relevant uncertainties [%]

Mineral soils	Carbon stocks [t C ha^{-1} 30 cm^{-1}]	Uncertainty C [%]	Nitrogen stocks [t N ha^{-1} 30 cm^{-1}]	Uncertainty N [%]
Brandenburg	55.4	18.6	4.4	19.7
Berlin	53.3	20.6	4.4	21.5
Baden-Württemberg	72.7	19.3	6.9	20.3
Bavaria	69.4	20.5	6.6	21.6
Bremen	74.3	22.2	5.6	22
Hesse	62.6	19.6	6	20.7
Hamburg	75.5	19.6	5.4	20
Mecklenburg-Western Pomerania	52.1	20.8	4.7	21.9
Lower Saxony	73.7	20.2	5.8	21
North Rhine-Westphalia	70.4	19.9	6.1	20.8
Rhineland-Palatinate	66.2	20.2	6.6	21.5
Schleswig-Holstein	75.3	19.9	5.9	20.5
Saarland	68.1	19.3	6.4	20.4
Saxony	65.2	20.5	5.6	21.5
Saxony-Anhalt	71.4	23.2	6.1	24.1
Thuringia	67.4	21.5	6.4	22.8

Estimation of emissions from mineral soils due to land-use changes from Settlements

The procedure used in the case of land-use changes from Settlement areas to other land-use categories is in accordance with the relevant general method (Chapter 6.1.2.1). The starting

point for the calculation, in each case, consists of the currently recorded SOC stocks for the relevant land point. An effective conversion period of no more than 20 years is assumed.

6.1.2.1.7 Terrestrial Wetlands and Other Land

Terrestrial Wetlands

The mean carbon stocks for mineral soils in Terrestrial Wetlands (no soil carbon stocks are listed for water bodies; peat extraction areas are found only on organic soils) were derived from the Digital Basic Landscape Model (Digitales Basis-Landschaftsmodell (Basis-DLM; ATKIS®), the soil map scaled to 1:1,000,000 (BÜK 1000; BGR (1995 & 1997);BGR (1997)) and the results of the Agricultural Soil Inventory; Jacobs et al. (2018). In the process, these wet areas shown in the B-DLM (with a depth to water table < 10 cm) that contain no organic soils were intersected with the dominant soil associations shown in the BÜK 1000 (cf. Chapter 6.1.2.1.2). The wet soil area proportions determined this way for the individual dominant soil associations were assigned the following: the carbon stocks determined in the Agricultural Soil Inventory for grassland soils with groundwater level ≤ 3 – i.e. soils that, at their highest groundwater level, are either occasionally (72%), often (25%) or permanently (3%) flooded. As a result, it was possible to derive specific carbon stocks for wet mineral soils for each relevant dominant soil association. The dominant soil associations of the BÜK 1000 Soil map for the Federal Republic of Germany 1:1,000,000 were superimposed on a map of the federal states. Then, using the resulting polygons, area-weighted mean organic carbon stocks were calculated for mineral soils in Terrestrial Wetlands for each of the federal states (cf. Table 326).

Table 326: Mean area-related carbon stocks [t C ha^{-1}] and their uncertainties (%) in mineral soils of Terrestrial Wetlands to a soil depth of 30 cm

Mineral soils	Carbon stocks [t C ha^{-1}]	Uncertainty C [%]	Nitrogen stocks [t N ha^{-1} 30 cm^{-1}]	Uncertainty N [%]
Brandenburg	104.2	29.4	8.4	27.7
Berlin	104.2	29.4	8.4	27.7
Baden-Württemberg	103.9	11.8	9.7	11.2
Bavaria	101.2	15.7	9.9	15.6
Bremen	123.1	19.7	13.2	17.2
Hesse	105.8	38.7	10.6	28.0
Hamburg	105.7	117.0	7.6	17.6
Mecklenburg-Western Pomerania	85.9	116.8	6.7	22.3
Lower Saxony	104.1	25.9	8.7	14.3
North Rhine-Westphalia	84.5	11.9	7.5	17.7
Rhineland-Palatinate	81.5	30.6	8.9	15.7
Schleswig-Holstein	119.8	40.8	10.6	11.6
Saarland	101.8	12.3	10.4	30.6
Saxony	87.6	20.1	6.8	32.9
Saxony-Anhalt	111.0	16.0	8.6	15.8
Thuringia	116.2	100.0	9.7	25.6

Other Land

The database on which the BÜK 1000 (BGR) soil map is based shows nearly no dominant soil profiles for soils on Other Land. It shows these profiles only for Forest Land, Cropland and Grassland sites. To date, carbon stocks of mineral soils have been derived from the soil characteristics listed for these land-use categories in the map legend. The values given for the stocks, 56 t C/ha, were very high and based solely on estimates. To improve the inventory in this area, therefore, a method for deriving the carbon stocks of mineral soils under Other Land needed to be developed that would use actual measurements and take regional site factors into account. For estimation purposes, therefore, the data set of the Agricultural Soil Inventory (Jacobs et al., 2018) was used as a basis. As a rule, Other Land consists of vegetation-free areas that predominantly have very low soil organic carbon content although they may include areas with higher soil organic carbon contents (such as in the catchment areas of watercourses). For this reason, the average carbon and nitrogen stocks of mineral soils were estimated using the smallest value of each of the federal states in the Agricultural Soil Inventory. Furthermore, it was assumed that these values represented the upper bounds for soil carbon/nitrogen stocks in the land-use category Other Land for the relevant federal state. The average value was then obtained in each case on the basis of the standard deviation for the C and N stocks of all of the mineral soil sites on which the relevant determination was based. The values for carbon and nitrogen stocks in mineral soils determined at regional level for the federal states will be used for all emission calculations in connection with the land use category “Other land” starting with this submission. The average carbon and nitrogen stocks are listed in Table 327.

Table 327: Average carbon and nitrogen stocks [t C ha^{-1}], and their uncertainties (standard deviation [%]) in mineral soils on Other Land to a soil depth of 30 cm and at the federal state level

Mineral soils	Carbon stocks [t C ha^{-1} 30 cm^{-1}]	Uncertainty C [%]	Nitrogen stocks [t N ha^{-1} 30 cm^{-1}	Uncertainty N [%]
Brandenburg	10.3	44.0	0.9	40.5
Berlin	29.1	30.1	2.5	14.4
Baden-Württemberg	10.0	21.1	1.0	22.1
Bavaria	10.0	24.6	0.9	24.8
Bremen	23.1	37.1	2.0	37.1
Hesse	21.5	19.2	2.0	19.8
Hamburg	21.1	50.2	2.2	40.2
Mecklenburg-Western Pomerania	13.4	35.2	1.7	29.0
Lower Saxony	19.3	35.6	1.1	26.3
North Rhine-Westphalia	16.8	26.1	2.2	20.8
Rhineland-Palatinate	7.6	18.3	1.1	19.1
Schleswig-Holstein	17.9	36.2	1.7	26.8
Saarland	32.8	19.9	1.8	25.3
Saxony	22.1	25.9	1.9	23.3
Saxony-Anhalt	17.8	28.2	1.6	28.7
Thuringia	15.1	29.2	1.6	29.0

6.1.2.1.8 Uncertainties

Except where a different value is explicitly listed, half of the 95% confidence interval is always used as the measure of uncertainty. In the case of samples that do not exhibit a normal distribution, the upper and lower bounds are given as well. The uncertainties for the carbon stocks of mineral soils of forest land and for the changes in these stocks over time were statistically calculated from the measurements of the Forest Soil Inventory (Wellbrock et al. (2016)); cf. Chapter 6.4.3.3); the uncertainties for the land-use categories Hops, Vineyards, Orchards, Tree nurseries, Short-rotation plantations, Terrestrial Wetlands, Settlements and Other Land were calculated from the measurements of the Agricultural Soil Inventory (Jacobs et al. (2018)). Within the scope of the error propagation calculation, the uncertainties for $Cropland_{annual}$ and Grassland were derived from the statistical parameters calculated by the map creation model (Chapter 6.1.2.1.4; Chapter 6.1.2.1.5) and from the uncertainties of the process model used (Chapter 6.1.2.1.1 ff.).

6.1.2.1.9 Planned improvements

The planned improvements for the coming years include the following:

1. Improvement of the model-based calculation of carbon stock changes on Cropland. Improvement of data with a view to management/data input.
2. Introduction of the model-based calculation of carbon and nitrogen stocks in mineral soils in the land-use category Grassland for each point on the sampling grid.
3. Development of a method to determine the development of carbon stock changes in mineral settlement soils
   a. of the remaining category Buildings and open areas.
   b. Introduction of sealing and emission factors for mineral soils in the subcategory Roads and Railway track beds.

6.1.2.2 Emissions from organic soils (3.D; 4.A to 4.F; 4(II))

CO_2, N_2O and CH_4 emissions from organic soils are reported in the land-use categories Forest Land, Cropland, Grassland (in the strict sense), Woody Grassland, Terrestrial Wetlands, industrial Peat Extraction and Settlements (subcategories Buildings and open areas and Areas with photovoltaic plants) (N_2O from drained organic soils is reported under Cropland and Grassland in CRF Sector 3.D.1.f). Reporting also covers methane emissions from drainage ditches, as well as carbon losses in connection with dissolved organic carbon (DOC). In Germany, the majority of organic soils is drained.

Emissions are calculated by multiplying the peatland areas per subcategory by a use-specific emission factor.

Equation: For land-use changes, the emission factor for the final category is used right away:

$$E_{orgsoil} = \sum_{i=1}^{n} (A_i * EF_i)$$

- $E_{orgsoil}$ = CO_2, N_2O and CH_4 emissions from organic soils in a land-use category [kt C]
- A_i = Peatland area under a certain land use [kha]
- EF_i = Land-use-specific emission factor [t C ha^{-1} a^{-1}]
- I = Conversion or remaining categories
- N = Number of conversion and remaining categories

The present inventory is based on a new, highly detailed map showing the locations and drainage of organic soils ((Wittnebel et al., 2023); Chapter 6.1.2.2.1). In addition, this submission makes use of extensive measurement data on GHG emissions from organic soils in Germany that were taken from various research projects, especially the Organic Soils (Organische Böden) project, a collaborative research project of the Thünen Institute[81], using standardised measurement protocols (a small quantity of the data was obtained from the relevant national literature).

For every one of the 1,945,718 detection points on organic soils, the CO_2 and CH_4 emissions calculations are now carried out as a function of the depth to the water table. The depth-to-water-table data are taken from a digital, dynamic groundwater map that is updated annually (cf. Chapter 6.1.2.2.2). The CO_2 and CH_4 emissions are calculated with response functions as a function of the depth to the water table. They are calculated individually for each survey point (cf. Chapter 6.1.2.2.2). The response functions are used for all land-use categories except for Forest Land and Woody Grassland. The database for the activity data and emission factors, and the relevant derivations, meet the criteria for an IPCC Tier 3 method. However, to ensure transparency and consistency with other activity data, N_2O emissions estimates and other pools (DOC, drainage ditches), a national Tier 2 method was developed from this (Tiemeyer et al., 2020).

Implementation of these systems fulfils an European Commission recommendation calling for the development of systems regarding emissions from organic soils in Germany to record and report on changes in soil carbon stocks resulting from management measures aimed at reducing emissions or promoting carbon sequestration in the remaining categories 4.B and 4.C (cropland management (CM) and grazing land management (GM) respectively) (“Member State recommendations on reporting systems for cropland & grazing land management emissions & removals” (Ecofys & Environment Agency Austria, 2017), pursuant to EU Regulation (EU) 2018/841. In addition, the system enables mandatory reporting on emissions from “managed wetlands” as prescribed by the EU Regulation from 2026.

6.1.2.2.1 Activity data

The map of organic soils in Germany used in submissions prior to 2024 (parametrised area data, scale ~1:10,000-1:200,000; grid width 25 m), which fully maps the IPCC definition of organic soils (Roßkopf et al., 2015), was updated by harmonising the latest soil data from the federal states (Wittnebel et al., 2023). Also, topological inaccuracies which hamper useful parametrisation were removed before the data were extracted into the LULUCF reporting pattern. The modified organic soil map now covers 1,945,718 ha, largely due to the improved small-scale coverage of organic soils, meaning that it now covers 6.7% more area than the map used in the preceding submissions (1,822,109 ha). Unlike the previously used map, the current map of organic soils includes peatland covered with mineral sediments (3.4% of the map area) (Wittnebel et al., 2023).

The nationwide digital altitude model, which forms the basis for three of the prediction variables used in the upscaling approach, was updated to the latest version of 2020 and has a grid resolution of 5 m (the model used in submissions before 2024 had a 25 m grid).

The far more accurate assignment of locations in the new organic soils map means that small-scale structures can now be recorded and a highly precise time series of land use and land-use changes on organic soils can be reported. There have only been slight changes to area shares of the land-use categories in absolute and percentage terms compared with the previous

[81] www.organische-boeden.de

submission (Table 328). Grassland in the strict sense is now far and away the predominant use. Table 328 shows the areas of organic soils broken down by land-use categories.

The regional distribution of the water levels in organic soils, which serves as a basis for emissions calculation, is derived pursuant to (Bechtold et al., 2014) and based in part on the organic soils map (Roßkopf et al., 2015) along with long-term series of measurements of water levels in organic soils (cf. Chapter 6.1.2.2.2).

The area for organic soils under agricultural use, as reported in the agricultural sector (CRF Table 3.D.1.f), does not differ from the area as reported in the LULUCF sector. The cropland soil areas under cultivation are the same in both sectors subject to reporting obligations. In the LULUCF sector, the areas of the subcategories “Grassland (in the strict sense)” and “Woody Grassland” are subsumed under Grassland. Woody Grassland areas are not agricultural land in the strict sense. For this reason, they are not listed in 3.D.1.f. All the same, in the interest of obtaining a consistent description of the entire German area, they have to be included in the LULUCF sector.

To determine CH_4 emissions from drainage ditches, the ditches’ areas and the land uses on the areas bordering them must be determined. To this end, buffer zones were formed around the linear elements of the ATKIS Digital Basic Landscape Model (Basis-DLM) that represent drainage ditches as indicated by the legend information. This made it possible, together with the updated overview of organic soils (Wittnebel et al., 2023) and the ATKIS Basis-DLM, to determine the entire area of all ditches for drainage of organic soils for all land-use categories (Table 328).

Table 328: Areas of organic soils and drainage ditches, by land-use categories, for the year 2024, in hectares [ha]

	Area of organic soils	Area share	Area of drainage ditches
Forest Land	283,067	14.65	816
Cropland	332,402	17.21	925
Grassland (in the strict sense)	1,008,254	52.19	5,983
Woody grassland	46,819	2.42	756
Terrestrial Wetlands	138,033	7.14	526
Water bodies	23,936	1.24	4,299
Peat extraction	10,034	0.52	42
Settlements	89,337	4.62	453
Other Land	36	0	0
∑	1,931,918	100	13,800

6.1.2.2.2 Emissions calculation

The emission factors were developed in accordance with the guidelines in the 2013 IPCC Wetlands Supplement (IPCC et al., 2014). Empirical models (Tier 3) were used to calculate CO_2 from the soil (CO_2-C on-site) and CH_4 from the soil (CH_{4_land}) for all land-use categories. For forest soils, the necessary emission factors were taken from the 2013 IPCC Wetlands Supplement (IPCC et al., 2014). For N_2O, emission factors were developed from national annual measurements (Tier 2). For CO_2 from dissolved organic carbon (CO_2-C_{DOC}) and CH_4 from drainage ditches (CH_{4_ditch}), the standard values in the 2013 IPCC Wetlands Supplement (IPCC et al., 2014) were used.

CO_2 from the soil (CO_2-C_{onsite})

The database consists of representatively surveyed, quality-checked, national annual measurements (261 measurement years, 118 sites, 17 different peatland areas). From these data, Tiemeyer et al. (2020) derived an empirical (non-linear) response function for emissions as a function of the groundwater level. This function was then used to calculate the emissions from groundwater stocks modelled for each year for every point on organic soils. The required water level data were calculated separately for the relevant years using the machine learning model in (Bechtold et al., 2014).

The model was improved for this submission. Firstly, the main data set, the peat water level database for Germany, was expanded

- from 53 wetland areas with 1,094 observation wells and 7,155 average annual water levels between 1988 and 2012 (submissions prior to 2024)
- to 93 wetland areas with 1,671 observation wells and 10,761 average annual water levels between 1988 and 2024 (previous submission)
- to 125 wetland areas with 1,799 observation wells and 11,852 average annual water levels between 1988 and 2025 (this submission).

These include the continuously updated measurements from the national Peatland Monitoring for Climate Protection in the Open Countryside (MoMoK, https://moorbodenmonitoring.thuenen.de/) whose data collection is representative of the land-use distribution and the properties of organic soils in Germany, thus substantially improving the data available for emissions reporting.

Secondly: In earlier submissions, the effects of the climatic conditions on the predicted water levels were ascertained using the average climatic conditions over the entire time period of the training data set (1980-2010). To remedy this inaccuracy and present the emissions from organic soils more precisely, annual weather data (climatic water balances in winter and in summer) have been used for each report year since the 2024 submission so as to predict the peat water levels. This results in a significant weather-related dynamism in the emissions. The influence that the different calculation methods have on the shape of the emission curves based on climatic parameters and the weather is shown in Figure 69. Over time the absolute emission totals are the same. This makes for a highly suitable cumulative parameter over time since the emission $curve_{climate}$ is almost identical to the calculated trend curve of the emission $curve_{weather}$. The actual emission event, however, does not reflect this; (Chapter 6.1.2.2.3; Figure 69).

Since only few emission observations exist for organic soils covered by minerals, and since these are inadequate for generalisation purposes, a conservative approach was selected for the estimation of the emissions from these soils. For soils with mineral coverage > 0.3 m, the modelled peat water levels were increased by the depth of the respective mineral coverage prior to the calculation of the CO_2 emissions, reducing their impact on the national budget.

Since the model predicts transformed water levels, and since uncertain water levels feed into the emission calculation, in some cases expected values and uncertainties of the water levels and emissions were determined by a Monte Carlo simulation.

The response function from Tiemeyer et al. (2020) is based on only a few, uncertain measurements from forest land areas. For this reason, the standard emission factor given in the 2013 IPCC Wetlands Supplement (IPCC et al., 2014) was used for points under Forest Land. The same factor was also used for the subcategories Woody Grassland and Hedges.

CH_4 from the soil (CH_{4_land})

The database consists of representatively surveyed, quality-checked, national annual measurements (296 measurement years, 137 sites, 17 different peatland areas). The emissions were calculated with an approach similar to that used for CO_2 based on Tiemeyer et al. (2020) and Bechtold et al. (2014). Since the response function for Forest Land is based on a very small number of data points and is predominantly influenced by just two measurements, the standard emission factor given by the 2013 IPCC Wetlands Supplement (IPCC et al., 2014) was used for points under Forest Land and for the category Woody Grassland.

N_2O

The database consists of representatively surveyed, quality-checked, national measurements that cover at least one year (320 sites, 21 different peatland areas). Since it was not possible to identify any functional relationships, the average measurement values for the various land-use categories were used as the emission factors (Tiemeyer et al., 2020).

6.1.2.2.3 Implied emission factors (IEFs)

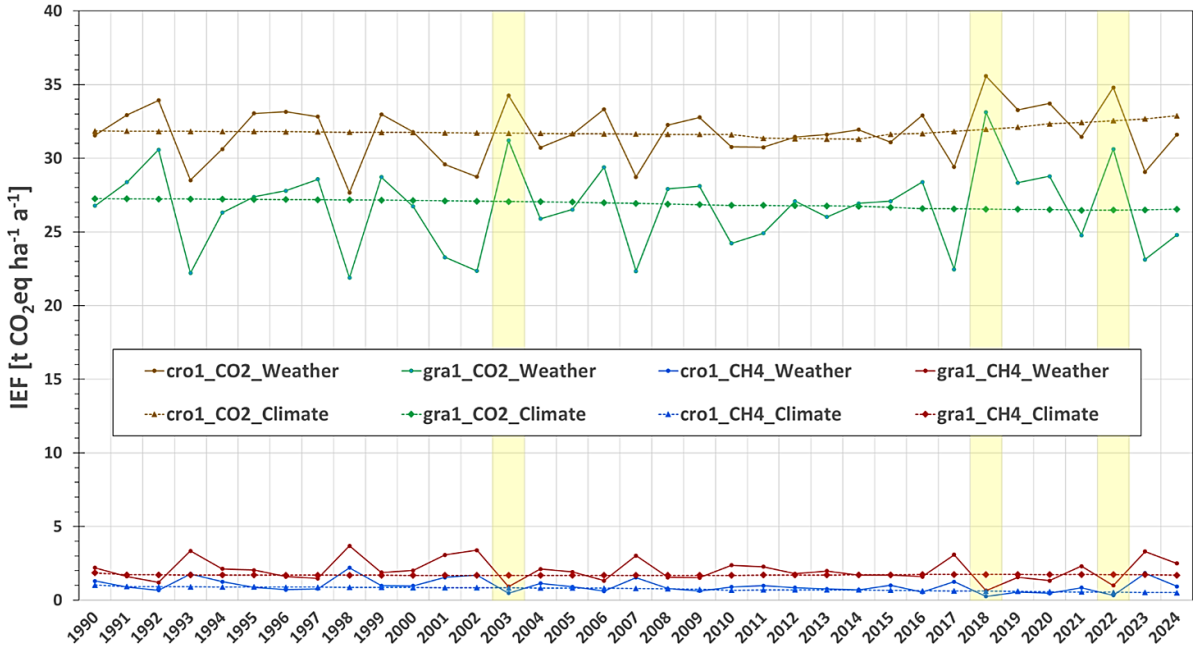
During inventory preparation, emissions from organic soils are calculated with implied emission factors, including specific factors for each GHG and each land-use category. The emission factors given by the 2013 IPCC Wetlands Supplement (IPCC et al., 2014) are valid for specific conditions of organic soils. When determining emissions from a given land-use category, the following also have to be taken into account: non-drained, wet areas; carbon discharge with the soil water in the form of dissolved organic carbon (DOC); methane emissions from ditches draining organic soils. This procedure yields the implied emission factors (IEFs) given in Table 329 for CO_2, CH_4 and N_2O emissions from Germany's organic soils for the year 2023. The CO_2 and CH_4 emissions are weather-dependent. As a result, the implicit emission factors vary over the course of the time series: in dry years they are higher for CO_2 and lower for CH_4, in wet years vice versa.

Table 329: Implied emission factors (IEF) and their uncertainties (95% percentile) for CO_2 onsite + DOC, CH_{4_land} + CH_{4_ditch} and N_2O onsite from Germany's organic soils (4.A - 4.E; 4(II)) for the year 2024

Land use	CO_2-onsite + DOC		CH_{4_land} + CH_{4_ditch}		N_2O-onsite	
	IEF	95% percentile	IEF	95% percentile	IEF	95% percentile
	t CO_2-C ha^{-1} a^{-1}		kg CH_4 ha^{-1} a^{-1}		kg N_2O-N ha^{-1} a^{-1}	
Forest Land	10.58	(8.51 - 13)	3.12	(1 - 6.44)	2.33	(0 - 5.12)
$Cropland_{annual}$	26.48	(17.33 - 32.68)	55.71	(30.8 - 228.04)	10.43	
Hops	26.58	(14.87 - 36.65)	50.67	(24.82 - 200.95)	10.45	
Vineyards	16.26	(7.7 - 23.33)	9.36	(3.53 - 41.67)	11.1	
Orchards	19.41	(11.03 - 27.03)	99.9	(56.86 - 342.15)	9.42	
Tree nurseries	20.29	(13.88 - 25.04)	103.09	(60.22 - 389.78)	9.34	
Christmas tree plantations	18.86	(12.54 - 23.48)	119.5	(64.46 - 490.03)	9.01	
Short-rotation plantations	27.98	(5.41 - 49.3)	71.05	(22.77 - 275.4)	10.1	
Grassland (in the strict sense)	26.23	(14.94 - 34.55)	52.67	(25.67 - 211.34)	4.23	
Woody grassland	20.8	(13.95 - 25.86)	119.26	(83.61 - 319.13)	2.23	(0.86 - 7.8)
Hedges	26.45	(13.25 - 36.17)	73.07	(33.51 - 304.99)	2.55	(0.18 - 12.28)
Terrestrial Wetlands	11.94	(7.19 - 20.83)	60.76	(25.65 - 149.79)	0.35	(0.06 - 1.11)
Peat extraction	5.86	(3.63 - 8.08)	6.44	(1.86 - 15.07)	0.84	(0.43 - 1.19)
Settlements	22.23	(15.77 - 26.88)	57.87	(29.91 - 209.55)	3.56	(1.4 - 12.37)

Figure 58 shows this situation using the *Cropland$_{annual}$* and *Grassland (in the strict sense)* land-use categories as an example. Model calculations using parameters as a model input to describe the climate rather than the weather cannot reproduce the actual emission event over time; however, they capture the sum of emissions over time very well (Figure 69; cf. Chapter 6.1.2.2.2). This is why the calculations using weather input variables are applied in the inventory.

Figure 69: Time series of the implied emission factors (IEF) for CO_2 onsite + DOC and CH_{4_land} + CH_{4_ditch} [t CO_2 equivalents] from organic soils in Germany for the land-use subcategories Cropland$_{annual}$ (cro1) and Grassland in the strict sense (gra1)



Yellow shading: Extremely dry years

Source: own illustration, Thünen-Institut

6.1.2.3 Carbon emissions from biomass (4.A through 4.F)

6.1.2.3.1 General remarks

In the framework of the German GHG inventory, emissions from the above-ground and below-ground biomass pools are listed for

- the remaining categories Forest Land, Hops, Vineyards, Orchards, Tree nurseries, Christmas tree plantations, Short-rotation plantations, Woody Grassland, Hedges, Terrestrial Wetlands, Buildings and open areas
- all conversion categories

For the remaining categories Cropland$_{annual}$ and Grassland (in the strict sense), and for unchanging crop types (annual or perennial), no carbon-stock changes are listed since, pursuant to the IPCC Guidelines (2006 IPCC Guidelines, IPCC (2006a)), in these subcategories an equilibrium condition is assumed for the carbon fluxes of the annual biomass pools. With the gain-loss method, therefore, $\Delta C = 0$ (Equation 2.7 in the 2006 IPCC Guidelines, IPCC (2006a)). "NA" is entered in the corresponding fields in the CR tables. For the remaining categories Water bodies and Other Land, no emissions from plant biomass occur since these sites are free of vegetation.

In the case of land use changes, annual arable crops, differentiated by crop type, cannot be explicitly and comprehensively verified spatially using the current system. As a result, a mean carbon-stocks value weighted by crop type and area under cultivation – a mixed value for the biomass of all annual crops – has to be derived from official statistics (Statistisches Bundesamt, FS 3, R 3.2.1) (cf. Chapter 6.1.2.3.3). The official statistics are the only consistent data source (with regard to both content and chronological coverage) that supports nearly complete coverage derivation (subject to the limitations of official statistics, such as exclusion limits), weighted by yields and areas of representative carbon stocks for herbaceous plants from agricultural production in Germany. Currently, this derivation is carried out to a maximally disaggregated degree at the federal state level. As a result, in the case of land-use changes to and from $Cropland_{annual}$, all calculations of emissions from biomass are based on 16 different and annually differentiated regional strata.

Emissions from biomass are listed in the year in which they occur. To this end, a method is used that, in particular, takes account of the specific composition and development of the plant biomass in the various individual land-use categories. With this approach, the plant biomass carbon stocks (divided into various compartments) and their changes during their life and cultivation cycles are continuously modelled and recorded (cf. Chapter 6.1.3.2).

6.1.2.3.2 General calculation methods

The carbon-stock changes resulting from land-use changes are determined, and reported, for both annual and perennial biomass. The biomass stocks changes are calculated in accordance with the gain-loss method (2006 IPCC Guidelines). In the process, national data on the relevant carbon-stock changes, divided by above-ground and below-ground biomass, are drawn upon to determine removals and emissions of CO_2.

The carbon-stock changes in biomass are estimated by subtracting the complete biomass carbon stocks directly prior to the land-use conversion from the stocks that grow in the first year following the conversion, with reference to the area affected by the change (in accordance with Equation 2.16, 2006 IPCC Guidelines, IPCC (2006a)):

Equation 34:

$$\Delta C_{Bio} = \sum_{i=1}^{n} \left(A_i * EF_{final} - A_i * EF_{initial} \right)$$

- ΔC_{Bio}: = Change in the biomass carbon stock for a given land-use category in the year of the use change [t]
- A_i = Area on which the land-use change occurred [ha]
- EF_{final} = Plant-specific biomass carbon stock in the first year following the use change [t ha^{-1}]
- $EF_{initial}$ = Plant-specific biomass carbon stock prior to the land-use change [t ha^{-1}]
- N = Number of conversion categories
- I = Conversion categories

6.1.2.3.3 Annual crops and Grassland: calculation methods and emission factors

For annual crops and grassland, the calculation method set forth in Chapter 6.1.2.3.2 has the following outcome:

- following land-use changes from/to these categories, the entire biomass carbon stocks are credited in the year of the land-use change; also, in the case of land-use changes to these categories, an equilibrium condition is assumed as of the second year
- in the remaining categories, an equilibrium is assumed for the plant biomass of the relevant crops; consequently, no emissions are reported (and "NA" is entered into the corresponding fields in the Common Reporting Tables)

The carbon stocks for the above-ground and below-ground biomass of plants of annual Cropland and horticultural crops, and of Grassland (in the strict sense), are derived annually on the basis of harvest surveys of the Federal Statistical Office; in the process, the same data sources and algorithms are used as are used for calculation of crop residues in CRF sector 3.D. The official statistics are the only Germany-wide, consistent (in terms of both content and chronology) data source that supports derivation, on a complete-coverage basis, of representative emission factors for herbaceous plants from agricultural production in Germany (cf. Chapter 6.1.2.3.1). These emission factors are listed in regionalised form for the individual German federal states.

The mean carbon stocks of cropland and horticultural crops are determined on the basis of harvest data and area under cultivation for a total of 65 field crops. These include:

- Winter wheat, spring wheat, rye, triticale, maslin, winter barley, spring barley, oats, mixed grains other than maslin, grain maize;
- Field peas, broad beans;
- Potatoes, sugar beets, fodder beets;
- Winter oilseed rape;
- Clover, alfalfa, grass, silage maize;
- Cauliflower, broccoli, Chinese cabbage, kale, kohlrabi, Brussels sprouts, red cabbage, white cabbage, savoy, oak-leaf lettuce, iceberg lettuce, endive, lamb's lettuce, head lettuce, lollo lettuce, radicchio, romaine lettuce, rocket, other lettuce types, spinach, rhubarb, asparagus, celery, fennel, celeriac, horseradish, carrots, radishes, (larger) radishes, red beets, pickling cucumbers, slicing cucumbers, edible pumpkins, courgette, sweet corn, bush beans, broad beans, runner beans, split peas, peas, bunching onions, onions, parsley, leeks and chives.

For Grassland (in the strict sense), the data consists of harvest and cultivation-area data for all statistically recorded

- meadows
- mowed pastures
- pastures
- mountain pastures and rough pastures

The dry biomass of individual plant parts is derived from harvest data pursuant to Rösemann et al. (2015) and uses relevant ratios and water content data obtained from various sources. The data and methods used are consistent with those used to calculate nitrogen in crop residues (CRF 3.D.1.d).

For calculation of biomass carbon stocks, an average carbon content of 45% by weight was assumed - and used instead of the IPCC standard value (50% by weight) - since Osowski et al.

(2004) give carbon contents of 44-48% by weight for plants in central Europe and since Pöpken (2011), in her studies of cultivated trees (carried out for the German inventory), also found average values of 45-46% by weight.

Using all these data, mean carbon stocks are calculated in relation to the area. For each specific crop, this is done by multiplying the relevant areas under cultivation ([ha]) by the corresponding yields ([t biomass ha^{-1}]). The resulting products (on a by-crop basis; absolute harvested quantities of individual herbaceous plants or parts thereof [t]) are converted to dry matter and carbon content, summed and then divided by the relevant area sum [ha]. This approach yields area-weighted, yield-weighted averages, for herbaceous plants from agricultural production [t C ha^{-1}], that are representative for Germany. These area-based mean carbon stocks [t C ha^{-1}] in the above-ground and below-ground biomass of field crops and grasses are used as emission factors. This approach is in accordance with the methods set forth in the 2006 IPCC Guidelines.

The results for annual crops of Cropland and horticultural areas are shown in Table 330, while those for Grassland crops in the strict sense are shown in Table 330. The calculations of carbon-stock changes due to land-use changes are always based on the current regional value for the year in question.

Table 330: Area-based carbon stocks of the biomass of annual crops on Cropland and horticultural land, broken down by federal state, total (biototal), above-ground (bioabove) and below-ground (biobelow) biomass for 2024, in [t C ha-1 ± half of the 95% confidence interval]

	Bio_{total}	Bio_{above}	Bio_{below}
Baden-Württemberg	5.62 (± 9.8%)	4.41 (± 11.2%)	1.21 (± 19.9%)
Bavaria	5.96 (± 11.5%)	4.52 (± 13.5%)	1.44 (± 22.3%)
Berlin	2.89 (± 13%)	2.25 (± 14.5%)	0.64 (± 27.3%)
Brandenburg	4.12 (± 10.7%)	3.27 (± 12.8%)	0.85 (± 17.3%)
Bremen	6.13 (± 13.7%)	4.59 (± 16.4%)	1.54 (± 23.8%)
Hamburg	5.27 (± 10.6%)	4.27 (± 12.3%)	1.00 (± 21.1%)
Hesse	5.61 (± 9.3%)	4.23 (± 9.7%)	1.37 (± 23.4%)
Mecklenburg-Western Pomerania	5.87 (± 10.9%)	4.51 (± 12.4%)	1.37 (± 22.9%)
Lower Saxony	6.70 (± 13.8%)	4.66 (± 16%)	2.04 (± 27%)
North Rhine-Westphalia	6.83 (± 11%)	4.91 (± 11.7%)	1.92 (± 25.6%)
Rhineland-Palatinate	5.80 (± 9.3%)	4.27 (± 9.8%)	1.52 (± 22.5%)
Saarland	3.87 (± 8.8%)	3.16 (± 9.9%)	0.72 (± 19.4%)
Saxony	5.26 (± 9.7%)	4.08 (± 11.1%)	1.18 (± 20.1%)
Saxony-Anhalt	5.98 (± 10.5%)	4.41 (± 11.2%)	1.56 (± 25.4%)
Schleswig-Holstein	5.74 (± 11.9%)	4.51 (± 14.3%)	1.23 (± 19.7%)
Thuringia	5.52 (± 9.5%)	4.31 (± 10.8%)	1.21 (± 20.4%)

Table 331: Area-based carbon stocks of the biomass of annual crops on Grassland in the strict sense, broken down by federal state, total (bio_{total}), above-ground (bio_{above}) and below-ground (bio_{below}) biomass for 2024, in [t C ha^{-1} ± half of the 95% confidence interval]

	Bio_{total}	Bio_{above}	Bio_{below}
Baden-Württemberg	6.24 (± 32.2%)	3.47 (± 38.5%)	2.77 (± 54.2%)
Bavaria	8.55 (± 32.1%)	4.75 (± 38.4%)	3.80 (± 54.1%)
Berlin	5.20 (± 29.6%)	2.89 (± 35.4%)	2.31 (± 49.8%)
Brandenburg	5.18 (± 32.6%)	2.88 (± 39.0%)	2.30 (± 54.8%)
Bremen	7.88 (± 37.8%)	4.38 (± 43.3%)	3.50 (± 62.4%)
Hamburg	8.54 (± 36.4%)	4.75 (± 43.5%)	3.80 (± 61.2%)
Hesse	6.12 (± 30.1%)	3.40 (± 36.1%)	2.72 (± 50.7%)
Mecklenburg-Western Pomerania	4.88 (± 31.8%)	2.71 (± 38.1%)	2.17 (± 53.5%)
Lower Saxony	7.86 (± 36.8%)	4.37 (± 44.0%)	3.49 (± 61.8%)
North Rhine-Westphalia	6.22 (± 29.7%)	3.45 (± 35.5%)	2.76 (± 49.9%)
Rhineland-Palatinate	6.48 (± 30.8%)	3.60 (± 36.8%)	2.88 (± 51.7%)
Saarland	4.69 (± 29.4%)	2.61 (± 35.1%)	2.09 (± 49.3%)
Saxony	6.06 (± 31.0%)	3.37 (± 37.1%)	2.69 (± 52.1%)
Saxony-Anhalt	5.17 (± 32.6%)	2.87 (± 39.0%)	2.30 (± 54.9%)
Schleswig-Holstein	8.40 (± 32.9%)	4.67 (± 39.4%)	3.73 (± 55.4%)
Thuringia	6.52 (± 34.8%)	3.62 (± 41.7%)	1.74 (± 58.6%)

6.1.2.3.4 Perennial crops: calculation methods and emission factors

For perennial plant biomass outside of Forest Land, anthropogenic CO_2 emissions resulting from carbon-stock changes are now being listed at the time at which they occur. To make this possible, the complete growth cycles of the various woody plants and understory vegetation have to be determined and then modelled over time as a function of rotation cycles and operational duration. The carbon stocks of plant biomass consist of various different compartments, depending on the land use and crop involved. The relevant land-use categories and perennial crops, the assumed composition of the plant biomass and the biomass's rotation cycles are shown in Table 332.

Table 332: Land-use categories with perennial woody crops outside of Forest Land, their compartments and rotation cycles [a]

Land-use category	Abbreviation	Compartments (weighting factor)	Rotation cycle [a]	Rotation cycle+
Orchards	croo	Fruit trees (1), grassland (0.75)	20	Next cycle
Vineyards	crow	Vines (1), grassland (0.75)	30	Next cycle
Tree nurseries	crot	Forest trees (0.33), ornamental trees and shrubs (0.33), grassland (0.33)	10	Equilibrium
Christmas tree plantations	crox	Coniferous trees (1), grassland (0.75)	10	Next cycle
Short-rotation plantations	cros	Deciduous trees (1)	10	Next cycle
Hedges/field shrubs	gra2/gra3	Hedge shrubs/deciduous trees (1)	12	Next cycle

Land-use category	Abbreviation	Compartments (weighting factor)	Rotation cycle [a]	Rotation cycle+
Terrestrial Wetlands	wett	Hedge shrubs/deciduous trees (0.33); grassland (0.66)	20	Equilibrium
Settlements	set1	Hedge shrubs/deciduous trees (0.25); grassland (0.25)	44	Equilibrium

During rotation periods, the compartments are treated in different ways. A site's current biomass carbon stocks in a specific year are obtained as the sum of the current stocks of the compartments involved. The calculation method is also based on the following additional assumptions:

- The biomass stocks of perennial crops outside of Forest Land are determined at every sample point; this is required for annual determination of the change in the absolute stocks.
- The biomass stocks of the various different perennial crops depend on the crops' rotation cycles. The system-relevant maximum stocks are attained in the last year of the cycle.
- At the end of a rotation period, a new growth cycle begins, regardless of whether the crop is in a conversion category or a remaining category.
- Regardless of the rotation cycles involved, the conversion period lasts no longer than 20 years (the "effective conversion time" concept (Chapter 6.1.2)); at the end of the conversion period, the crop is transferred into the remaining category that corresponds to the relevant conversion category and it remains in its current rotation cycle. Only the allocation of the current stocks and emissions changes.
- In the case of land-use changes from one land-use category with perennial crops to any other land-use category, the current carbon stocks of all compartments are recorded completely as emissions in the year of the land-use change.
- All points that showed perennial crops for the year 1990 were assigned a stage of crop-specific rotation period using a random generator.
- As *short-rotation plantations* are not explicitly listed in the B-DLM, the area allocation (points) is carried out using a random generator as a function of the data from the official statistics for the relevant survey times. Official German statistics have only been explicitly collecting data on short-rotation plantations since 2010.

The annual emissions calculation is carried out pursuant to Equation 2.7 IPCC 2006, Vol. 4:

Equation 35:

$$\text{Emission}\ [\text{t}\ \text{CO}_2\ \text{ha}^{-1}\text{a}^{-1}] = \left(\text{C}_{\text{curr year}} - \text{C}_{\text{prev year}}\right) * {}^{-44}/_{12}$$

- $\text{C}_{\text{curr year}}$ = Carbon stocks in the current year [t C ha^{-1} a^{-1}]
- $\text{C}_{\text{prev year}}$ = Carbon stocks of the previous year [t C ha^{-1} a^{-1}]

The carbon stocks are determined specifically for the various crops as follows:

Equation 36:

$$C_{cultspec} = C_{cultspec_{abo}} + C_{cultspec_{bel}}$$

- $C_{cultspec}$ = Crop-specific biomass carbon stocks [t C ha^{-1} a^{-1}]
- $C_{cultspec_abo}$ = Above-ground crop-specific biomass carbon stocks [t C ha^{-1} a^{-1}]
- $C_{cultspec_bel}$ = Below-ground crop-specific biomass carbon stocks [t C ha^{-1} a^{-1}]

The carbon stocks in above-ground and below-ground plant biomass are calculated as follows: the carbon stocks of the subcompartments (which are required for this purpose) are multiplied by a specific weighting factor that depends, in each case, on the reference value (such as area, above-ground biomass) being used for the relevant subcompartment. The terms for pruning and herbaceous plants (gra1) are optional depending on the crop involved:

Equation 37:

$$C_{abo} = C_{stem,branch} * GF + C_{cut} * GF + C_{gra1_{abo}} * GF$$

- C_{abo} = Above-ground biomass carbon stocks [t C ha^{-1} a^{-1}]
- $C_{stem,\ branch}$ = Above-ground carbon stocks of woody plants (stem, branches) [t C ha^{-1} a^{-1}]
- GF = Crop-specific weighting factor$_{reference\ value}$
- C_{cut} = Carbon stocks of pruned material [t C ha^{-1} a^{-1}]
- $C_{gra1\ abo}$ = Above-ground herbaceous biomass carbon stocks [t C ha^{-1} a^{-1}]

Equation 38:

$$C_{bel} = C_{roots} * GF + C_{gra1_{bel}} * GF$$

- C_{bel} = Below-ground biomass carbon stocks [t C ha^{-1} a^{-1}]
- C_{roots} = Below-ground carbon stocks of woody plants (roots) [t C ha^{-1} a^{-1}]
- $C_{gra1\ bel}$ = Below-ground herbaceous biomass carbon stocks [t C ha^{-1} a^{-1}]
- GF = Crop-specific weighting factor$_{reference\ value}$

6.1.2.3.5 Derivation of emission factors for perennial woody crops

In the framework of the research project “Development of methods for determining the biomass of perennial woody plants, outside of forests” (Methodenentwicklung zur Erfassung der Biomasse mehrjährig verholzter Pflanzen außerhalb von Waldflächen), carbon-stock data specific to each federal state were collected for above-ground and below-ground biomass of orchards, vineyards and Christmas tree plantations in Germany. The mean carbon stocks of the plants in tree nurseries were then estimated on the basis of these data and of results of the National Forest Inventory. The mean tree biomass values for short-rotation plantations and hops plantations were derived from literature and research-project data specific to each federal state.

6.1.2.3.5.1 Orchards

In the framework of the aforementioned research project, with trees taken from Germany's two main fruit-growing regions (Altes Land ("Old country"): northern Germany, and Lake Constance region: southern Germany), a total of 100 fruit trees (91 apple trees, 6 cherry trees and 3 plum trees), of differing ages and types, were destructively sampled. In addition, the following data were collected from 210 living apple trees:

- Diameter at stem base
- Diameter at breast height
- Base

Only commercial fruit cultivation was considered in this context. With the entirety of the data collected in the research project, and the results of official statistics (fruit tree cultivation surveys Statistisches Bundesamt Statistisches Bundesamt (FS 3, R 3.1.4) [82]), it proved possible to determine the total carbon stocks in the above-ground and below-ground biomass of the various fruit trees and shrubs for various age classes and for all years of the fruit cultivation surveys (Statistisches Bundesamt, FS 3, R 3.1.4) (2002, 2007, 2012, 2017). In the process, the values derived for apple trees were also assigned to pear trees, while those derived for cherry and plum trees were also assigned to damson, mirabelle and greengage trees.

For the inventory, orchards are georeferenced only generally; they cannot be differentiated by fruit tree types. For this reason, a long-term, area-weighted figure for the average carbon stocks in the above-ground phytomass of fruit trees and shrubs was derived from the data. This was done by dividing the sum of the total carbon stocks of each partition of an age class by the relevant area under cultivation. This procedure did not lend itself to the below-ground plant biomass, since the original data obtained in the research project varied widely, for sampling-related reasons, and no significant dependence on the above-ground biomass could be derived. For this reason, the below-ground plant biomass was derived from the above-ground biomass using the equation from (Mokany et al., 2006a)[83].

From the values derived with this method, it was then possible to use regression to derive a sigmoid function for the above-ground biomass that describes with a high degree of significance the ratio of carbon stocks in fruit trees to the trees' age:

[82] The fruit tree cultivation surveys are representative statistical surveys of Germany's commercial fruit cultivation sector that are carried out every 5 years. For the present submission, the results of the fruit-cultivation surveys of 2002, 2007, 2012 and 2017 were used. In the surveys, the Federal Statistical Office determines the sector's total numbers of apple, pear, sweet-cherry, sour-cherry, plum, damson, mirabelle and greengage trees in different age classes as well as the areas under cultivation with trees in the various age classes. The fruit tree cultivation surveys are exhaustive surveys.

[83] $Phytomass_{below\text{-}ground} = 0.489 * (Phytomass_{above\text{-}ground}$Woody Grassland$)^{0.890}$ – In their survey project, Mokany, K., Raison, R. J., & Prokushkin, A. S. (2006b). Critical analysis of root: shoot ratios in terrestrial biomes [Journal Article]. *Global Change Biology*, *12*(1), 84-96. http://reddcr.go.cr/sites/default/files/centro-de-documentacion/mokany_et_al._2006_-_critical_analysis_root_to_shoot_ratios.pdf derived, for numerous types of vegetation, root/shoot ratios as a function of biomass, climatic parameters and local site parameters. Their results were then adopted as default values in the 2006 IPCC Guidelines IPCC. (2006a). *2006 IPCC guidelines for national greenhouse gas inventories* [Report]. S. Eggleston, L. Buendia, K. Miwa, T. Ngara, & K. Tanabe. https://www.ipcc-nggip.iges.or.jp/public/2006gl/.

Equation 39:

$$C_{croo_{stem,branch}} = -1{,}9798 + \frac{16{,}9435}{\left(1+e^{-\frac{a-13{,}0365}{6{,}1938}}\right)}$$

- $C_{croo\ stem,\ branch}$ = Carbon stocks in stems and branches of fruit trees [t C ha^{-1}]
- A = Number of years following initial planting (1, 2, 3 - 20) after stock renewal

All of the inventory calculations related to fruit trees are based on this formula (Mokany et al.) and the values for below-ground biomass derived with it.

Other assumptions include:

- The annual quantity pruned amounts to 20% of above-ground biomass (PÖPKEN 2011)
- 75% of orchards' areas have herbaceous-plant/grass cover
- The rotation period for orchards is assumed to be 20 years (figures range between 12 and 25 years; calculated from the tree biomass distributions in the various age classes as given by the Federal Statistical Office: 18.3 years); after this time, a complete stock renewal is carried out (not with grass)

The above-ground plant biomass stocks for orchards are calculated using

Equation 40:

$$C_{croo_{abo}} = C_{croo_{stem,branch}} + C_{croo_{cut}} + C_{gra1_{abo}} * 0{,}75$$

- $C_{croo\ stem,\ branch}$ = Carbon stocks in stems and branches of fruit trees [t C ha^{-1}]
- $C_{croo\ cut}$ = Carbon stocks of annually pruned material [t C ha^{-1}]
- $C_{gra1\ abo}$ = Carbon stocks in the above-ground biomass of Grassland (in the strict sense) [3.78 t C ha^{-1}]

The below-ground plant biomass stocks for orchards are calculated by:

Equation 41:

$$C_{croo_{roots}} = 0{,}489 * {C_{croo_{abo}}}^{0{,}89}$$

- $C_{croo\ roots}$ = Carbon stocks of below-ground biomass of fruit trees [t C ha^{-1}]
- $C_{croo\ abo}$ = Carbon stocks of above-ground biomass of fruit trees [t C ha^{-1}]

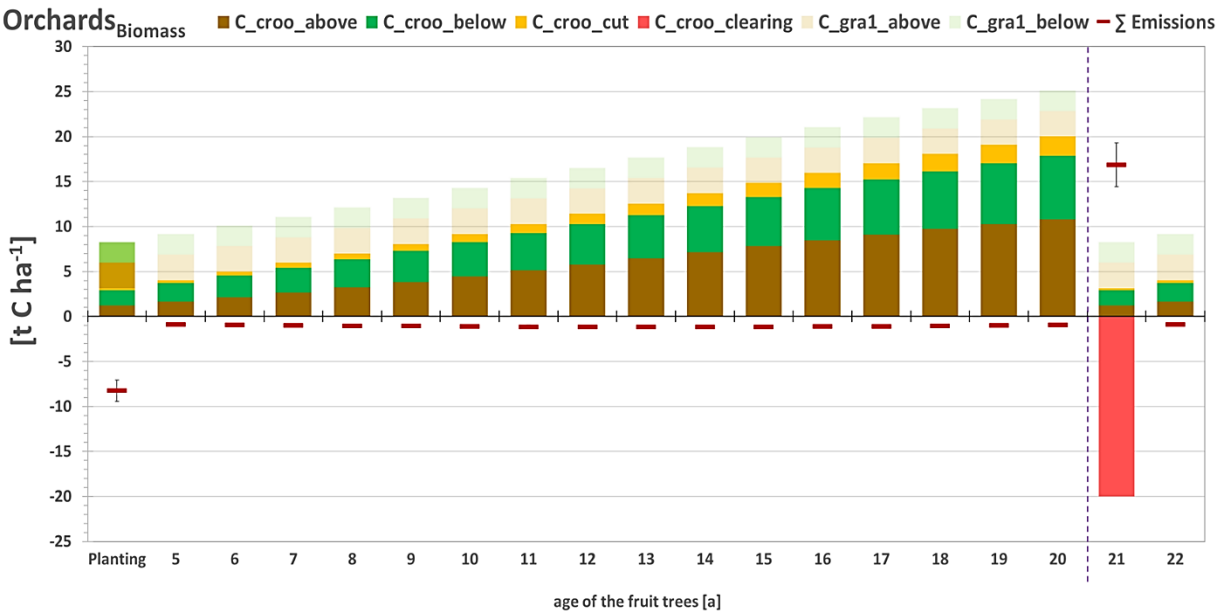
Equation 42:

$$C_{croo_{bel}} = C_{croo_{roots}} + C_{gra1_{bel}} * 0{,}75$$

- $C_{croo\ bel}$ = Carbon stocks of below-ground biomass of fruit trees [t C ha^{-1}]
- $C_{croo\ roots}$ = Carbon stocks of root biomass in [t C ha^{-1}]
- $C_{gra1\ bel}$ = Carbon stocks in the below-ground biomass of Grassland (in the strict sense) [3.03 t C ha^{-1}]

The total carbon stocks in the plant biomass of orchards and the resulting emissions to be taken into account are calculated using the methods described in Chapter 6.1.2.3.2 and Chapter 6.1.2.3.3. The development of orchards' carbon stocks over the course of multiple rotation cycles and the related emissions are shown in Figure 70. Fruit trees are usually grown in orchards before they are planted in plantations. An age of 4 years is assumed so as to avoid being counted twice when a new orchard area is established for fruit trees.

Figure 70: Development of carbon stocks [t C ha^{-1}] in compartments of orchards and the resulting emissions [t C ha^{-1}], in successive rotation cycles (|). Transparent bars are emissions-relevant only in the case of land use changes



Source: own illustration, Thünen-Institut

6.1.2.3.5.2 Vineyards

In the project "Development of methods for determining the biomass of perennial woody plants, outside of forests" (Methodenentwicklung zur Erfassung der Biomasse mehrjährig verholzter Pflanzen außerhalb von Waldflächen) (Pöpken, 2011), a total of 74 grapevines were destructively sampled for the purpose of determining a country-specific value for carbon stocks of grapevines. The ages of the vines were 15 and 25 years. In the testing, the vines' mass, and the water and carbon content of the above-ground and below-ground plant parts, were determined (Pöpken, 2011). From these data it proved possible, using nonlinear regression, to determine a highly significant relationship between the ages and carbon stocks of the above-ground and below-ground biomass of grapevines. Since vineyards in Germany contain an average of 4,000

grapevines per ha (Pöpken, 2011), the carbon stocks per area unit (ha) were calculated by multiplying the carbon stocks of individual plant compartments/total plants by 4,000. The above-ground and below-ground plant biomass is calculated using the following equations:

Equation 43: Calculation of above-ground biomass of grapevines

$$C_{crow_{vine}} = (-0{,}004 * a^2 + 0{,}0234 * a) * \frac{4000}{1000}$$

- $C_{croo\ vine}$ = Carbon stocks of grapevine in [t C ha^{-1}]
- a = Number of years following initial planting (1-30)

Equation 44: Calculation of below-ground biomass of grapevines

$$C_{crow_{roots}} = (0{,}0001 * a^2 + 0{,}0096 * a) * \frac{4000}{1000}$$

- $C_{croo\ roots}$ = Carbon stocks of grapevine roots in [t C ha^{-1}]
- a = Number of years following initial planting (1-30)

In vineyards in Germany, grassland plants are normally cultivated on the strips of land between grapevine rows. The reasons for this include erosion protection. In vineyards, as in orchards, grassland plants are assumed to account for 75% of the area under cultivation in each case. In other studies, it was found that the amount of material pruned annually is equivalent to about 0.81 t C ha^{-1}. Grass fractions and pruned material are taken into account only in the cases of first-time initial planting and of use changes from vineyards to a different land-use category. The operational duration is the same as the rotation period and amounts to 30 years. For vineyards, therefore, the carbon stocks in biomass are calculated as follows:

Equation 45: Sum of above-ground biomass of vineyards [t C ha^{-1}]

$$C_{crow_{abo}} = C_{crow_{vine}} + C_{crow_{cut}} + C_{gra1_{abo}} * 0{,}75$$

- $C_{croo\ abo}$ = Carbon stocks of above-ground biomass of vineyards [t C ha^{-1}]
- $C_{croo\ vine}$ = Carbon stocks of above-ground biomass of grapevines [t C ha^{-1}]
- $C_{croo\ cut}$ = Carbon stocks of material annually pruned from grapevines [t C ha^{-1}]
- $C_{gra1\ abo}$ = Carbon stocks of above-ground biomass of grassland between plant rows [t C ha^{-1}]

Equation 46: Sum of below-ground biomass of vineyards [t C ha^{-1}]

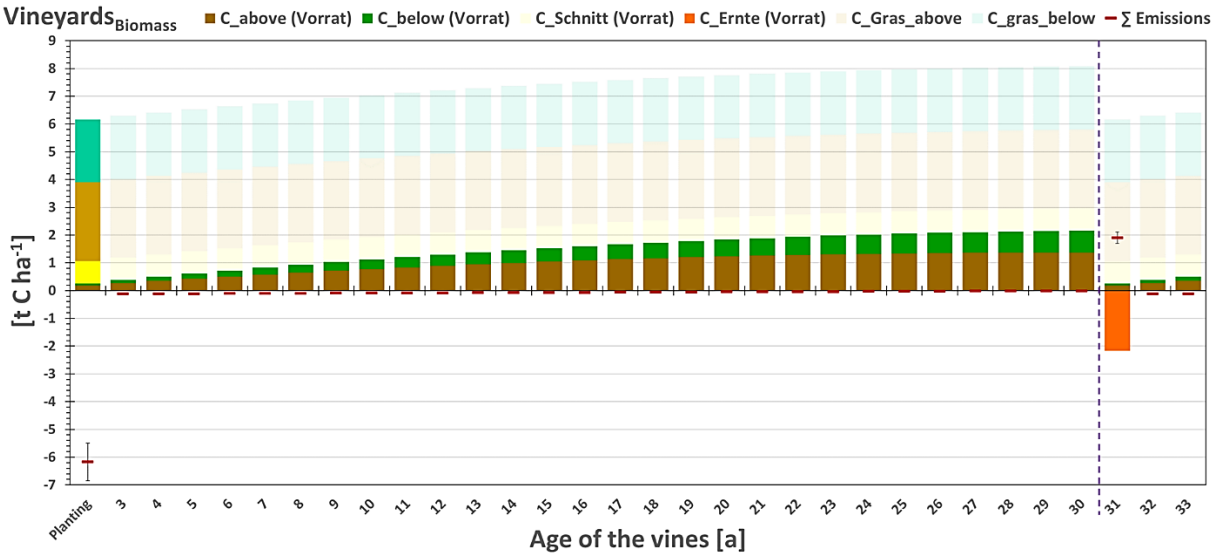
$$C_{crow_{bel}} = C_{crow_{roots}} + C_{gra1_{bel}} * 0{,}75$$

- $C_{croo\ bel}$ = Carbon stocks of below-ground biomass of vineyards [t C ha^{-1}]
- $C_{croo\ roots}$ = Carbon stocks of below-ground biomass of grapevines [t C ha^{-1}]
- $C_{gra1\ bel}$ = Carbon stocks of below-ground biomass of grassland between plant rows [t C ha^{-1}]

The total carbon stocks in the plant biomass of vineyards and the resulting emissions to be taken into account are calculated using the methods described in Chapter 6.1.2.3.2 and Chapter 6.1.2.3.3. The development of vineyards' carbon stocks over time and the associated emissions

are shown in Figure 71. Vines are usually raised in nurseries in the first year; to avoid them being counted twice, the model counts them as being planted biennially.

Figure 71: Development of carbon stocks [t C ha^{-1}] in compartments of plant biomass of vineyards and the resulting emissions [t C ha^{-1}] in successive rotation cycles (|). Transparent bars are emissions-relevant only in the case of land-use changes



Source: own illustration, Thünen-Institut

6.1.2.3.5.3 Tree nurseries

An exhaustive tree nursery survey carried out at 4-year intervals by Statistisches Bundesamt (FS 3, R 3.1.7) provides information about the tree species cultivated in tree nurseries (crot). The 2017 survey showed that German tree nurseries grow primarily ornamental plants and other trees and shrubs (about 80%); only 20% of their area was used for cultivation of forest plants (Statistisches Bundesamt (FS 3, R 3.1.7)). Since no studies have been carried out of the average biomass stocks in trees and shrubs cultivated in tree nurseries in Germany, the average carbon stocks per unit of tree nursery area were derived from biomass stock values for woody plants specific to the federal state. To this end, the following assumptions were made:

- The plants cultivated in tree nurseries consist of 2/3 ornamental trees and shrubs and 1/3 forest trees (actually, the latter are cultivated on only about 20% of the nurseries' available space; but since tree nurseries also cultivate coniferous trees for the Christmas season and for use as ornamental trees as well as "forest trees" such as oak and beech, the relevant percentage was increased to 33%).
- Tree nursery plants remain in the nursery for a maximum of 10 years.
- The age classes within the various tree/shrub groups are evenly distributed.
- Nurseries have 6,000 plants per ha (this is equivalent to an average distance between plants of about 120-130 cm).
- In addition, 1/3 of nurseries' areas are covered with herbaceous plants/grass; this is taken into account once in the year of initial planting; after that, it is taken into account only in the case of use changes from crot to a different LUC.

- Rotation period: 10 years; it is assumed that the tree/shrub system reaches an equilibrium 10 years after the initial planting in which removals and additions are in balance. For this reason, as of the 10th year the average of the tree/shrub biomass produced in 10 years is assumed to represent the equilibrium value. As of the 11th year, no further emissions are reported.

The fruit tree carbon stocks derived from the results of the project "Development of methods for determining the biomass of perennial woody plants, outside of forests" (Pöpken) were also applied to ornamental trees and shrubs in a representative approach. For half of the larger trees and shrubs, the carbon stocks determined for cherry and plum trees were applied; for half of the smaller trees and shrubs, the stocks determined for apple trees were used (cf. Chapter 6.1.2.3.5.1). For the calculation of the biomass of forest trees, the methods developed by (Bösch & Kändler) for calculating forest biomass were applied. These methods are described in Chapter 6.4.2.2. The below-ground biomass of the various tree groups was estimated using the formula from Mokany et al. (2006b) (cf. Chapter 6.1.2.3.5.1).

From the carbon stocks of the various tree groups, age-dependent average values were obtained that represent the carbon stocks in the plant biomass of tree nurseries' woody plants. These carbon stocks were set in relation to the plants' ages. This made it possible to obtain highly significant regression equations for both above-ground and below-ground biomass that serve as a basis for all relevant calculations:

Equation 47: Above-ground biomass for tree nurseries [t C ha^{-1}]

$$C_{crot_{abo}} = 0{,}2673 * a^2 - 0{,}0744 * a + \frac{C_{gra1_{abo}}}{3}$$

- $C_{crot\ abo}$ = Carbon stocks of above-ground biomass of tree nurseries in [t C ha^{-1}]
- a = Number of years following initial planting (1-10)
- $C_{gra1\ abo}$ = Carbon stocks in the above-ground biomass of Grassland (in the strict sense) [3.78 t C ha^{-1}]

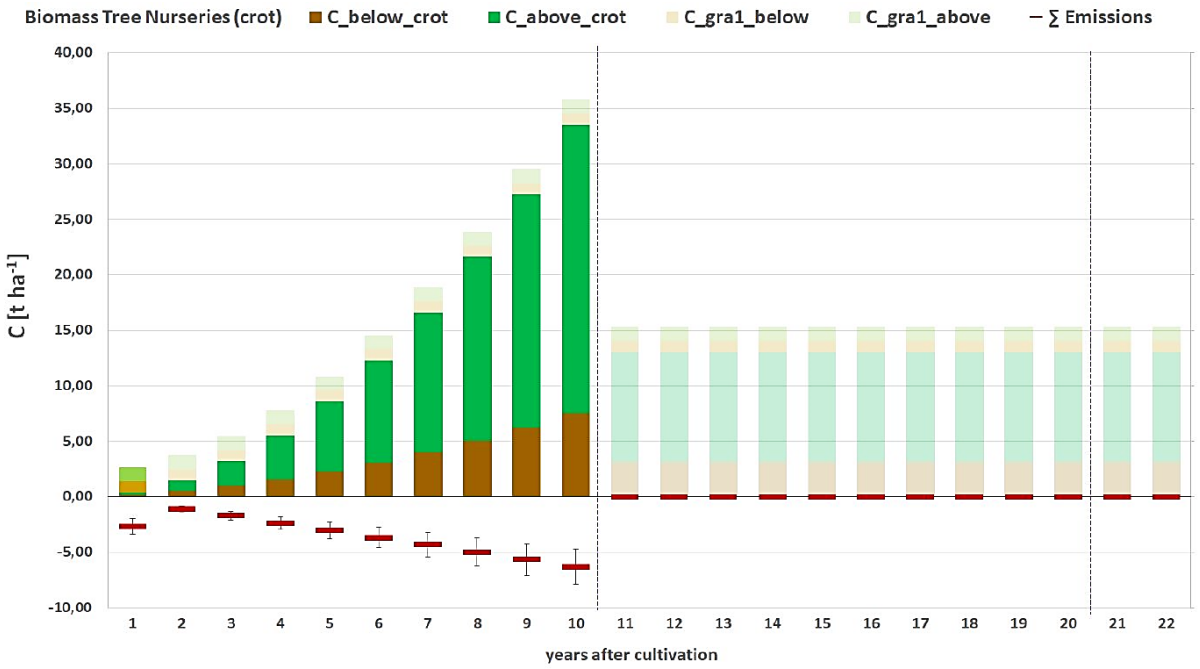
Equation 48: Below-ground biomass for tree nurseries [t C ha^{-1}]

$$C_{crot_{bel}} = 0{,}0599 * a^2 + 0{,}1562 * a + \frac{C_{gra1_{bel}}}{3}$$

- $C_{crot\ bel}$ = Carbon stocks of below-ground biomass of tree nurseries in [t C ha^{-1}]
- a = Number of years following initial planting (1-10)
- $C_{gra1\ bel}$ = Carbon stocks in the below-ground biomass of Grassland (in the strict sense) [3.03 t C ha^{-1}]

Apart from the aforementioned deviations, the total carbon stocks in the plant biomass of tree nurseries and the resulting emissions and their allocation are calculated using the methods described in Chapter 6.1.2.3.2 and Chapter 6.1.2.3.3. Figure 72 shows the development of carbon stocks in tree nurseries during successive rotation cycles, along with the resulting emissions.

Figure 72: Development of carbon stocks [t C ha^{-1}] in compartments of plant biomass of tree nurseries (SOC) and the resulting emissions [t C ha^{-1}] in successive rotation cycles (|). Transparent bars are emissions-relevant only in the case of land-use changes and of the end of an operational period



Source: own illustration, Thünen-Institut

6.1.2.3.5.4 Christmas tree plantations

Areas for cultivation of Christmas trees (crox) normally contain both coniferous trees and herbaceous plants. The area share for the latter is assumed to be 75%, and the carbon stocks in herbaceous biomass are calculated using the relevant value for Grassland (in the strict sense) as a proxy. Virtually no data are available on plant biomass of Christmas trees. PÖPKEN (2011) cites studies by the University of Copenhagen that obtained a value of 50 t biomass ha^{-1} for rotation periods of 8-12 years. For this reason, the duration of an average rotation cycle was assumed to be 10 years. Since the aforementioned 50 t biomass ha^{-1}, which corresponds to 22.5 t C ha^{-1}, refer to the total biomass, the below-ground fraction of that biomass was determined to be 5.95 t C ha^{-1} using the formula by MOKANY et al. (2006). This results in a value of 16.56 t C^{-1} for the above-ground biomass of Christmas trees. To determine the annual carbon-stock changes in the above-ground biomass of Christmas trees, a value was distributed linearly among the years of the relevant rotation cycle. As a result, the above-ground carbon stocks are calculated with:

Equation 49: Above-ground biomass of Christmas tree plantations

$$C_{crox_{abo}} = a * 1{,}656 + C_{gra1_{abo}} * 0{,}75$$

- $C_{crox\ abo}$ = Carbon stocks of above-ground biomass of Christmas tree plantations [t C ha^{-1}]
- $C_{gra1\ abo}$ = Carbon stocks in the above-ground biomass of herbaceous, annual plants [3.78 t C ha^{-1}]
- a = Number of years following initial planting (with a rotation cycle of 10 years)

The plantations' below-ground biomass is calculated by combining the below-ground biomass for the trees as determined with the equation of MOKANY et al. (2006) with the below-ground biomass of the herbaceous plants:

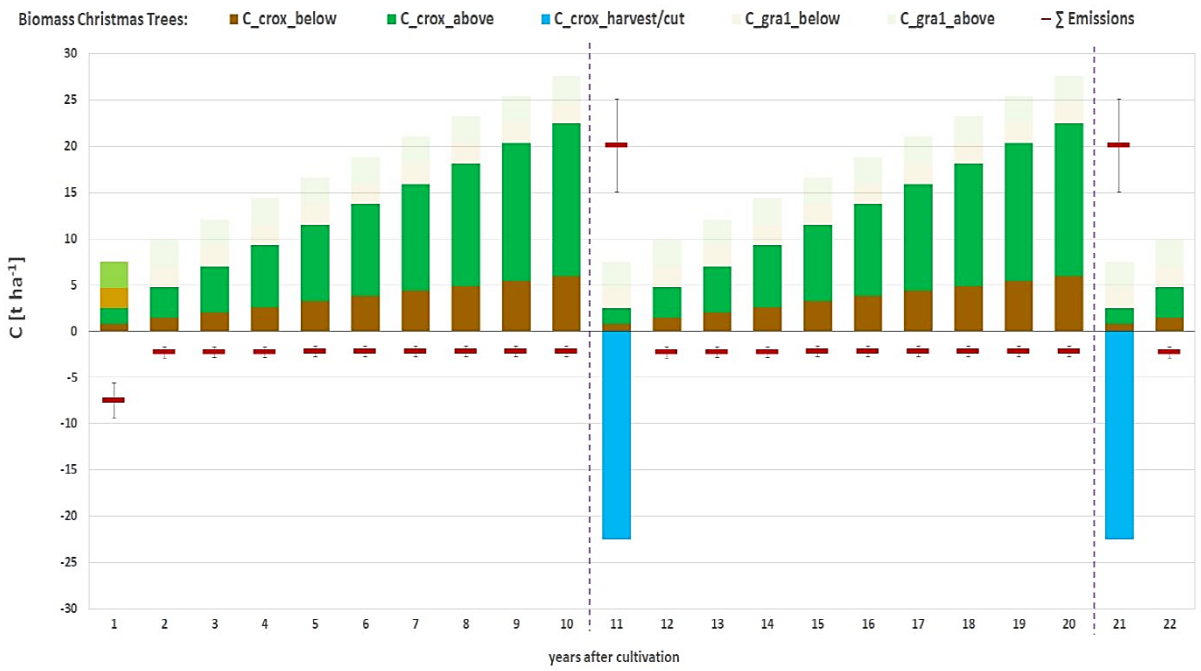
Equation 50: Below-ground biomass of Christmas tree plantations

$$C_{croz_{bel}} = 0{,}489 * x^{0{,}89} + C_{gra1_{bel}} * 0{,}75$$

- $C_{crox\ bel}$ = Carbon stocks of below-ground biomass of Christmas tree plantations [t C ha^{-1}]
- x = Carbon stocks in the above-ground biomass $C_{crox\ abo}$
- $C_{gra1\ bel}$ = Carbon stocks in the below-ground biomass of herbaceous, annual plants [3.03 t C ha^{-1}]

It is assumed that, at the end of a rotation cycle, the woody biomass in Christmas tree plantations is completely replaced; in other cases, the methods described in Chapter 6.1.2.3.2 and Chapter 6.1.2.3.3 are used. Under this approach, the development of carbon stocks in Christmas tree plantations during successive rotation cycles and the related emissions are as shown in Figure 73.

Figure 73: Development of carbon stocks [t C ha^{-1}] in compartments of plant biomass of Christmas tree plantations (crox) and the resulting emissions [t C ha^{-1}], in successive rotation cycles (|). Transparent bars are emissions-relevant only in the case of land-use changes



Source: own illustration, Thünen-Institut

6.1.2.3.5.5 Short-rotation plantations

In Germany, pursuant to Article 2 of the Federal Forest Act (BWaldG, 2015), short-rotation plantations are not considered Forest Land, and are therefore reported solely in the land-use category Cropland. Since short-rotation plantations are also listed as cropland in the framework of the National Forest Inventory, there is no risk of double-counting in this area. The biomass

occurring following the harvest that is used solely for energy generation is listed in 4.B as a carbon-stock change. This prevents double counting in the energy sector and under harvested wood products (HWP) (cf. Chapter 6.10.1).

To obtain country-specific, mean carbon stocks for the biomass of short-rotation plantations, data were derived from the relevant literature. The overviews created by Walter et al. (2015), Horn (2013), Gurgel (2011), Kern et al. (2010), Biertümpfel et al. (2009), Boelcke (2007), Stolzenburg (2006) and Maier and Vetter (2004) were important here. This work includes the results obtained on 23 experimental short-rotation plantation sites, which are distributed throughout Germany (Bavaria, Baden-Württemberg, Thuringia, Saxony, Brandenburg, Mecklenburg-Western Pomerania and Lower Saxony). As a group, the sites cover all the country's relevant climate zones (precipitation: 550-1,550 mm), average annual temperatures 6.8-10.1°C), soil types (light to heavy soils) and geographic regions (lowlands to mid-elevation mountains). Short-rotation plantations were established on a total of 62 test areas, with main species including poplars (58%) and willow (34%), although birch (3%), alder, black locust (robinia) and foxglove tree (paulownia) (5%) were also planted. The rotation periods ranged from one to ten years, and averaged 4.2 years. Since these studies cover all relevant operational aspects of short-rotation plantations in Germany, including spatial distribution, site conditions, vegetation and management practices[84], they are representative.

From the results of these studies, an average annual dry yield of 9.05 (-6.0% / +9.9%) t ha^{-1} a^{-1} of above-ground biomass was derived for short-rotation plantations in Germany. In light of the circumstances prevailing in Germany, an average operational duration of 20 years and an average rotation cycle of 10 years were assumed. At the end of the rotation period, all the plants in the plantation are cut back radically (to a height of 10-20 cm), while the below-ground biomass remains intact. As a result, the entirety of the above-ground biomass is credited as an emission. Subsequent emissions occur only through growth of above-ground biomass. At the end of the operational period, the above-ground and below-ground phytomass is completely removed and the plantation is replanted. For derivation of the growth curves of the above-ground biomass, the average annual dry harvest is converted into carbon using a factor of 0.45 and then multiplied by the number of years in the operational period.

Equation 51: Above-ground biomass of short-rotation plantations

$$C_{cros_{abo}} = a * 9{,}05 \ * 0{,}45$$

- $C_{cros\ abo}$ = Above-ground biomass of short-rotation plantations [t ha^{-1}]
- 9.05 = Average dry harvest of above-ground biomass in short-rotation plantations [t ha^{-1}]
- 0.45= Carbon fraction in dry plant biomass
- a = Number of years following initial planting

[84] Implementation of findings ARR 2021, KL.12, Table 5; 2020, KL.5+6, Table; 2018, KL.10+11; for better transparency: Throughout Germany, no data are collected on management/fertilisation of agricultural areas. As a result, no concrete information can be provided here about fertilisation of short-rotation plantations. In general, relevant studies and cultivation recommendations indicate that fertilisation is required only in very exceptional cases, however, since these plantations normally receive adequate supplies of key nutrients by natural means (DBU. (2010). *Kurzumtriebsplantagen: Handlungsempfehlungen zur naturverträglichen Produktion von Energieholz in der Landwirtschaft - Ergebnisse aus dem Projekt NOVALIS* [Bricht]. D. B. U. (DBU). https://edocs.tib.eu/files/e01fn12/690161034.pdf; p. 19) and: "Overall, average input rates of ≥ 10 kg N ha^{-1} a^{-1} can be assumed for short-rotation plantations with the result that annual inputs from atmospheric deposition alone suffice to compensate for harvesting-related N removals" (ibid.; p. 20).

The below-ground biomass was determined using the above-ground carbon stocks using the formula of (Mokany et al.).

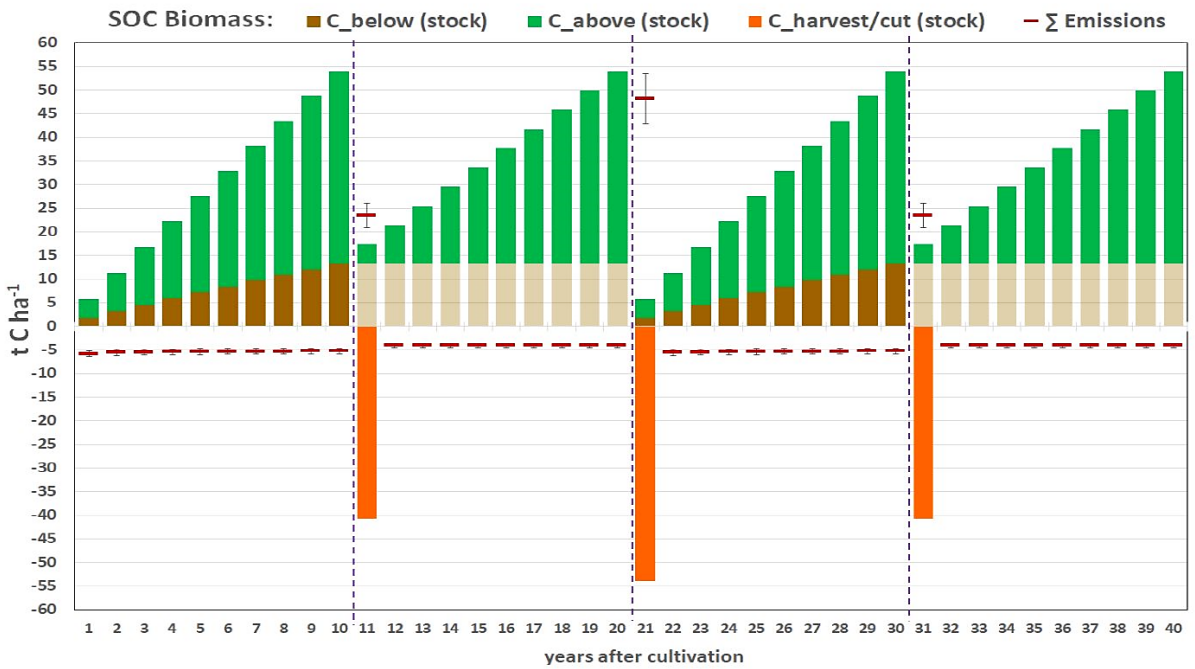
Equation 52: Below-ground biomass of short-rotation plantations

$$C_{cros_{bel}} = 0{,}489 * x^{0{,}89}$$

- $C_{cros\ bel}$ = Below-ground biomass of short-rotation plantations in [t ha^{-1}]
- x = Carbon stocks in the above-ground biomass $C_{cros\ abo}$

The total carbon stocks in the plant biomass of short-rotation plantations and the resulting emissions and their allocation are calculated using the methods described in Chapter 6.1.2.3.2 and Chapter 6.1.2.3.3. Figure 74 shows the development of carbon stocks in short-rotation plantations during successive rotation cycles, along with the resulting emissions.

Figure 74: Development of carbon stocks [t C ha^{-1}] in compartments of plant biomass of short-rotation plantations (SOC) and the resulting emissions [t C ha^{-1}] in successive rotation cycles (|). Transparent bars are emissions-relevant only in the case of land-use changes and of the end of an operational period



Source: own illustration, Thünen-Institut

6.1.2.3.5.6 Hops

The values for the biomass of hops originate from research work and publications of the hops research centre of the Bavarian state research centre for agriculture (Bayerische Landesanstalt für Landwirtschaft). Portner et al. (2019) quantitatively determined the total above-ground biomass of hops and cover crops grown at two sites in the Hallertau area. Graf et al. (2014); Graf (2016) and Sobotik et al. (2018) estimated that the quantity of below-ground biomass found in hops amount to 50% of the plant's above-ground biomass. With these data, the carbon stocks shown in Table 330 result for the various biomass compartments of hops. The values listed under "Hops" serve as the basis for all emissions calculations related to hops. The stock changes in the phytomass of hops plants resulting from use and land-use changes are calculated – and

the relevant emissions credited – with the methods set forth in Chapter 6.1.2.3.2 and Chapter 6.1.2.3.3.

Table 333: Area-based carbon stocks of the biomass of hops plantations and cover crops, and their sum totals, pursuant to Portner et al. (2019), in [t C ha^{-1} ± half of the 95% confidence interval]

Crop	Carbon stocks		
	$Phytomass_{total}$	$Phytomass_{above}$	$Phytomass_{below}$
Hops	4.77 ± 0.84	3.18 ± 0.32	1.59 ± 0.80
Cover crop	0.61 ± 0.3	0.45 ± 0.18	0.15 ± 0.08
Hops-cultivation area	5.38 ± 0.89	3.64 ± 0.39	1.74 ± 0.80

6.1.2.3.6 Calculation methods and determination of emission factors for hedges and field copses

The carbon stock of phytomass of hedges/field copses (gra2) consists of the compartments above-ground and below-ground phytomass and the dead organic matter (Equation 53).

Equation 53:

$$C_{bio_{gra2}} = C_{gra2\ bio\ abo} + C_{gra2\ bio\ stump} + C_{gra2\ bio\ coarse\ roots} + C_{gra2\ bio\ fine\ roots} + C_{necromass}$$

- C_{bio_gra2} = Carbon stocks of the phytomass of hedges/field copses [t C ha^{-1}]
- $C_{gra2_bio_abo}$ = Carbon stocks of the harvestable above-ground phytomass of hedges/field copses [t C ha^{-1}]
- $C_{gra2_bio_stump}$ = Carbon stocks of the above-ground phytomass of stumps of hedges/field copses [t C ha^{-1}]
- $C_{gra2_bio_coarse_roots}$ = Carbon stocks of the phytomass of coarse roots of hedges/field copses [t C ha^{-1}]
- $C_{gra2_bio_fine_roots}$ = Carbon stocks of the phytomass of fine roots of hedges/field copses [t C ha^{-1}]
- $C_{necromass}$ = Total carbon stock of phytomass of dead coarse roots, dead wood and litter of hedge plants [t C ha^{-1}] (Equation 54)

Equation 54:

$$C_{necromass} = C_{gra2\ dead\ course\ roots} + C_{gra2\ bio\ dead\ wood} + C_{gra2\ bio\ litter}$$

- $C_{gra2_dead_coarse_roots}$ = Carbon stocks of the phytomass of dead coarse roots of hedges/field copses [t C ha^{-1}]
- $C_{gra2_bio_dead_wood}$ = Carbon stocks in the dead wood of hedges/field copses [t C ha^{-1}]
- $C_{gra2_bio_litter}$ = Carbon stocks in the litter of hedges/field copses [t C ha^{-1}]

The determination of the carbon stock of the individual compartments of hedges/field copses (gra2) was made using the study findings of Pöpken (2011) and (Drexler et al., 2021; Drexler et al., 2023) and additional data from the literature ((Crossland, 2015),(Axe et al., 2017),(Lingner,

Thiessen, & Hartung, 2018), (Lingner, Thiessen, Müller, et al., 2018)). In the context of the studies by Pöpken (2011) and (Drexler et al., 2021), (Drexler et al., 2023), the above-ground biomass (cut material) was subject to destructive studies in more than 50 hedges; also, the phytomass of the stumps and the below-ground biomass (coarse and fine roots) and the necromass (dead root mass, dead wood and litter) was surveyed at 15 plots (Drexler et al., 2023). The hedges studied varied widely in terms of:

1. Age
   a. approx. 4-28 years old
2. Size
   a. Height, about 2-15 m
   b. Depth, about 1-10 m
   c. Length, about 100-500 m
3. Species composition
   a. Typical hedge plants, such as dog rose (Rosa canina), blackthorn / sloe (Prunus spinosa), common hazel (Corylus avellana), elder (Sambuccus spec.), hawthorn (Crataegus spec.), honeysuckle (Lonicera spec.) and willow (Salix spec.)
   b. Trees, such as field maple (Acer campestre), common hornbeam (Carpinus betulus), willow (Salix spec.), beech (Fagus sylvatica), linden (Tilia spec.) and elm (Ulmus spec.)

As a result, the study included a representative spectrum of these field trees and shrubs. The mass, water content and carbon content of these wood samples were measured in the laboratory, enabling the absolute and area-related carbon stock to be determined in connection with the field measurements.

Above-ground phytomass

Using this data, sigmoidal regression was used to determine a highly significant correlation between the average carbon stock of the harvestable above-ground biomass of hedges and their age. The quality of the model was boosted by logarithmisation of the input data, the residues are not auto-correlated, the data of the source population are normally distributed around the regression line and the variance is constant.

Equation 55:	**Function to calculate the harvestable above-ground phytomass of hedges depending on their age**

$$\ln C_{gra2\ bio\ abo} = \frac{4{,}1841}{\left(1+e^{\left(-\frac{ln\ x-1{,}4226}{0{,}229}\right)}\right)}$$

- r^2 = 0.9088 standard error ((95% CI)/2): 12.1%
- LN [$C_{gra2\ bio\ abo}$] = Logarithm of the average carbon stock of above-ground biomass in hedges/field copses [t C ha^{-1}]
- LN[x] = Logarithm of the age of the above-ground biomass in hedges/field copses after planting/cutting [a]

The final determination of the C stock takes place by delogarithmisation of the result of Gleichung 58 and the application of a variance-based bias correction following (Demetrescu et al., 2020).

Equation 56:

$$C_{gra2\ bio\ abo} = e^{\left(\ln C_{gra2\ bio\ abo} + \ln \frac{varianz}{2}\right)}$$

- $C_{gra2_bio_abo}$ = Carbon stocks of above-ground biomass in hedges [t C ha^{-1}]
- LN [$C_{gra2_bio_abo}$] = Logarithm of the average carbon stock of above-ground biomass in hedges [t C ha^{-1}]
- LN [variance/ 2] = Variance-based bias correction factor (n. DEMETRESCU et al. 2020)

The carbon stock thus ascertained is the harvestable portion of the above-ground biomass, the pruning matter after maintenance/harvest pruning. The overall uncertainty shows a log-normal distribution and amounts to -18.4% and +27.1% respectively.

The studies by (Drexler et al., 2023) showed that the plant stumps, the non-harvested parts of the above-ground biomass, form a substantial portion of the above-ground biomass of hedge plants. The average proportion of the mass of the stumps is 39% of the carbon stock of the harvestable phytomass (Equation 57). The uncertainties of the carbon stocks in the phytomass of stumps are naturally relatively large due to the highly varied nature of the plants (95% CI: 17.1% - 66.9%) and show a log normal distribution.

Equation 57: Carbon stock in the phytomass of plant stumps

$$C_{gra2\ bio\ stump} = C_{gra2\ bio\ abo} * 0.39$$

- $C_{gra2_bio_stump}$ = Carbon stocks of the above-ground phytomass in stumps of hedges/field copses [t C ha^{-1}]
- $C_{gra2_bio_abo}$ = Carbon stocks of the harvestable above-ground biomass in hedges/field copses [t C ha^{-1}]

Below-ground biomass

The studies by (Drexler et al., 2021; Drexler et al., 2023) on below-ground carbon stocks show that their share of their total phytomass is much larger than previously assumed. The(Drexler et al., 2023) carbon stocks measured in field tests by (Drexler et al., 2023) in the living, below-ground phytomass of hedge plants in Germany are larger than the values previously calculated using the formula by (Mokany et al., 2006b) by a factor of 2-2.3. In (Drexler et al., 2023), below-ground living phytomass (coarse and fine roots) is, on average, 70% of the harvestable above-ground phytomass (95% CI: 42.3% - 107.8%).

Equation 58: Below-ground carbon stock in the phytomass of hedge plants

$$C_{gra2\ bio\ below} = C_{gra2\ bio\ abo} * 0.7$$

- $C_{gra2_bio_below}$ = Carbon stocks of the below-ground phytomass of hedges/field copses [t C ha^{-1}]
- $C_{gra2_bio_abo}$ = Carbon stocks of the harvestable above-ground biomass in hedges/field copses [t C ha^{-1}]

Necromass

(Drexler et al., 2023) also recorded the carbon stock of the dead organic matter of phytogenic origin on their test sites. The necromass consists of dead wood, litter and dead roots (Equation 59). It is assumed that the quantities of necromass ascertained in the studies correspond to the long-term equilibrium state. The proportion of this carbon stock in terms of the harvestable above-ground biomass is 7% for dead root mass, 6% for dead wood and 5% for litter, an average of 18% in total (95% CI: 13.2% - 23.7%). The necromass of hedges is allocated to the biomass pool, not the pool of dead organic matter. The carbon stock of the necromass of hedges is calculated in line with

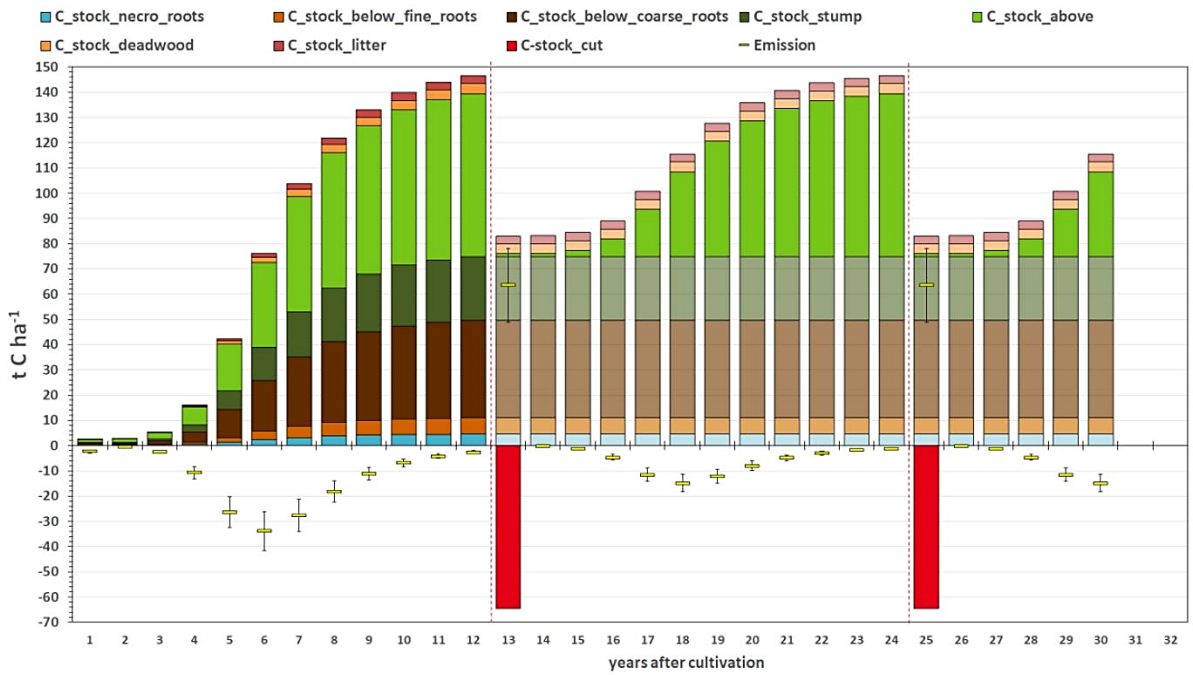
Equation 59:

$$C_{Necromass} = C_{gra2\ bio\ abo} * 0.18$$

- $C_{Necromass}$ = Total carbon stock of phytomass of dead coarse roots, dead wood and litter of hedge plants [t C ha^{-1}]
- $C_{gra2_bio_abo}$ = Carbon stocks of the harvestable above-ground biomass in hedges/field copses [t C ha^{-1}]

The total stocks per age class are obtained from the sum of all compartments. A rotation cycle of 12 years is assumed. This is in line with the average rotation cycle for hedges in Germany, i.e. the period after which the hedge is cut back hard for rejuvenation purposes. Since the below-ground biomass remains intact, this means that as of the 13th year emissions arise only as a result of growth and cutting of above-ground biomass. The development of carbon stocks in the plant biomass of hedges/field copses is shown in Figure 75.

Figure 75: Development of carbon stocks [t C ha^{-1}] in compartments of plant biomass of hedges/field copses and the resulting emissions [t C ha^{-1}] in successive rotation cycles (|); transparent bars are emissions-relevant only in the case of land-use changes



Source: own illustration, Thünen-Institut

In the case of land-use changes from hedges/field copses to other land-use categories, the sum of the current carbon stocks of all compartments of the biomass of hedges/field copses is normally balanced with the biomass stocks of the follow-on use that grows in the first year (cf. Chapter 6.1.2.3.2 and Chapter 6.1.2.3.3). Land-use changes from hedges/field copses to Forest Land are an exception to this rule. In these cases, only half of the current biomass in the hedges/field copses is taken into account as an emission. This correction was introduced because an evaluation of National Forest Inventory data found that in about 50% of these land-use changes, biomass of the category hedges/field copses enters completely into the biomass of the Forest Land.

6.1.2.3.7 Terrestrial Wetlands and Settlements

Terrestrial Wetlands (wett)

As a rule, Terrestrial Wetlands are covered with trees and shrubs (throughout a spectrum ranging from scattered bushes to actual forests), mosses and grasses. A survey on the basis of the B-DLM showed that in 2022 approx. 47% of the area of terrestrial wetlands were covered with trees and shrubs, and 22% with grasses, the rest predominantly with moss communities (in-house evaluation, unpublished). Accordingly, the inventory uses the following assumption for the area-related distribution of carbon stocks in biomass: 50% trees and shrubs; 20% grasses and 30% mosses. Since no specific biomass surveys of these types of land have been carried out in Germany, the values for hedges/field copses are used as an approximation for areas with trees and shrubs (Chapter 6.1.2.3.6) and the values for Grassland (in the strict sense) for areas with grasses (Chapter 6.1.2.3.3). Data about the dry mass of mosses on peatland/wetland areas display a very wide range in the literature (< 0.1 t ha^{-1} a^{-1} - >15 t ha^{-1} a^{-1} (e.g. (Moore et al., 2002), (Gunnarsson, 2005), (Oestmann et al., 2022)). Averages are cited as between 2-3 t ha^{-1} a^{-1} (Gunnarsson, 2005), (Oestmann et al., 2022). For this reason, a value of 2.5 t ha^{-1} is assumed for the dry mass of living phytomass of mosses, corresponding to a carbon stock of 1.25 t C ha^{-1}. The carbon stocks of Terrestrial Wetlands, including below-ground and above-ground biomass, are calculated as follows:

Equation 60: Carbon stock of the biomass of terrestrial wetlands

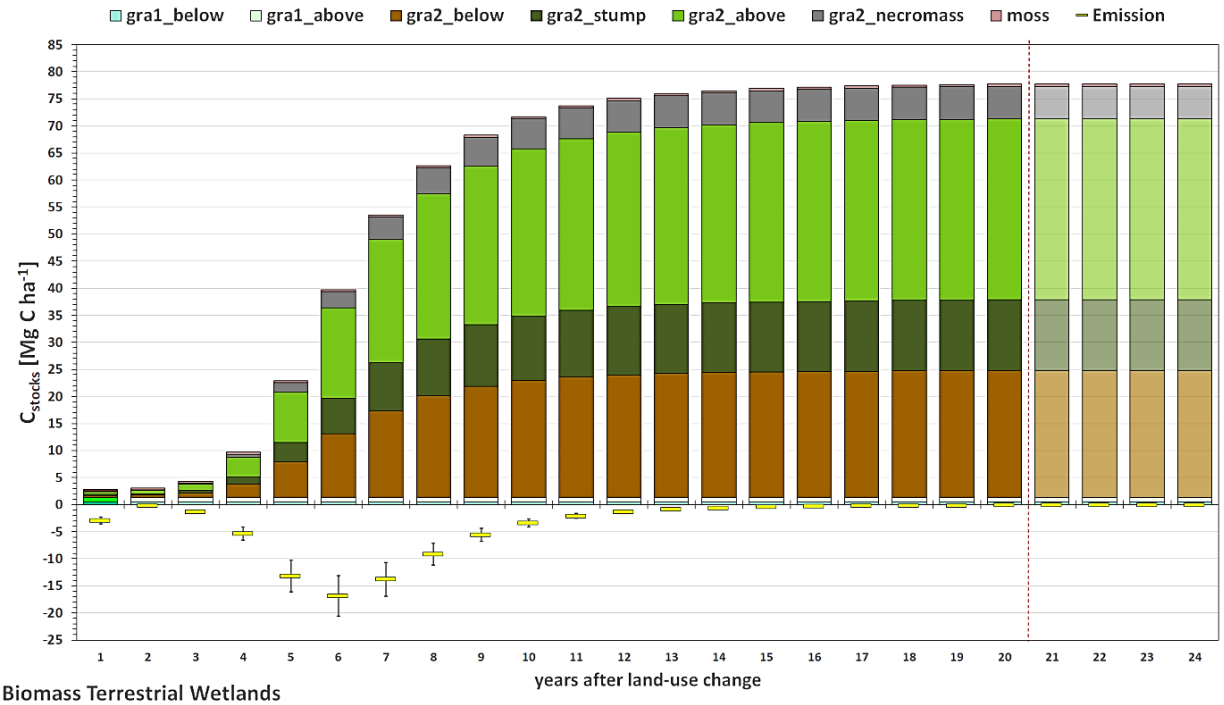
$$C_{wett} = 0.5C_{gra2} + 0.2C_{gra1} + 0.3\ C_{Moos}$$

- Carbon stocks of the above-ground/below-ground biomass of hedges/field copses in year x following initial planting [t C ha^{-1}] (Chapter 6.1.2.3.6)
- C_{gra1} = Carbon stocks of the above-ground/below-ground plant biomass of Grassland (in the strict sense) [t C ha^{-1}] (Chapter 6.1.2.3.3)
- C_{wett} = Carbon stocks of the above-ground/below-ground biomass of terrestrial wetlands in year x following initial planting [t C ha^{-1}] (Chapter 6.1.2.3.6)
- C_{moss} = Carbon stocks in the mosses of terrestrial wetlands [t C ha^{-1}]

The total carbon stocks in the plant biomass of Terrestrial Wetlands and the resulting emissions to be taken into account are calculated using the methods described in Chapter 6.1.2.3.6 and Chapter 6.1.2.3.3. It is assumed that after 20 years carbon stocks reach an equilibrium state for woody plants. Consequently, as of the 21st year, no further emissions are reported for each relevant survey point. In the case of grass-like plants and mosses, the equilibrium is already

attained in the second year after planting. The following figure shows the resulting development of carbon stocks over time.

Figure 76: Development of carbon stocks [t C ha^{-1}] in compartments of plant biomass of Terrestrial Wetlands (wettwett) and the resulting emissions [t C ha^{-1}] until an assumed equilibrium state is reached (|). Transparent bars are emissions-relevant only in the case of land-use changes



Biomass Terrestrial Wetlands

Source: own illustration, Thünen-Institut

Settlements – Buildings and open areas (set1)

Settlement and transport areas include significant portions of unsealed land that is covered with vegetation. A large-scale study by the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR), an institute based in the Federal Office for Building and Regional Planning (BBR), determined these portions for settlement areas in Germany by way of remote sensing and geoinformatics (BBSR et al., 2022). The proportion of vegetation cover to the total of *buildings and open areas* is 45%. Of this area, on average 17% is covered by trees and 83% by herbaceous plants (BBSR et al., 2022); cf. Chapter 6.2.5).

Emission factors for biomass of urban greenery

In the absence of country-specific data on carbon stocks and growth rates of urban trees and shrubs, the values measured in Germany for hedges and woody grassland were used in the 2025 submission, firstly because the carbon stocks they contain was determined to be representative and specific to the federal state (e.g. (Drexler et al., 2021)), and secondly because of the variability of the types of urban woody plants, ranging from small-garden hedges to hedges of any description and on to roadside and forest trees. Due to the apparently high annual growth rates compared with the default values of the IPCC Guidelines ((IPCC, 2006a); (IPCC, 2019)), these were not accepted by the TERT in the 2025 ESD review. Consequently, new emission factors for woody plants in Germany's settlement areas were derived in accordance with the method of the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2019). Emission factors were derived separately for above- and

below-ground biomass based on the US datasets (Nowak & Crane, 2002); (Nowak et al., 2002); (Nowak et al., 2008); (Nowak et al., 2013) from which the default factors of the guidelines ((IPCC, 2006a); (IPCC, 2019)) were mainly derived.

To ensure comparability with the environmental conditions in Germany, only results from US states in the temperate climate zone were used to derive the emission factors. The following steps form the basis for deriving the average growth rates of urban woody plants in Germany (*parameters in italics*: Data taken from the result tables of the original US literature; **parameters in bold**: Data derived from the literature values):

1. Calculation of the **absolute crown cover area [ha]** by dividing the *annual gross increase* by the measured *annual gross increase per ha of crown cover*

2. Calculation of the **carbon stocks per ha of crown cover [t C ha^{-1}]** by dividing the *absolute carbon stocks in urban trees/shrubs* by the **crown cover area**

3. Determination of the **equilibrium age of urban tree/shrub populations** by dividing the *total carbon stocks* by the product of *annual gross increase × 0.74* (0.74: factor for determining net increase from gross increase (Nowak et al., 2013)

4. Determination of the **total annual net increase [t C ha^{-1} crown cover a^{-1}]** by dividing the *total carbon stocks* by the **equilibrium age**

5. Determination of the **annual net increase of below-ground biomass [t C ha^{-1} crown cover a^{-1}]** by multiplying the **total net growth rate** by the factor *0.26* (root-shoot ratio for temperate latitudes as per CAIRNS et al. 1997)

6. Determination of the **annual net increase of above-ground biomass [t C ha^{-1} crown cover a^{-1}]** by subtracting the **annual net increase of below-ground biomass** from the **total annual net increase**

Table 334: Derivation of the annual carbon increase of urban woody plants in the temperate climate zone and the period until equilibrium is attained based on data from NOWAK et al. 2013

	Carbon stocks	Gross increase	Growth rate		Years until equilibrium	Crown cover	Carbon stocks per ha	Biomass_growth rate		
			Gross	Net				Bio_total	Bio_above	Bio_below
	[t C]	[t C a^{-1}]	[t C ha^{-1} crown cover a^{-1}]		[a]	[ha]	[t C ha^{-1}]	[t C ha^{-1} crown cover a^{-1}]		
Connecticut	23,300,000	724,000	2.39	1.77	43.5	302,929	76.92	1.75	1.39	0.36
Illinois	18,700,000	688,000	2.83	2.09	36.7	243,110	76.92	1.75	1.39	0.36
Maine	3,800,000	109,000	2.21	1.64	47.1	49,321	77.05	1.76	1.39	0.36
Massachusetts	35,900,000	1,187,000	2.54	1.88	40.9	467,323	76.82	1.75	1.39	0.36
Michigan	22,900,000	654,000	2.2	1.63	47.3	297,273	77.03	1.76	1.39	0.36
Minnesota	9,300,000	275,000	2.29	1.69	45.7	120,087	77.44	1.77	1.4	0.36
Nebraska	1,600,000	51,000	2.38	1.76	42.4	21,429	74.67	1.7	1.35	0.35
New Hampshire	7,100,000	202,000	2.17	1.61	47.5	93,088	76.27	1.74	1.38	0.36
New York	32,100,000	1,005,000	2.4	1.78	43.2	418,750	76.66	1.75	1.39	0.36
North Dakota	400,000	12,000	2.23	1.65	45	5,381	74.33	1.69	1.34	0.35
Oregon	8,100,000	255,000	2.42	1.79	42.9	105,372	76.87	1.75	1.39	0.36
Rhode Island	4,100,000	139,000	2.58	1.91	39.9	53,876	76.1	1.73	1.38	0.36
South Dakota	700,000	21,000	2.36	1.75	45	8,898	78.67	1.79	1.42	0.37
Vermont	1,500,000	42,000	2.13	1.58	48.3	19,718	76.07	1.73	1.38	0.36
Washington	13,800,000	463,000	2.58	1.91	40.3	179,457	76.9	1.75	1.39	0.36
Wisconsin	9,400,000	275,000	2.25	1.67	46.2	122,222	76.91	1.75	1.39	0.36
Mean					44		76.6	1.75	1.39	0.36

The calculations are summarised in (Table 334). The emission factors are the averages of the values calculated for the individual states; the differences between the individual states are small when expressed per hectare (Table 334); the overall uncertainty of the values is > 30% (± half of the 95% CI):

- The mean time to reach equilibrium was rounded to 44 years (± 18.2%).
- Average carbon stocks per ha of crown cover: 76.60 t C ha^{-1} (± 24.0%)
- Total annual net growth rate: 1.75 t C ha^{-1} crown cover a^{-1} (± 30.1%)
- Net growth rate of above-ground biomass: 1.39 t C ha^{-1} crown cover a^{-1} (± 37.1%)
- Net growth rate of below-ground biomass: 0.36 t C ha^{-1} crown cover a^{-1} (± 30.7%)

For areas with herbaceous vegetation, the factors and methods for Grassland (in the strict sense) are applied (gra1; Chapter 6.1.2.3.3). The average carbon stocks in the annual biomass of this subcategory are 6.73 t C ha^{-1} for each state.

Calculation of biomass carbon stocks in settlement areas

The carbon stocks for the biomass of Buildings and open areas (set1) are derived from

Equation 61: Carbon stocks in the phytomass of buildings and open areas (set1)

$$C_{set1} = A_{set1} * 0{,}45 * (0{,}17 C_{urban\ trees} + 0{,}83 C_{gra1})$$

- C_{set1} = Carbon stocks of the above-ground/below-ground biomass of buildings and open areas in settlement areas in year x following initial planting [t C ha^{-1}]
- A_{set1} = Area of building and open areas [ha]
- 0.45 = Factor for the unsealed area (45%)
- C_{urban_trees} = Carbon stocks of the above-ground/below-ground biomass of urban trees in year x following initial planting [t C ha^{-1}] (Chapter 6.1.2.3.6)
- C_{gra1} = Carbon stocks of the above-ground/below-ground plant biomass of Grassland (in the strict sense) [t C ha^{-1}] (Chapter 6.1.2.3.3)
- 0.17 = Area factor: 17% of unsealed soil consists of urban trees and shrubs
- 0.83 = Area factor: 83% of unsealed soil consists of herbaceous plants

The total carbon stocks in the plant biomass of Settlement areas and the resulting emissions to be taken into account are calculated using the methods described in Chapter 6.1.2.3.2 and Chapter 6.1.2.3.3. The following thus applies to settlement areas:

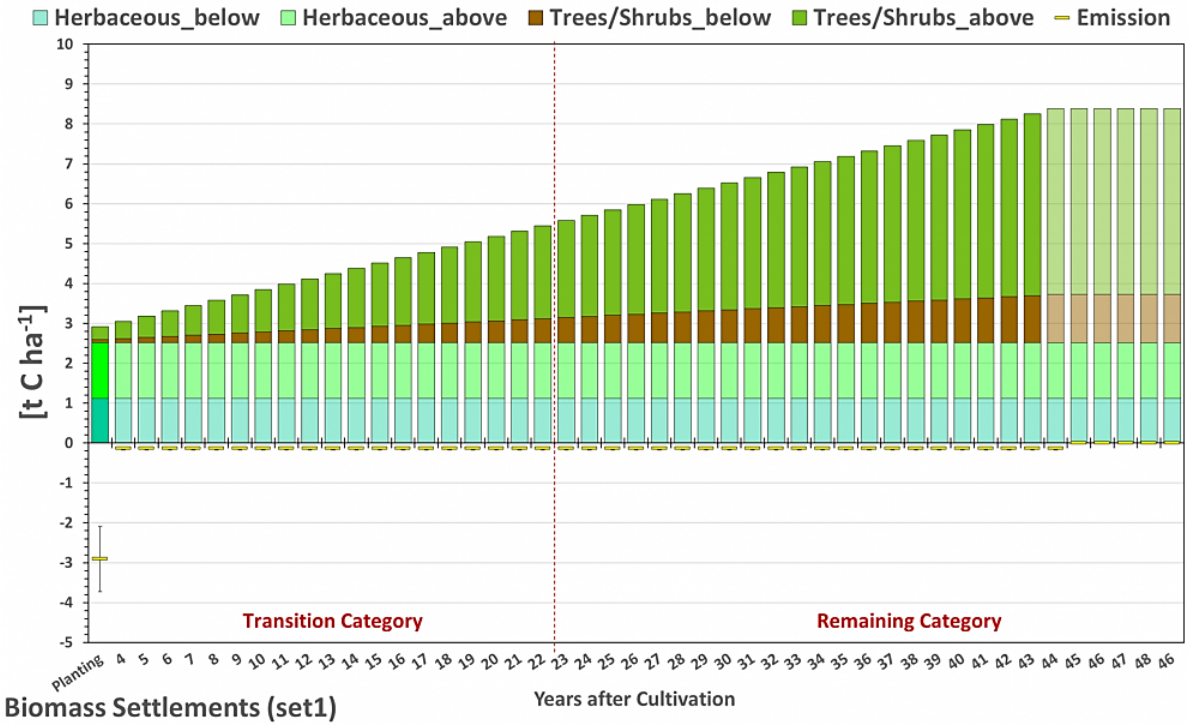
- The woody plants that are initially planted come from tree nurseries. To avoid double counting, it is assumed that these woody plants are planted at the age of 3.
- The woody plants reach their equilibrium state at the age of 44, i.e. after having been planted in unsealed areas of the subcategory “Buildings and open areas” 41 years earlier. Consequently, as of the 42nd year after planting, i.e. when the woody plants reach the age of 45, no further emissions are reported for the relevant survey point. Emissions are reported

both in the transitional categories and, after the 20-year transitional period, in the remaining category.

- Herbaceous plants achieve equilibrium in the first year of planting.

The following figure shows the resulting development of carbon stocks over time.

Figure 77: Development of carbon stocks [t C ha^{-1}] in compartments of plant biomass of buildings and open areas (set1) in settlement areas in Germany, and the resulting emissions [t C ha^{-1}], in successive rotation cycles (|). Transparent bars are emissions-relevant only in the case of land-use changes



Source: own illustration, Thünen-Institut

Areas with photovoltaic plants (setp) are treated the same way as Grassland (in the strict sense) when it comes to activity data and emission factors (Chapter 6.1.2.3.3).

TERT accepted this revised method for estimating urban biomass ((EEA, 2025); Reference: No 3502/B2025/EEA.60384) and recommended using the method for the entire time series. Germany implemented the recommendation with this submission.

6.1.2.3.8 Forest Land

The carbon-stock changes of plant biomass on Forest Land resulting from land use and land-use changes are calculated using the methods set forth in Chapters 6.1.2.3.1 ff. For the calculation of the emission factor for the conversion of Forest Land into other land uses (deforestation), the data from the National Forest Inventories of 2002, 2012 and 2022, and the 2018 Carbon Inventory were used. From 1990 to 2011, an average EF for Germany was used and from 2012, stratified EFs were derived in line with the major forest areas. The method used to derive the EF is described in Chapter 6.4.2.2 ff. The annual carbon-stock changes in forest biomass, following afforestation, are shown in Table 351 in Chapter 6.4.2.2.2.

6.1.2.4 Carbon emissions from dead organic matter (4.A to 4.F)

Emissions from dead organic matter are reported only for the land-use category Forest Land and for land-use changes from Forest Land to one of the other land-use categories in 4.B - 4.E. For this reporting, dead organic matter is subdivided into the two pools dead wood and litter. Descriptions of the method used for this and the accompanying results are presented in Chapter 6.4.2.3 for dead wood, and in Chapter 6.4.2.4 for litter (in both cases, in the land-use category Forest Land).

In the land-use-change categories 4.B - 4.E, emissions from dead organic matter are included with emissions from living biomass, since estimates of emissions from living biomass are always based on entire plants. To prevent double counting in these conversion categories, emissions from dead organic matter are marked IE (included elsewhere) in the CRF tables. In category 4.F, NO (not occurring) is used, since, by definition, the areas in this category have no vegetation cover.

6.1.2.5 Direct N_2O emissions from nitrogen fertilisation of forest land and other land areas (4(I))

No nitrogen fertilisation in Forest Land, Wetlands and Settlements is carried out in Germany. In CRF 4(I), therefore, NO (not occurring) is entered for all activities.

6.1.2.6 Emissions from flowing and standing artificial water bodies, and from drainage or organic and mineral soils

In accordance with the 2006 IPCC Guidelines (IPCC, 2006a) and the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2019), methane emissions from artificial flowing and standing water bodies that are subject to fluctuations in their water levels are now being reported (for the first time) under Flooded Land remaining Flooded Land. To this end, the land-use subcategory *Flooded Land* was further subdivided into the following categories:

1. Natural water bodies (wetl, wetr): All flowing and standing water bodies that do not fall under wetd, wetb and wets
2. Standing artificial water bodies (wetb):
   a. Reservoirs, quarry ponds and mining lakes
   b. Ponds, water storage facilities, artificial freshwater basins of all types (exception: wastewater treatment facilities)
3. Flowing artificial water bodies (wetd): Channels and drainage ditches for water resources management (exception: drainage ditches on organic soils),
4. Artificial water bodies used for navigation (wets): Harbour basins along inland water bodies, and canals for shipping

Emissions from soil drainage in Germany are reported for organic and mineral soils by recording emissions from drainage ditches. Emissions from rewetting of organic soils are taken into account only in the case of methane related to flooding of former peat extraction areas. Otherwise, they are listed in the CRF as NO (not occurring). This method is in line with the corresponding remarks in the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2019).

In accordance with the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2019), only the Managed Land Proxy (MLP) is to be applied. With the MLP, it is assumed that all emissions originating from managed land are anthropogenic.

Carbon emissions from drainage of organic soils are included in CRF 4.A - 4.F. In CRF 4(II), the values for N_2O and CH_4 as well as for CO_2 IE (included elsewhere) are entered for organic soils.

The methane emissions of the remaining subcategories are reported in CRF 4(II). A description of the method used to derive activity data and emission factors for organic soils is presented in Chapter 6.1.2.1.9 Emissions from organic soils.

Methodology

Standing artificial water bodies - wetb

In Standing artificial water bodies, the emissions from

- Reservoirs, quarry ponds and mining lakes
- Ponds, water storage facilities and artificial freshwater basins of all types

are subsumed.

The methane emissions for this subcategory are calculated in accordance with the default method of the 2019 Refinement to the 2006 IPCC Guidelines IPCC (2019), for artificial lakes/reservoirs, quarry ponds and mining lakes, pursuant to Formula 7.10 (IPCC (2019); p. 7.12):

$$F_{CH4_tot} = F_{CH4_reservoir} + F_{CH4_downstream}$$

$$F_{CH4_reservoir} = \alpha_r * EF_{r_CH4>20a} * A_{reservoir}$$

$$F_{CH4_downstream} = \alpha_r * EF_{r_CH4>20a} * A_{reservoir} * R$$

- F_{CH4_tot} = All annual methane emissions from artificial reservoirs, quarry ponds and mining lakes that are more than 20 years old [kg CH_4 a^{-1}]
- $F_{CH4_reservoir}$ = Annual methane emissions from the surfaces of artificial reservoirs, quarry ponds and mining lakes (that are more than 20 years old) [kg CH_4 a^{-1}]
- $F_{CH4_downstream}$ = Annual methane emissions from artificial reservoirs, quarry ponds and mining lakes (that are more than 20 years old) that occur downstream of the relevant dam [kg CH_4 a^{-1}]
- α_r = Adjustment factor for the emission factor that depends on the trophic state of the reservoir, quarry pond or mining lake (dimensionless)
- $EF_{r_CH4>20a}$ = Methane emission factor for artificial reservoirs, quarry ponds and mining lakes that are more than 20 years old [kg CH_4 ha^{-1} a^{-1}]
- $A_{reservoir}$ = Surface area of artificial reservoirs, quarry ponds and mining lakes (more than 20 years old) [ha]
- R = Ratio of the methane emissions of artificial reservoirs, quarry ponds and mining lakes (more than 20 years old) that occur downstream from the dam [kg CH_4 a^{-1}] to the methane emissions emitted from the water bodies' surfaces [kg CH_4 a^{-1}]

For ponds, water storage facilities and artificial freshwater basins of all types, Formula 7.12 (IPCC (2019); p. 7.17) is used:

$$F_{CH4_ponds} = \alpha_p * EF_{p_CH4>20a} * A_{ponds}$$

- F_{CH4_ponds} = The total annual methane flows of ponds, water storage facilities and artificial freshwater basins of all types [kg CH_4 a^{-1}]
- α_p = Adjustment factor for the emission factor that depends on the trophic state of the pond, water storage facility or artificial freshwater basin (of any type) (dimensionless)
- $EF_{p_CH4>20a}$ = Methane emission factor for ponds, water storage facilities and artificial freshwater basins that are more than 20 years old [kg CH_4 ha^{-1} a^{-1}] A_{ponds} = Surface area of ponds, water storage facilities and artificial freshwater basins of all types (older than 20 years) [ha]

Flowing artificial water bodies - wetd and water bodies used for navigation (harbour basins, canals) - wets

Flowing artificial water bodies mainly includes channels and drainage ditches for water resources management, and water bodies used for navigation.

The methane emissions for this subcategory are calculated in accordance with the default method of the 2019 Refinement to the 2006 IPCC Guidelines and also with Formula 7.12 (IPCC (2019)); p. 7.17):

$$F_{CH4_channels} = \alpha_c * EF_{c_CH4>20a} * A_{channels}$$

- The total annual methane flows of channels and drainage ditches [kg CH_4 a^{-1}]
- α_c = Adjustment factor for the emission factor that depends on the trophic state of the relevant channel or relevant drainage ditch for water resources management (dimensionless)
- $EF_{c_CH4>20a}$ = Methane emission factor for channels and drainage ditches for water resources management that are more than 20 years old [kg CH_4 ha^{-1} a^{-1}]
- $A_{channels}$ = The surface area of channels and drainage ditches for water resources management (older than 20 years) [ha]

Activity data

The basis for determination of the activity data for the subcategories of the subcategory *Water bodies* consists of the following data sources:

- Data sets of the Basic Digital Landscape Model (B-DLM) of the Official topographic-cartographic information system (ATKIS®), for the years 2000, 2005, 2010, 2015, 2020 and 2022 (AdV 2000; 2005; 2010; 2015; 2020; 2022)
- A data set of the BfG (Bundesanstalt für Gewässerkunde – Federal Institute of Hydrology), with georeferenced data on artificial standing water bodies > 50 ha
- A study on surveys of ponds in Bavaria (Seitel & Oberle, 2022).
- Data sets of official statistics on aquaculture operations and on the sizes of their facilities at German federal state level (Statistisches Bundesamt, 2022a)

By combining statistical data with data sets obtained in georeferenced formats using geoinformational methods, it was possible to determine the areas of Germany's standing and flowing artificial water bodies, differentiated by types. The areas of natural water bodies are obtained by deducting the areas determined using this method from Germany's total water body area.

The areas for the various water body categories were kept static in the inventory, since

- only in recent years have these areas been included in the B-DLM, and since, in light of the area changes detected in previous years, these areas do not represent true land-use changes as they are cartographic artefacts
- the area data are a combination of georeferenced data and of statistical data that ultimately has lost its georeferencing

The basis for determining the areas is the areas of the LUM 2021 (the best B-DLM). With regard to land changes related to the wetlands category, the following rules apply:

- No land-use changes to/from Natural water bodies and Flowing artificial water bodies to/from other land-use categories, until a reliable, georeferenced AD basis becomes available. In general, this also applies to Standing artificial water bodies, with one exception: land-use changes from *Peat extraction* to Standing artificial water bodies are permitted unilaterally
- No land-use changes between Natural water bodies, Standing artificial water bodies and Flowing artificial water bodies
- Terrestrial wetlands and Peat extraction are handled in the same manner used to date, apart from the fact that land-use changes between (to/from) these categories and Natural water bodies, Standing artificial water bodies and Flowing artificial water bodies are excluded (exception: Peat extraction to Standing artificial water bodies)

Emission and adjustment factors

Natural water bodies

Pursuant to the 2019 Refinement IPCC (2019), GHG emissions do not have to be reported for Natural water bodies; consequently, no emission factors (EFs) are required for that category.

Standing artificial water bodies - wetb

Emission factors

Methane emissions from Germany's standing artificial water bodies (artificial reservoirs, quarry ponds and mining lakes; and ponds, water storage facilities and artificial freshwater basins of all types) are calculated using the default emission factors in the 2019 Refinement IPCC (2019). For cool, temperate latitudes, that factor is as follows:

For reservoirs, quarry ponds and mining lakes (> 20 a):

$EF_{r_CH4>20a}$ = 54.0 [kg CH_4 ha^{-1} a^{-1}] (95% - Confidence interval: -10.6% / 10.2%) (IPCC (2019); p. 7.15; Table 7.9)

Ponds, water storage facilities, artificial freshwater basins of all types:

$EF_{p_CH4>20a}$ = 183 [kg CH_4 ha^{-1} a^{-1}] (95% - Confidence interval: -35.5% / 24.6%) (IPCC (2019); p. 7.18; Table 7.12)

Adjustment factors

The adjustment factor α for the trophic state of the water bodies was determined on a country-by-country basis for reservoirs, quarry ponds and mining lakes (αr), and for ponds, water storage facilities and artificial freshwater basins of all types (αp). The basis for this consisted of the research project "Ecological assessment of artificial and significantly modified lakes, and highland lakes, on the basis of the phytoplankton biological component and in accordance with the requirements of the EU Water Framework Directive" (Ökologische Bewertung von künstlichen und erheblich veränderten Seen sowie Mittelgebirgsseen anhand der biologischen Komponente Phytoplankton nach den Anforderungen der EU-Wasserrahmenrichtlinie) (Hoehn et al., 2009), which determined, for example, trophic classes for 280 artificial and 16 natural standing water bodies in Germany (including lakes in low mountains, mining lakes, flooded open-pit mines, reservoirs and special types of lowland water bodies). On the basis of that study, each trophic class was assigned an average adjustment factor α in accordance with Table 7.11 (p. 7.15) of the 2019 Refinement (IPCC, 2019). To this end, the range of the adjustment factors listed in the Refinement (IPCC, 2019) for the various trophic classes was adapted to the higher resolution of the research project. This was done by dividing the range by the number of subcategories, and by distributing the range linearly among the trophic classes. From the resulting new upper and lower bounds, the average values were assigned to the German trophic classes as trophic adjustment factors α_i (Table 335).

Table 335: Determination of average trophic adjustment factors αi (pursuant to the 2019 IPCC Refinement) for Germany's artificial standing water bodies, by trophic class (Hoehn et al., 2009)

LAWA 2009; Hoehn et al.		IPCC (2019 refinement)		Allocation of trophic adjustment factors αi			Uncertainty (assumption: Range = 95% CI)	
Trophic class	Abbreviation	Trophic class	αi	αi US	αi _OS	αi _Trophic-class-average	[%]	Distribution
oligotrophic	ol	oligotrophic	0.7	0.7	0.7	0.7	50	normal
mesotrophic 1	meso 1	mesotrophic	0.7 - 5.3	0.7	3	1.85	62.2	normal
mesotrophic 2	meso 2			3	5.3	4.15	27.7	normal
eutrophic 1	eu 1	eutrophic	5.3 - 14.5	5.3	9.9	7.6	30.3	normal
eutrophic 2	eu 2			9.9	14.5	12.2	18.9	normal
polytrophic 1	poly 1		14.5 - 39.4	14.5	22.8	18.65	22.3	normal
polytrophic 2	poly 2			22.8	31.1	26.95	26.7	normal
hypereutrophic	hyper	hypereutrophic		31.1	39.4	35.25	26.7	normal

The adjustment factors determined this way were allocated by way of the trophic classes to the water bodies covered by the German study and weighted on the basis of the number of different water body types in the various trophic classes (Table 336).

Table 336: Determination of average trophic adjustment factors in light of the trophic states of Germany's artificial standing water bodies, on the basis of HOEHN et al. 2009

Water body type	oligotrophic	mesotrophic 1	mesotrophic 2	eutrophic 1	eutrophic 2	polytrophic 1	polytr. 2 / hypertrophic	∑ Water bodies
	Number							
Quarry pond	11	24	21	21	11	3	2	93
Pond						1	8	9
Natural lake	4	4	5		1		2	16
Storage facility	1				1		4	6
Mining lake	20	8	5	1				34
Dammed reservoir	35	27	33	11	12	11	9	138
∑ total	71	63	64	33	25	15	25	296
∑ without natural lakes	67	59	59	33	24	15	23	280
αi_trophic-class average	0.7	1.85	4.15	7.6	12.2	18.65	31.1	
	ol	**meso 1**	**meso 2**	**eu 1**	**eu 2**	**poly 1**	**poly 2 / hyper**	**Adjustment factor**
	αi trophic-class average * number							αi_Average
Quarry pond	7.7	44.4	87.15	159.6	134.2	55.95	62.2	5.9
Pond						18.65	248.8	29.7
Natural lake	2.8	7.4	20.75		12.2		62.2	6.6
Storage facility	0.7				12.2		124.4	22.9
Mining lake	14	14.8	20.75	7.6				1.7
Dammed reservoir	24.5	49.95	136.95	83.6	146.4	205.15	279.9	6.7
αr Dammed reservoir/mining lake/quarry pond	46.2	109.15	244.85	250.8	280.6	261.1	342.1	5.8
αp_Pond/storage facility	0.7				12.2	18.65	373.2	27.0

The trophic adjustment factors for ponds and storage facilities determined in this way are considerably larger than those for the other artificial water bodies since ponds and storage facilities are mostly eutrophic to hypereutrophic. The other artificial water bodies have intermediate, and comparable, trophic states. Their states are very similar to those of natural lakes. Mining lakes are an exception here as they are predominantly oligotrophic to mesotrophic (Hoehn et al., 2009).

For artificial lakes over organic soils, or over catchment areas characterised by organic soils, an equal distribution between mesotrophic and eutrophic is assumed since these lakes can all exhibit these trophic states depending on their surrounding areas, inflows, water quality characteristics and management (Riedmüller et al., 2013) and (Mauersberger & Kopp, 2006).

In light of these results, the following weighted, average trophic adjustment factors were determined:

1. Ponds, water storage facilities and artificial freshwater basins of all types αp = 27.0
2. Reservoirs, quarry ponds and mining lakes,
   a. mineral subsoil/catchment area αr_mineral = 5.8
   b. organic subsoil/catchment area αr_organic = 7.6

For the factor R as well, which describes the ratio between a) the methane emissions of dammed reservoirs (more than 20 years old) at or below the dam's spillway and b) the methane emissions from their surfaces, the default factor of the 2019 Refinement (IPCC (2019)) is used. The median value for this ratio, which is dimensionless, is as follows (95% confidence interval of the median):

R = 0.09 (-44.4% / 144.4%) (Table 7.1; p. 7.15; IPCC 2019)

Flowing artificial water bodies - wetb and water bodies used for navigation (harbour basins, canals) - wetd

The default value for the emission factor for channels, and for drainage ditches for water resources management, is

$EF_{c_CH4>20a}$ = 416 kg CH_4 ha^{-1} a^{-1} (95% - Confidence interval: -37.7% / 60.8%) (IPCC (2019); p. 7.18; Table 7.12)

the default value for the dimensionless adjustment factor for the emission factor, as a function of the trophic state of the flowing water bodies

α_c = 1 (IPCC 2019; p. 7.17; Equation 7.12)

6.1.2.7 Direct nitrous oxide (N_2O) emissions from nitrogen mineralisation 4(III) (CRF 4(III))

The direct (CRF 4 (III)) N_2O emissions tied to losses of organic soil substance resulting from land-use changes and land-management measures have been determined in accordance with the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories IPCC (2019). To that end, the carbon-stock changes determined for the individual land-use-change areas were divided by the mean C/N ratios for the corresponding soils; this yielded the absolute changes in soil nitrogen stocks (Equation 11.8 in the 2006 IPCC Guidelines IPCC IPCC (2006a)). The N stocks for forest soils were taken from soil maps (cf. Chapter 6.1.2.1.3) based on the results of the Forest Soil Inventory (Wellbrock et al., 2016). The emission factors for the remaining land-use categories were derived from the regionalised results of the Agricultural Soil Inventory with regard to the C/N ratios of mineral soils (Jacobs et al., 2018) (cf. Chapter 6.1.2.1.4, Chapter 6.1.2.1.5; Chapter 6.1.2.1.6 and Chapter 6.1.2.1.7). At present, the C/N ratios for mineral soils, in the category *Terrestrial Wetlands*, can only be regionalised at the federal state level.

For determination of the direct emissions, the absolute nitrogen-stock differences were multiplied by the IPCC default value specified for the climate and type of input of 0.006 kg N_2O-N $(kg\ N)^{-1}$ (updated Table 11.1 (IPCC, 2019)) in accordance with Equation 11.1 in the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006a). The uncertainties are summarised in the relevant chapters for the individual land-use categories (cf. Chapters 6.4.3, 6.5.3, 6.6.3, 6.7.3 and 6.8.3 Uncertainties and time series consistency).

The nitrous oxide emissions are also subject to conversion times and, as is the case with the carbon-stock changes, they are distributed over 20 years. The methods used for carbon also apply with regard to the effective conversion time. For Forest Land, the remarks made with regard to derivation of the implied emission factors for carbon also apply with regard to derivation of the implied emission factors for nitrogen (cf. Chapter 6.1.2.1.1).

Pursuant to the IPCC Guidelines of 2006 (IPCC, 2006a) and 2019 IPCC (2019), direct nitrous oxide emissions from decomposition of organic matter in the remaining category Cropland[85] and the remaining category Grassland (in the strict sense) are reported in the agricultural sector, under 3.D.1.e.

6.1.2.8 Indirect nitrous oxide (N_2O) emissions from cultivated soils (CRF 4(IV))

The indirect N_2O emissions tied to losses of organic soil substance resulting from land-use changes and land-management measures have been determined in accordance with the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories IPCC (2006a) and shown in CRF Table 4(III). Indirect N_2O emissions from atmospheric deposition are reported in the agricultural sector (CRF 3.B.5). In CRF Table 4(III), therefore, the corresponding columns are labelled with the notation key IE.

To determine the indirect nitrous oxide emissions, the carbon-stock changes determined for the individual land-use change areas were divided by the mean, area-weighted C/N ratios for the corresponding soils; this yielded the absolute changes in soil nitrogen stocks (Equation 11.8 in the 2019 IPCC Guidelines IPCC (2019)). The N stocks for forest soils were taken from soil maps (cf. Chapter 6.1.2.1.3) based on the results of the Forest Soil Inventory (Wellbrock et al., 2016). The emission factors for the remaining land-use categories were derived from the regionalised results of the Agricultural Soil Inventory with regard to the C/N ratios of mineral soils (cf. Chapter 6.1.2.1.4, Chapter 6.1.2.1.5; Chapter 6.1.2.1.6 and Chapter 6.1.2.1.7). At present, the C/N ratios for mineral soils, in the category *Terrestrial Wetlands*, can only be regionalised at the federal state level.

To estimate the indirect nitrous oxide emissions, the N-stock differences pursuant to Equation 11.10 of the 2019 Refinement to the IPCC Guidelines were multiplied by the standard factors $Frac_{Leach\text{-}(H)}$ (0.24 kg N_2O-N (kg N)$^{-1}$) and EF_5 (0.011 kg N_2O-N (kg N)$^{-1}$) (IPCC, 2006a). The uncertainties are listed in the uncertainties chapters for the respective land-use categories (cf. Chapters 6.4.3, 6.5.3, 6.6.3, 6.7.3 and 6.8.3). The results are entered in CRF Table 4(III).

The nitrous oxide emissions are also subject to conversion times and, as is the case with the carbon-stock changes, they are distributed over 20 years. The methods used for carbon also apply with regard to the effective conversion time. For Forest Land, the remarks made with regard to derivation of the implied emission factors for carbon also apply with regard to derivation of the implied emission factors for nitrogen (cf. Chapter 6.1.2.1.1).

Pursuant to the IPCC Guidelines of 2006 (IPCC, 2006a) and 2019 IPCC (2019), direct nitrous oxide emissions from decomposition of organic matter in the remaining category Cropland[86] and the remaining category Grassland (in the strict sense) are reported in the agricultural sector, under 3.D.1.e.

6.1.2.9 Burning of biomass (CRF 4(IV))

In Germany, combustion of biomass in the land-use sector takes place solely in the form of wildfires. The resulting emissions are entered in CRF 4(IV). A description of the method used for estimating forest fire emissions is presented in Chapter 6.4.2.7.5 (forest fires) in the land-use category Forest Land.

[85] Sum of emissions from the remaining categories and conversion categories among the land-use categories *$Cropland_{annual}$, Hops, Orchards, Vineyards, Tree nurseries, Christmas tree plantations* and *Short-rotation plantations*

[86] Sum of emissions from the remaining categories and conversion categories among the land-use categories $Cropland_{annual}$, Hops, Orchards, Vineyards, Tree nurseries, Christmas tree plantations and Short-rotation plantations

No emissions from burning of biomass occur in the land-use categories Cropland, Grassland, Wetlands and Other Land. For all categories, a distinction is made between controlled burning and wildfires, however. Wildfires seldom occur in these land-use categories in Germany and are thus not recorded: the greenhouse gas emissions are negligible. In CRF 4(IV), NO (not occurring) is entered for that category.

No large anthropogenic wildfires, such as the peat fire in 2018, were recorded between 2019 and 2024.

Controlled burning (on-site burning of biomass) is prohibited by law in Germany (Article 3 of the German Ordinance on direct payments (DirektZahlVerpflV); Bundesgesetzblatt (2004)) and thus is assumed not to occur. This applies to all land-use categories. In CRF 4(IV), NO (not occurring) is entered for that category.

6.1.2.10 Uncertainties

Uncertainties in the LULUCF section of the German greenhouse gas inventory are determined in accordance with the 2006 IPCC Guidelines and the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000). The uncertainty statistics commonly given for a normal distribution include the 95% confidence interval, ± half of the 95% confidence interval or 1.96 x the standard error, in % of the mean. In the case of asymmetric distributions, such as triangular or log-normal distributions, the uncertainties are expressed as percentages of the position scale, and as upper and lower bounds; these are usually determined using the quantiles (p = 0.025 and p = 0.975). In accordance with above guidelines, the propagation of uncertainties was calculated using a conservative estimation in which the distance between the extreme value of the sloping axis section and the position scale is defined as half of the 95% confidence interval. Due to a lack of uncertainty estimates for the relevant emission factors, it was not possible to calculate uncertainties for harvested wood products.

The total uncertainty of the LULUCF sector of the German GHG inventory amounts to 15.5% with respect to the level of emissions for the year 2024. The largest contribution to the total uncertainty comes from the CO_2 emissions (76.8%). The total uncertainty contributions from emissions of methane (23.1%) and nitrous oxide emissions (0.1%) are marginal.

With respect to pools, organic soils make far and away the largest contribution (94.9%) to the total uncertainty of the LULUCF inventory. The contribution of mineral soil is 1.7%, while biomass contributes 1.2 %, water bodies 1.4%, and DOM 0.8%.

All in all, the land-use categories Grassland (in the strict sense) (89.8%), $Cropland_{annual}$ (5.5%), Forest Land (2.2%) and Settlements (0.2%) account for the respective shares of the total uncertainty of the German LULUCF inventory.

6.1.3 Quality assurance and control

General quality control (QC) and, for 4.A to 4.G and the land areas, category-specific quality control and quality assurance (QA) were carried out according to the requirements of the QSE manual and its associated applicable documents by the relevant involved experts and the Single National Entity (SNE).

During the QA, detailed checklists were used and individual checks carried out to review and document the results in accordance with the quality management guidelines of the Thünen Institute (Thünen-Institut (TI), 2016). The Single National Entity archives the Thünen checklists along with other documents of importance for quality control. These documents are thus also available for the purpose of external review.

6.1.3.1 The Thünen Institute's quality management for emissions inventories

The Thünen Institute's quality management for emissions inventory preparation was developed in line with the IPCC guidelines and the QSE manual (Chapter 1.2.2.3). The framework for the quality management and the process for carrying it out are described in detail in the relevant concept (BMELV, 2016) and in the provisions for implementation of the concept (Thünen-Institut (TI), 2016). All documents and data are added to the inventory description that is archived by the Single National Entity. The requirements and procedures set forth by the provisions for implementation of the concept were fully complied with. The following section describes the special additional quality controls carried out for the present submission.

6.1.3.2 Input data, calculation procedures and emissions results

In a first step, the land-use matrix was checked for quality and then approved for emissions calculation. Quality checks covered the decision trees and the results of the annual land-use matrix and of the 20-year conversion period. The following section lists key test criteria for the land-use matrix that were applied in this year's tests. These criteria exceed the requirements set forth by the provisions for implementation of the concept. They apply for the entire land-use matrix and for the two submatrices for mineral and organic soils:

- The national area is constant.
- The national area is the same as that used in the previous year.
- The areas of the land-use categories are the same as or very similar to the corresponding areas used in the previous year; if there are any discrepancies, they can be explained.
- The areas and area trends are consistent with the relevant statistical data; if and where they are not consistent, the discrepancies can be explained.
- The sums of the total areas, consisting of remaining areas and areas with land-use changes, are correct.
- Other Land areas remained the same or decreased; no land-use changes to the category Other Land occurred.
- Peat extraction areas were listed separately.

The emissions calculations were carried out using the quality-assured land-use matrix. The calculations of emissions for annual land-use changes and the conversion time were implemented step-by-step and documented in tables on the basis of the area data and emission factors/implied emission factors (IEFs). The tables were reviewed for:

1. Correctness of the calculations,
2. Consistency of the time series,
3. Consistency with the calculations of the previous year.

The following test criteria were also applied:

- Emission factors:
  - The calculations of the emission factors and implied emission factors (IEFs) are correct.
  - The time series for the emission factors is consistent; any changes from year to year can be explained.

- The emission factors are the same as those of the previous year, except for changes in data and methods: new emission factors are plausible and differences from those of the previous year are explainable and fully documented.
- Uncertainties are correctly reported and consistent with those of the previous year.

► Calculations:

- The basic calculations and the calculations for the annual land-use changes and the conversion time are correct.
- The overview tables, which serve as the basis for the CRF and the text, are correct.
- The emissions results are consistent with those of the previous year; any discrepancies can be explained as the result of use of new data and methods.

► Results of quality controls:

- All calculations are correct.
- The time series are consistent. Any major year-to-year changes result solely from the periodicity of data and from linear interpolation between periods.
- No unexplainable outliers were found in the relative differences with regard to the emissions of the previous year. All changes from the previous year were correctly documented and included in the National Inventory Report.

For quality control purposes, after the relevant activity data and implied emission factors (IEFs) were entered into the Central System of Emissions (CSE) database, the emissions as calculated in the CSE were compared with emissions results obtained from calculations made outside of the database environment. All quality control steps and their results are fully recorded in the inventory description that is also archived by the Single National Entity.

6.1.3.3 Verification

The inventory in the LULUCF sector is prepared primarily with data from inventories and surveys that are unique to Germany. This means that no comparable data are available that could be used to verify it. The inventories and surveys that are used include the National Forest Inventory (NFI), the Forest Soil Inventory and the Agricultural Soil Inventory, the data from the ATKIS® official topographic-cartographic information system and forest-fire statistics. These sources serve as sources of primary statistics. To ensure data quality, inventories such as the NFI and the BZE carry out their own extensive quality assurance and controls (cf. also Chapter 6.4.4). All of the results used include error information that enters into the uncertainties calculation for the LULUCF inventory.

The results and implied emission factors (IEFs), differentiated by carbon pools and land-use categories, were compared with those of neighbouring countries. Details are provided in the Category-specific quality assurance/control and verification chapters for the various land-use categories.

6.1.3.4 Improvement measures, reviews and reports

6.1.3.4.1 General information and chronology of the development of the inventory and methods

In recent years, in the compilation of the German LULUCF inventory

- the reporting spectrum was expanded several times to include additional categories
- numerous changes were made to the methods to calculate the GHG emissions for all land-use categories and pools
- the spatial resolution of the inventory was increased.

Each year, these measures made it necessary to fully recalculate the time series of the GHG emissions in the LULUCF inventory, resulting in some cases in substantial discrepancies between the results of the GHG calculations in individual years. The reasons for the changes in methodology were

- requirements of the UNFCCC Review (e.g. ARR/2018/DEU - ARR/2022/DEU)
- requirements of the EU Review (e.g. ESD Reviews; (Ecofys & Environment Agency Austria, 2017)
- in-house measures/inventory plan

in order to keep improving, completing and perfecting the German LULUCF inventory, comprehensively to the highest possible reporting standard. The explicit geographical determination of the emissions, using regionally specific emission factors and activity data with very high spatial resolution, also aims to make it possible to record the effects of site-specific management measures (positive and negative) on the GHG emissions of the various pools and land-use categories and to map them in the inventory. The measures taken to improve the LULUCF inventory since 2020 are listed in Table 337.

Table 337: Changes in the methods used to compile the German LULUCF inventory from 2020-2025, broken down by pool

Organic soils		
submission	**Method change**	**Reasons**
2021	- New method to determine the CO_2 and CH_4 emissions for the land-use categories (LUC) $Cropland_{annual}$, Hops, Meadow orchards, Vineyards, Tree nurseries, Christmas tree plantations and Short-rotation plantations, Grassland in the strict sense, Trees and shrubs, Hedges and Terrestrial Wetlands and Settlements, depending on the groundwater level - Implementation of a model for complete-coverage calculation and regionalisation of groundwater levels in Germany's organic soils, on an annual basis	In-house measure: Implementation and improvement of the Tier 3 method as an important key category
2022	- Modification of the procedure to determine the sites of drainage ditches on organic soils - Correction of the algorithm for calculation of methane emissions of drainage ditches on organic soils - Change to the emission factor for nitrous oxide emissions from organic soils under Settlements	
2025	- Implementation of a new hydrological model to determine water levels in organic soils	
Mineral soils		
submission	**Method change**	**Reasons**
2021	- New procedure to determine GHG emissions from mineral soils in land-use changes from/to Settlements	e.g. ARR/2020/DEU L.6 (2015: L.9; 2016: L.9; 2018; L.5
2022	- Update of the value for carbon and nitrogen stocks of mineral soils in the category Settlements remaining Settlements	

2023	- Implementation of nationwide high-resolution maps of carbon and nitrogen stocks in mineral soils of the land-use categories Cropland, Grassland and Forest Land of Germany as a basis for the determination of regionally specific GHG emissions from mineral soils - Introduction of the SOM process model YASSO15 to calculate the GHG emissions from mineral forest soils for the period with available input data (since 2008) in combination with the stock-difference method (1990-2008) using the "overlapping method"	2016ARR/2022/DEU L.1; L.2; KL.2; EU-ESD Review 2019 Inventory plan/In-house measure: Implementation of a Tier 3 method ECOFYS & UMWELTAGENTUR ÖSTERREICH
2024	- Introduction of regionalised emission factors for mineral soils of the subcategory Terrestrial Wetlands (wettwett) - Modification of the input data for computer-based modelling with YASSO15	
2025	- Calculation of the carbon and nitrogen stock changes and of the CO_2 and N_2O emissions from the remaining categories Cropland and Grassland due to management using the RothC process model	

Biomass		
submission	**Method change**	**Reasons**
2021	- Introduction of new emission factors for above-ground and below-ground forest biomass	e.g. ARR/2022/DEU L.8; L.9; L.11; ARR/2020/DEU KL. 7 ARR/2018/DEU L.2; KL 10 – 12 ARR/2016/DEU KL. 13 ARR/2015/DEU KL.13 EU-ESD Review 2019 ECOFYS & UMWELTAGENTUR ÖSTERREICH Inventory plan/In-house measures: Implementation of a Tier 3 method Availability of the data of the current National Forest Inventory
2022	- Modification of the emission factors for above-ground and below-ground forest biomass - Implementation of models for calculation and tracing of carbon stocks in the biomass of perennial plants outside of Forest land, as a function of species, age and management aspects (such as rotation periods, cutting, new establishment), at every survey point and on an annual basis - Adjustment of the emission factors for biomass in connection with land-use changes from Woody Grassland to Forest Land	
2024	- Introduction of regionalised emission factors for biomass of annual herbaceous cropland and grassland plants	
2025	- New models to calculate the carbon stock of the biomass of hedges and field copses - New models to calculate the carbon stock of the biomass in Terrestrial Wetlands and Settlements - New regionalised emission factors for the forest biomass, derived from the results of the latest National Forest Inventory	

Dead organic matter (DOM: dead wood, litter)		
submission	**Method change**	**Reasons**
2021	- Introduction of new emission factors for dead wood	
2022	- Improvement of emission factors for dead wood	
2025	- New regionalised emission factors for dead wood, derived from the results of the latest National Forest Inventory	Availability of the data of the current National Forest Inventory

Water bodies		
submission	**Method change**	**Reasons**
2023	- Introduction of a method to estimate the methane emissions from artificial standing and flowing water bodies	In-house measure: Completion of the inventory
2025	- Calculation of the emissions for the LUC water bodies used for navigation - Adjustment of the emission factor for drainage ditches and channels	

Forest fire		
submission	**Method change**	**Reasons**
2023	- Inclusion of the biomass of the pools dead wood and litter in connection with wildfires	ARR/2022/DEU L.12

Land use		
submission	**Method change**	**Reasons**
2020-2024	- Thematic, spatial and chronological updating of the map data for determination of activity data with regard to designation of land uses and land-use changes, and adaptation of the land-use matrix over time	In-house measures: Completion and improvement of the accuracy of the inventory using the most up-to-date and best data sets, through increasing regionalisation and spatial resolution, and by increasingly disaggregated recording of various land-use types
2023	- Introduction of additional land-use subcategories ○ Hedges (LUC Grassland) ○ Natural water bodies (LUC Wetlands) ○ Standing artificial water bodies (LUC Wetlands) ○ Flowing artificial water bodies (LUC Wetlands) ○ Roads (LUC Settlements) - Implementation of models for estimation of emissions in the new land-use categories, including determination of activity data and emission factors	
2024	- Introduction of additional land-use subcategories ○ Bodies of water used for navigation (LUC Wetlands) ○ Railway facilities (LUC Settlements) - Implementation of models for determination of activity data in the new subcategories	
2025	- Thematic, spatial and chronological updating of the map data for determination of activity data with regard to designation of land uses and land-use changes, and adaptation of the land-use matrix over time - New activity data basis for hedges	
Information technology		
submission	**Method change**	**Reasons**
2023	- Complete reprogramming and implementation of the LULUCF calculation model in the programming languages R and C++	In-house measures to improve the inventory in order to undertake inventory calculations comprehensively to the highest reporting standard, transparently, consistently and accurately; quality control/assurance
2024	- Correction of errors in the program code of the LULUCF calculation model regarding ○ Random age allocation of multi-annual trees and shrubs in areas whose time of establishment is unknown ○ Calculation of emissions from mineral soils in the Land of Bavaria	

6.1.3.4.2 Current improvements

The 2026 submission also includes updates to the LULUCF inventory and implements improvements and changes to methods (Table 338). These are fundamental in nature and required a complete recalculation of the GHG emissions for the entire reference period.

Table 338: Improvements, updates and methodological changes to the compilation of the 2026 German LULUCF inventory

Organic soils		
submission	**Method change**	**Reasons**
2026	• Modification of the hydrological model to determine groundwater levels in organic soils	In-house measure: Improvement of the Tier 3 method as an important key category
Mineral soils		
submission	**Method change**	**Reasons**
2026	• Modification of the model to calculate carbon stocks in mineral soils on Cropland; implementation of calculations for individual sites	e.g. ARR/2022/DEU EU-ESD Review 2019 ECOFYS & UMWELTAGENTUR ÖSTERREICH In-house measure: Implementation of a Tier 3 method
	• Adjustment of the carbon stocks to include a sealing factor for settlement and open areas, and to correct the mass balance virtually	

Organic soils		
	• Modification of the input data for computer-based modelling with YASSO15	
Biomass		
submission	**Method change**	**Reasons**
2026	• New model to determine the development of perennial phytomass in settlement areas, a new sealing factor and new distribution coefficients for the various plant types	EU-ESD Review 2025 In-house measure: Update and improvement of the Tier 3 method
Land use		
submission	**Method change**	**Reasons**
2026	• Introduction of the new land-use category photovoltaic areas under LUC settlements • Division of the Natural water bodies categories into the subcategories Rivers (wetr) and Lakes (wetl) • Implementation of a new method to determine land use prior to 2010 • Deliberate inclusion of Meadow orchards; reported in Orchards	In-house measures: Completion and improvement of the inventory's accuracy and completeness

6.1.4 Planned improvements

The following measures are currently being planned or worked on to improve and complete (expand the reporting spectrum) of the German LULUCF inventory. Their full implementation is planned for the medium term; where useful and possible, partial implementation will be brought forward (cf. mineral soil process model):

1. Improve the model used to calculate carbon and nitrogen stock changes in mineral soils in the remaining categories of the land-use category *Cropland* and *Grassland* (cf. also Chapter 6.1.2.1.9).
   a. Further develop the model used to calculate the carbon and nitrogen stock changes in mineral soils of the land-use categories Cropland and Grassland at hectare level, particularly with a view to input data (in progress, planned for the 2027 submission).
   b. Further development of the model to calculate the carbon and nitrogen stock changes in mineral soils of the land-use category *Grassland* on a regionalised basis at hectare level and over time (in progress, planned for the 2027/2028 submission).
2. Improve the methodology for recording GHG emissions in settlement areas
   a. Implement a method to record carbon and nitrogen stock changes in mineral soils of the remaining categories Settlement areas, particularly the subcategory *Buildings and open areas* (in progress; planned for the 2028 submission)
   b. Lend impetus to the subcategories *Roads* and *Railway facilities* (in progress; planned for the 2028 submission)
   c. Record emissions from the subcategories *Roads* and *Railway facilities*: Derive and implement emission factors for biomass and mineral soils (in progress; planned for the 2028 submission)
3. Improve the methodology to record GHG emissions from inland water bodies (planned for the 2028 submission).
   a. Record all inland water bodies (especially artificial water bodies) and their trophic state as completely as possible and georeferenced.
   b. Determine federal state-specific emission factors
4. Development of methods to record GHG emissions from coastal wetlands (planned for 2030 submission).
   a. Definition of the boundaries of the land-use category and its subcategories

b. Record relevant activity data
c. Determine federal state-specific emission factors

6.2 Land-use definitions and land-use classification systems, and their reflection in the LULUCF categories

6.2.1 Forests

The definition of forest used in the German inventory conforms with that given in the 2006 IPCC Guidelines ((IPCC, 2006a): Vol. 4, Chapter 2.2). The way the national land-use systems are allocated to this category is based on Table 341 in Chapter 6.3.1.2.1.

The basis for reporting consists of the definition of forest used by the National Forest Inventory (NFI) (Polley, 2001):

"Forest" within the meaning of the NFI is any area of ground covered by forest vegetation, irrespective of the information in the relevant cadastral survey or similar records. The term "forest" also refers to clear-cut or thinned areas, forest tracks, dividing strips in forests, firebreaks, openings and clearings, forest glades, feeding grounds for game, timber yards/lumberyards, forest aisles for conduction, further areas linked to and serving the forest including areas with recreation facilities, overgrown heaths and peatland, overgrown former pastures, alpine pastures and rough pastures, as well as areas with dwarf pines and green alders. Heaths, peatland, pastures, alpine pastures and rough pastures are considered to be overgrown if the naturally regenerated forest cover has reached an average age of five years and if at least 50% of the area is covered by forest. Forested areas of less than 1,000 m^2 located in farmland or in developed regions, narrow thickets less than 10 m wide, Christmas tree and decorative brushwood cultivations and parkland belonging to residential areas do not constitute forest within the meaning of the NFI. Watercourses with widths of up to 5 m do not break the continuity of a forest area.

At the same time, in a departure from the NFI definition of "forest", areas that the NFI counts as forest but assigns to the forest category "non-forest ground", i.e. because they are not wooded, were taken into account as "non-forest" in calculation of carbon stocks and carbon-stock changes. While short-rotation plantations are recorded separately in the NFI, they are not forest within the meaning of the NFI, the Federal Forest Act and the present inventory. They are thus reported under Cropland.

Pursuant to the 2006 IPCC Guidelines (IPCC, 2006a), Land converted to Forest Land remains in that conversion category for at least 20 years and is only then included in Forest Land remaining Forest Land. For afforestation areas, data for the period as of 1970 are taken into account.

Germany has not selected the option "natural disturbances". Natural disturbances that occur are not considered separately; instead, they enter into the change calculations for the relevant pools.

6.2.2 Cropland

The definition of Cropland used in the German inventory conforms with that given in the 2006 IPCC Guidelines ((IPCC, 2006a): Vol. 4, Chapter 3.2). The way the national land-use systems are allocated to this category is based on Table 341 in Chapter 6.3.1.2.1. The land-use category Cropland is divided into seven subcategories: $Cropland_{annual}$, Hops, Orchards, Vineyards, Tree nurseries, Christmas tree plantations and Short-rotation plantations.

In CRF 4.B, these subcategories are listed separately with regard to remaining categories and all conversion categories. Conversions among the Cropland subcategories are treated like land-use changes. In the tables, they are reported separately (CRF 4.B.1).

For the purposes of emissions calculations, these land-use systems are stratified by specific pools:

- Calculation of biomass stocks: Annually variable stratification by 65 annual crops, regionalised at the federal state level (Chapter 6.1.2.3.3), and permanent crops: Hops (Chapter 6.1.2.3.5.6), Orchards (Chapter 6.1.2.3.5.1), Vineyards (Chapter 6.1.2.3.5.2), Tree nurseries (Chapter 6.1.2.3.5.3), Christmas tree plantations (Chapter 6.1.2.3.5.4) and Short-rotation plantations (Chapter 6.1.2.3.5.5). Permanent crops accounted for 3.4% of the total Cropland area in 2024.
- Calculation of emissions from soils: Chronologically constant stratification in accordance with the pools organic soils and mineral soils, and broken down by uses (cf. Chapters 6.1.2.1 and 6.1.2.1.9). A complete-coverage 100 x 100 m grid map of the soil characteristics of mineral soils under annual Cropland, tied to numerous site-specific parameters, was prepared in a 100 x 100 m grid map (cf. Chapter 6.1.2.1.4).
- The total area of open drainage ditches is determined in addition to the area of organic soils under Cropland.
- Calculation of emissions from land-use changes: Annually updated stratification by the categories Cropland remaining Cropland and Land converted to Cropland. The relevant data are taken annually from the pertinent land-use information (Chapter 6.2 and Chapter 6.3).

6.2.3 Grassland

Grassland as defined in the German inventory is in line with the definition in the 2006 IPCC Guidelines ((IPCC, 2006): Vol. 4, Chapter 3.2). The way the national land-use systems are allocated to this category is based on Table 341 in Chapter 6.3.1.2.1.

Grassland is divided into three subcategories: a) areas covered with grasses and herbs (Grassland in the strict sense); b) areas that are covered with trees and shrubs (Woody Grassland) but that do not fall under the definition of Forest Land; and woody grassland areas with linear structures (Hedges). It also includes object type 4106 “swamp, reeds” from the Digital Basic Landscape Model (Basis-DLM) (Chapter 6.3.1.2.1), which consists of undrained organic soils under grassland. In the following, these areas are also referred to as “wet grassland”. In 2023, Grassland (in the strict sense) accounted for 90.4% of the total grassland area, while Woody Grassland accounted for 6.4% of that total area and Hedges accounted for 3.2%.

The subcategories in this area include the following types of land use and plants:

- Meadows, pastures, alpine pastures, rough pastures, heath areas, natural-condition grassland, recreational areas and swamp/reeds are grouped under “Grassland (in the strict sense)”.
- Extensive areas with field copses and shrubbery make up the subcategory “Woody Grassland.”
- Hedges are defined as consisting of shrubs (and trees, in some cases) growing in dense linear formations (with either one or multiple rows).

Conversions and changes between these subcategories are treated like land-use changes.

For emissions calculation, the grassland subcategories are stratified by pools.

- Calculation of biomass stocks: Stratification within the subcategories, by crop type. For Grassland (in the strict sense), the stratifications include above-ground and below-ground biomass of grasses and herbaceous plants (Chapter 6.1.2.3.3), regionalised at the federal state level. For Woody Grassland and Hedges, a model for calculation of the biomass of hedge plants and field copses as a function of age, rotation cycles, growth density and growth height has been developed (Chapter 6.1.2.3.6).
- Calculation of emissions from soils: Constant stratification over time, by organic soils and mineral soils; further differentiation by use; for mineral soils, regionalisation as a function of numerous covariates (cf. Chapter 6.1.2.1.5).
- Emissions from organic soils are reported as a function of depth to water table (cf. Chapter 6.1.2.2). In addition, the total area of drainage ditches has been estimated.
- Calculation of emissions from land-use changes: Annually updated stratification, by the remaining categories of *Grassland (in the strict sense)*, *Woody Grassland* and *Hedges*; and by land converted to *Grassland (in the strict sense)*, *Woody Grassland* or *Hedges*. The relevant data are taken annually from the pertinent land-use information (Chapter 6.2 and Chapter 6.3.1).

6.2.4 Wetlands

Pursuant to the 2006 IPCC Guidelines, the "Wetlands" land-use category must subsume all those land areas where soils are intermittently or constantly waterlogged, or covered with water, and that do not fall within the land-use categories 4.A, 4.B, 4.C and 4.E. In the German inventory, these areas are combined in the subcategories Terrestrial Wetlands (IPCC: *Other Wetlands*) and Water bodies (IPCC: *Flooded Land*). In addition, all areas that are related to Peat extraction are combined within an additional subcategory under the land-use category Wetlands (IPCC: *Peat Extraction*; cf. 2006 IPCC Guidelines, (IPCC, 2006a)). These peat extraction areas and their changes over time are recorded and listed in a spatially explicit manner.

In Germany, the majority (>90%) of these former wetland areas have been drained and either are used for agriculture or forestry or are located in Settlement areas. In 2022 these areas amounted to 1,660 kha ≙ 85.3% of the total area of organic soils. In accordance with the 2006 IPCC Guidelines, these areas are reported in the relevant land-use categories (CRF 4.A-4.C and 4.E). The subcategory Terrestrial Wetlands thus only includes Germany's few remaining hardly drained, semi-natural (i.e. subject to very little anthropogenic influence) peatlands, along with other wetlands on mineral soils.

In the subcategory *Water bodies*, a distinction is also made in terms of the degree of anthropogenic influence between a) flooded land[87] and b) natural water bodies, including non-regulated and regulated water bodies (the latter of which are not covered by reporting obligations). With a view to more effective determination of emissions from the subcategory Water bodies, the category Wetlands has been further subdivided and, with the 2024 submission, the subcategory artificial water bodies used for navigation has been introduced. The subcategory Water bodies now consists of the following subcategories:

[87] Water bodies that are regulated by human activities and that exhibit wide fluctuations in water level and/or changes in the area they cover (dammed reservoirs, etc.) (2006 IPCC Guidelines)

- Natural water bodies,
- Standing artificial water bodies,
- Flowing artificial water bodies
- Artificial water bodies used for navigation

Table 339 shows how Germany's wetlands areas were classified for the year 2024 in accordance with these provisions. It also includes the relevant definitions and areas. The data on drainage ditches on organic soils (italics), which are to be reported under 4.A, B, C and E, are also included.

Table 339: Subdivision of the land-use category *Wetlands* into subcategories pursuant to the 2006 IPCC Guidelines and the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2019); also included are the subcategories of the subcategory Water bodies and the relevant areas for 2024 [ha]

Subcategory	Abbreviation	Area composition	Area [ha]
Terrestrial Wetlands	wett	Terrestrial wetlands that do not fall into one of the other land-use categories (such as semi-natural peatlands)	153,100
Natural water bodies	wetl	Areas of flowing and standing water bodies were taken from the B-DLM and the wetb areas deducted	367,129
	wetr	Areas of flowing and standing water bodies were taken from the B-DLM	185,781
Peat extraction areas	wetp	Areas located on organic soils that are used for peat extraction	10,076
Artificial standing water bodies	wetb	Reservoirs, quarry ponds and mining lakes	34,104
	wetb	Ponds, water storage facilities, artificial freshwater basins of all types (exception: wastewater treatment facilities)	31,894
Artificial flowing water bodies	wetd	Channels and drainage ditches for water resources management, harbour basins along inland water bodies	23,261
Artificial water bodies used for navigation	wets	Harbour basins along inland water bodies and canals for shipping	17,571
Drainage ditches on organic soils		*(to be reported under 4.A - 4.E)*	13,800

The subcategories Peat Extraction, Terrestrial Wetlands and Water bodies differ in terms of their emissions behaviour. For this reason, they are listed as separate subcategories and reported separately in CRF (4.D and 4(II)) (for details, cf. Chapter 6.3.1). In the land-use category Wetlands, land areas are calculated by means of annually updated stratification by Terrestrial Wetlands, Water bodies and Peat extraction areas. In addition, the total areas of the subcategories Terrestrial Wetlands and Peat extraction areas are further subdivided into the categories a) land "remaining as ..." and b) land converted into Terrestrial Wetlands or Peat extraction areas.

The relevant area data are taken annually from the relevant land-use information (Chapter 6.3.1). Conversions between the subcategories are treated as land-use changes originating in other land-use categories in accordance with the guidelines in Chapter 6.1.2.6.

To calculate the emissions, the subcategories Peat Extraction, Terrestrial Wetlands and Water Bodies are stratified by pool.

Remaining category:

- Calculation of biomass stocks: No biomass occurs in the subcategories Water bodies and Peat Extraction. The biomass of the subcategory Terrestrial Wetlands was derived from the relevant figures for Grassland (in the strict sense), regionalised at the federal state level (Chapter 6.1.2.1.7).
- Calculation of emissions from mineral soils: No soil carbon stocks are listed for water areas; peat extraction areas are found only on organic soils. In the tables, the emissions are listed as not occurring (NO). For the subcategory Terrestrial Wetlands, emissions from mineral soils are derived from the relevant figures for Grassland (in the strict sense) (Chapter 6.1.2.1.7).
- Calculation of emissions from organic soils: For peat extraction areas, both on-site and off-site emissions are calculated (Chapter 6.7.2.4) in accordance with the 2006 IPCC Guidelines and the 2013 IPCC Supplement Wetlands. The subcategory Terrestrial Wetlands is divided into wet (depth to water table < 0.1 m) and drained areas (depth to water table > 0.1 m) (cf. Chapter 6.1.2.1.9); on-site emissions are reported; but no emissions are reported for the subcategory Water bodies.
- For the water body subcategories Standing artificial water bodies and Flowing artificial water bodies, methane emissions are reported as a function of the type and trophic state of the water body in each case (Chapter 6.1.2.6)

Conversion categories:

- Calculation of biomass stocks: In the case of land-use changes to Water bodies, the biomass stocks are set to “zero”. The biomass of the subcategory Terrestrial Wetlands has been derived from the relevant figures for Grassland (in the strict sense) and Woody Grassland (Chapter 6.1.2.3.7).
- Calculation of emissions from soils: No emissions occur in the subcategory Water Bodies. The subcategory Terrestrial Wetlands is divided in a constant manner over time into “organic soils” and “mineral soils”. For organic soils, on-site emissions are reported as a function of water level (Chapter 6.1.2.2). Emissions from mineral soils occur only in the subcategory Terrestrial Wetlands, since peat extraction areas, by definition, contain no mineral soils.

6.2.5 Settlements

The categories used by national land-use systems in connection with the categories Settlements and Transport, and the manner in which those categories are allocated to the IPCC’s Settlements land-use category, are shown in Table 341 in Chapter 6.3.1.2.1. The definition of settlements used in the German inventory conforms with the 2006 IPCC Guidelines ((IPCC, 2006a): Vol. 4, Chapter 2.2). The entire Settlement area has been subdivided into the subcategories Buildings and Open areas (set1), Roads (set2), and Railway track beds (set3) and Areas with photovoltaic plants (setp).

Settlement areas contain significant portions of unsealed land that is covered with vegetation. A large-scale study by the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR), an institute based in the Federal Office for Building and Regional Planning (BBR), determined these portions for settlement areas in Germany by way of remote sensing and geoinformatics (BBSR et al., 2022). Land covered with vegetation accounts for around 45% of urban settlement area and settlement open area as defined in BBSR 2022 (Table 340). The

total area of these two categories from the BBSR study (2022) correspond to the German subcategory Buildings and open areas (set1). The approximate vegetation mix on this land is as follows: 17% trees, 83% low vegetation (e.g. meadows, lawns, shrubs and bushes (Table 340).

Table 340: Calculation of share [%] of areas covered with vegetation of the total land-use subcategory Buildings and open areas (set1) and the share of herbaceous and woody plants of these areas

land-use category	Area [ha]			Share [%]	
	Total (1)	Trees (2)	Herbaceous plants (3)	Trees (2)	Herbaceous plants (3)
Built-up settlement area	3,381,402	216,410	1,159,821	6.4	34.3
Settlement open area	450,628	81,113	282,994	18	62.8
Buildings and open areas set1)	**3,832,030**	**297,523**	**1,442,815**	**7.8**	**37.7**
	∑set1	***1,740,338***		***45.4***	
	share ∑set1			***17.1***	***82.9***

Area data from LUM 2025; relative distribution of plants according to the 2022 (BBSR et al., 2022). Values calculated for the NID are in bold and italic

In Germany, large-scale photovoltaic plants are almost exclusively operated on grassland. For this reason, areas in the subcategory Areas with photovoltaic plants are treated the same way as Grassland in the strict sense; this applies to all areas in the remaining categories and conversion categories. As large-scale photovoltaic plants are mainly installed above the ground using, e.g. rammed foundations, ground screws or concrete foundations, there is no deduction in area due to construction sealing as the extent of sealing is typically very low.

In summary, the German inventory assumes soil sealing of around 55% for the subcategory Buildings and open areas, and 0% for Areas with photovoltaic plants.

For emissions calculation, the land-use category is stratified by specific pools:

- Calculation of biomass stocks: The biomass of the category Buildings and Open areas has been derived from the relevant figures for Grassland (in the strict sense) and from data given in the literature (Chapter 6.1.2.3.7).
- Calculation of emissions from soils: Constant differentiation over time by organic soils and mineral soils. The carbon stocks in mineral soils are derived as a function of land use from the data of the Forest Soil and Agricultural Soil Inventories, taking account of the degree of soil sealing involved (cf. Chapter 6.1.2.1) and of the relevant previous use. For organic soils, the values for Grassland (in the strict sense) are used on a proxy basis (Chapter 6.1.2.2).
- Calculation of emissions from land-use changes: Stratification by the remaining use, and by Land converted to Buildings and Open areas as well as Areas with photovoltaic plants, is carried out and annually updated. The relevant data are taken annually from the land-use information (Chapter 6.2 and Chapter 6.3.1).

6.2.6 Other Land

The following object types defined in ATKIS® are assigned to the category Other Land within the German reporting system, in accordance with the 2006 IPCC Guidelines: Area without vegetation (AAA_Ob.-No. 43007) and Area currently undefined (AAA_Ob.-No. 43008). The relevant areas are described and allocated in accordance with Table 341 in Chapter 6.3.1.2.1 and the algorithms described in that section.

6.3 Information on approaches used for determining relevant land areas and on the sources of land-use data used

6.3.1 Information on approaches used for depicting land areas and land-use databases that are used in inventory preparation

6.3.1.1 Introduction

The method for determining land-use changes in the LULUCF sector takes account of all land uses and land-use changes in a chronologically and spatially consistent manner, and separately for organic and mineral soils. A sample-based system is used. The method used is based on spatially explicit observations, meaning that it can be classified as an "Approach 3" pursuant to the 2006 IPCC Guidelines ((IPCC, 2006b): Vol. 4 Chapter 3.3.1). The reasons why this sample-based system was chosen are given in Freibauer et al. (2017).

The sampling system employs a regular 100 m x 100 m grid of sample points laid over Germany's total area. The grid chosen is based on the Digital Basic Landscape Model (Basis-DLM), whose most-precise data set for Germany includes areas as small as 1 ha. A total of 35,790,122 sample plots result. This procedure makes it possible to identify, on a detailed level, land uses and land-use changes on organic and mineral soils in all land-use categories.

6.3.1.2 Database and data processing

The land-use matrix (LUM) has been derived from the Basis-DLM. Where necessary, it has been supplemented with additional data sets (cf. Chapter 6.3.1.2.1). For a data source to be usable, its land-use classes – as assigned by way of interpretation or modelling – must lend themselves to translation into the IPCC land-use categories. Not every data set has to show all land-use classes; it suffices if at least one of the six main land-use categories can be identified. The land-use information in the various data sets uses geographic location for correlation with the sample points. As a result, chronologically distributed data are then available for each sample point.

The aim of this flexible survey system is:

- to identify the most reliable land-use information from the overall available information,
- to filter out and detect land-use changes, and
- to eliminate any possible uncertainties and sources of error.

6.3.1.2.1 Sources of data

The following data sources/sets were used:

- The Digital Basic Landscape Model (Basis-DLM) for the years 2010, 2015, 2020 and 2024
- Map of Germany's organic soils
- Hedge map of Germany produced by the Thünen Institute

The majority of the land-use information has been taken from the Basis-DLM.

The Digital Basic Landscape Model (Basis-DLM)

The Digital Basic Landscape Model (Basis–Digitale Landschaftsmodell; Basis-DLM) is the basis for Germany's Official Topographical-Cartographic Information System (Amtliches Topographisch-Kartographisches Informationssystem; ATKIS®), which is managed by the Working Committee of the Surveying Authorities of the Länder of the Federal Republic of

Germany (AdV). The ATKIS® system describes Germany's topography in terms of digital landscape and terrain models:

"The Basis-DLM uses a vector format to describe topographic objects of the landscapes and the relief of the earth's surface. Each object is assigned to a specific object type and defined in terms of its spatial position, geometric type, descriptive attributes and relations to other objects. Each object has an identification number (identifier) that is unique throughout all objects for Germany. In the Basis-DLM, spatial position is given true to scale, and independently of any representations, within the coordinate system used for land surveying. The object types contained in the DLM, and the manner in which the objects are to be formed, are defined in the ATKIS® object-type catalogue (ATKIS®-OK)" (AdV). The informational spectrum of the Basis-DLM is oriented to the contents of standard 1:25,000 topographic maps. At the same time, the Basis-DLM features greater precision of position (± 3m) for the most important point-shaped and line-shaped objects. Data of the Basis-DLM systems of the federal states are adopted by the Federal Agency for Cartography and Geodesy (BKG) and then checked, harmonised, georeferenced and processed, without any overlapping, for use within a nationally standardised Basis-DLM. The BKG also manages the data in a special database for the purposes of provision to federal authorities and other agencies.

The purpose of ATKIS® is to provide a landscape model (land cover model that is as up to date and as high-resolution as possible) of Germany, with regularly updated and expanded geometries and content. The surveying administrations of the federal states collect the data on an ongoing basis and not on a national basis as of a given cut-off date. As a result, new surveying results are continuously transmitted to the Federal Agency for Cartography and Geodesy (BKG) and integrated within ATKIS®. While five years is given as the time period within which a complete revision should be accomplished, that specification is applied very differently in the various federal states. In practice, the data for areas with vegetation cover are between one and seven years old. For areas of very high current interest, especially with regard to area changes - such as settlement and transport areas - a period of three to twelve months is prescribed for transfer into ATKIS®. The Basis-DLM version maintained and managed by the BKG is always the latest version. No history data are recorded, nor are old versions archived.

For the reporting by the Thünen Institute, this means:

- Basis-DLMs are obtained on an annual basis; the Basis-DLM for a given report year is obtained in September of that year;
- In each case, the version for the current year is archived within the institute.

Basis-DLM data sets have been available on an annual basis to the Thünen Institute only since 2005. One data set is available for the year 2000. No ATKIS® data exist for the years prior to 2000. Due to the multi-year revision cycles involved, Basis-DLM data records are used at five-year intervals to prevent the regional artefacts that can occur due to seemingly sudden massing of land-use changes in updating years.

In 2009, the Basis-DLM was adapted to a new data model. Somewhat later, the system began to be referred to as "Basis-DLM (as of 2013)". In the years 2009 to 2012, some German federal states provided data in the old model and some provided data in the new model. The Basis-DLM (as of 2013) has been used for all of Germany since 2013.

Each data set in the Basis-DLM (until 2012) comprises some 800 individual layers, with the layers differing in their degree of detail. For example, polygons with relatively low resolution (e.g, settlement areas) are found on the lowest level, while polygons with very high resolution

and rich detail (e.g. residential areas) are found on the highest level. A single record will thus contain numerous superimposed polygons that, in terms of content, can be assigned to the same LULUCF categories. All of this content, with all overlays, is put into the calculation system. As a result, data gaps occur only where the entire pertinent Basis-DLM data record contains no data. In a subsequent step, the various areas are merged with the points of the GHG sampling grid. Where a point touches several stacked areas, only a single value is chosen by way of a priority list. Where the same priorities overlap (for example, vegetation with vegetation), then that area with the lower ATKIS® identification value is selected. This method was carried out for the Basis-DLM (until 2012) from the year 2010. The Basis-DLM categories (until 2012) are assigned to the LULUCF categories using a translation table (cf. Table 341).

The new data model (Basis-DLM (as of 2013)) includes a layer designated "actual use" ("Tatsächliche Nutzung"). "All object types within this object-type area are included in the unbroken, overlap-free and complete-coverage description of the earth's surface (ground areas)". As a result, virtually no areas overlap. In general, the quality of the data has improved considerably: After use of all areas in the Basis-DLM (until 2012), about 0.05% of points cannot be assigned any information from the Basis-DLM. With the Basis-DLM (as of 2013), the corresponding figure has decreased to only 0.0003%. The Basis-DLM categories (as of 2013) are assigned to the LULUCF categories using a translation table (cf. Table 341).

Since 2024, the Basis-DLM is included pursuant to a new and somewhat more comprehensive object-type catalogue - OK 7.1.2. These categories are also assigned to the LULUCF categories using a translation table (Table 341).

The areas of linear elements like roads, hedges and flowing water bodies/ditches are derived from the Basis-DLM. These linear elements are classified. The characteristics assigned to each class buffered the linear elements in the map; this made it possible to display them on an area basis and georeferenced. Since the display of hedges in particular in the Basis-DLM is prone to gaps, a new, additional data source was used for the first time:

Germany's Hedge Map

This map was produced by the Thünen-Institute[88] and depicts the detectable hedges/linear woody structures in the farming landscape in the form of a grid dataset. The compilation of the map is based on the evaluation of nation-wide mosaics of very high-resolution geo-observation data. The evaluation is based on a deep learning approach (semantic segmentation) trained on the basis of reference data of the prevalence of hedges in Schleswig-Holstein and then applied to all of Germany's farming landscapes. The resolution of the satellite data used for the survey is 3 m x 3 m (pixel size). Since both the map of the hedges and the Basis-DLM are incomplete, the two sources are combined.

Updated map of organic soils in Germany

The "Updated map of organic soils in Germany" (Wittnebel et al., 2023) depicts Germany's organic soils and contains harmonised, geo-referenced information about soil type, characteristics and qualities of all organic soils in Germany, with or without anthropogenic imprint. The map is used for land-use recognition and the assignment of soil characteristics. The map is freely accessible at https://www.openagrar.de/receive/openagrar_mods_00087123.

[88] Authors: Javier Muro, Lukas Blickensdörfer, Axel Don, Anna Köber, Marcel Schwieder and Stefan Erasmi; publication in preparation; Thünen Institute 2024

Key for correlation of data-source and IPCC categories

The various land-use definitions used in the underlying data sources were correlated with the various LULUCF reporting categories (Table 341).

In the Basis-DLM, the catalogue of object types (OK) changed with the introduction of the new AAA model. For this reason, a new correlation table is being used for the submissions as of 2013. The six IPCC land-use categories are directly correlated with the object types used in the Basis-DLM (AAA levels) of ATKIS® (Table 341).

When creating the land-use matrix, the grid point allocation is computerised and carried out fully automatically using dedicated programmes. In support of that purpose, the allocation keys for these classification systems are included in digital form, with the result that any given grid point can always be unambiguously allocated to an object type key number and, thus, to a specific land-use category, regardless of the data source being used. The scripts for these programmes are maintained in the inventory description.

Table 341: Allocation of main object type index numbers and attributes in ATKIS® to IPCC land-use categories

ATKIS® Object-type catalogue					
Object number, AAA levels (as of 2013)	**Attribute AAA levels (as of 2024: OK 7.1.2)**	**Attribute AAA levels (as of 2013: OK 6.0.2)**	**Object number, levels (until 2012: OK 3.2)**	**Object type**	**Description/attributes pursuant to ATKIS® object-type catalogue**
IPCC category: Forest Land					
43002	VEG, all	VEG, all	4107	Forest Land	Deciduous, coniferous and mixed forest
IPCC category: Cropland					
43001	VEG 1010	VEG 1010	4101	Agriculture: Cropland	Area for cultivation of field crops (such as grain, legumes, root crops) and berries (such as strawberries) Cropland also includes rotational set-asides, permanent set-asides and areas set aside to achieve eligibility for EU compensation payments.
43001	VEG 1012	VEG 1012	4109	Agriculture: Hops	Hops
43001	VEG 1030	VEG 1030	4103	Agriculture: Horticultural land	Horticultural land is land for cultivation of vegetables, fruit and flowers, and for growing of cultivated plants.
43001	VEG 1031	VEG 1031	4109	Agriculture: Tree nursery	Tree nurseries are areas on which woody plants are grown from seeds, shoots and cuttings, and are transplanted multiple times in the process.
43001	VEG 1060	No allocation	No allocation	Agriculture: Christmas tree plantations	Christmas tree plantations are agricultural areas that are planted primarily with Christmas trees.
43001	VEG 1100	No allocation	No allocation	Agriculture: Short-rotation plantations	Short rotation plantations are areas where tree species are planted with the aim of harvesting wood at an early stage and where the stands have a rotation period of no more than 20 years.
43001	VEG 1011	VEG 1011	No allocation	Agriculture: Cropland orchards	Cropland orchards are cropland areas where fruit trees are grown.
43001	VEG 1021	VEG 1021	No allocation	Agriculture: Meadow orchards	Meadow orchards are grassland areas where fruit trees are grown.
43001	VEG 1013	No allocation	No allocation	Agriculture: Asparagus	Asparagus describes agricultural areas where asparagus is grown.
43001	VEG 1014	No allocation	No allocation	Agriculture: Hemp	Hemp describes agricultural areas where hemp is grown.
43001	VEG 1040	VEG 1040	4109	Agriculture: Vineyard	Vineyard
43001	VEG 1050	VEG 1050	4109	Agriculture: Orchards	Orchards
IPCC category: Grassland					

ATKIS® Object-type catalogue					
43001	VEG 1020	VEG 1020	4102	Agriculture: Grassland	Grassland is a grassy area that is mowed or grazed.
43001	VEG 1022	No allocation	No allocation	Agriculture: Salt meadow	Salt meadows are pastures that are flooded by the sea from time to time and where halophytic vegetation grows. Salt meadows form the natural transition between land and sea.
43001	VEG 1200	No allocation	No allocation	Agriculture: Fallow land	Fallow land describes agricultural areas that have not been farmed for some time.
43004			4104	Heath	A heath is a sandy area (typically) with certain typical shrubs and grasses, and with sparse, scrub tree cover.
43006			4106	Marsh	A marsh is a waterlogged area that is covered with water for part of the year. Areas that are wet for brief periods, after rainfall, are not considered marsh areas.
43007	FKT 1300	FKT 1300		Wasteland and vegetation-free areas: Semi-natural area	A semi-natural area is an area that is not used for crop cultivation and that is covered with grass, wild herbs and other plants.
43003			4108	Woody plants	Area covered with individual trees, groups of trees, bushes, hedges and shrubs.
43007	FKT 1200	FKT 1200		Wasteland and vegetation-free areas: Succession area	A succession area is an area that has been permanently set aside from agricultural or other existing use and that is allowed to revert to its original condition - for example, as Woody Grassland, a peatland or a heath.
54001	BWS 1100	BWS 1100		Hedge	A hedge consists of a dense row of mostly wild shrubs.
61003		BEZ ART2000 Knick		Wall hedge	Wall hedges consist of a stone wall with a hedge on top. They occur only in Schleswig-Holstein and in Lower Saxony.
IPCC category: Wetlands					
43005			4105	Peatland	Uncultivated area whose top layer consists of peaty or decomposed plant remains.
41005	AGT 4010	AGT 4010	2301	Open-pit mine: Peat extraction	
44001			5101	Natural flowing water bodies	Rivers at least 12 m wide
44004		FKT not 8300		Natural flowing water bodies	Rivers 3 m to 12 m wide, consisting of line elements
44003				Artificial flowing water bodies	Channels at least 12 m wide
		5103		Artificial flowing water bodies	Ditches 3 m to 12 m wide, consisting of line elements
44006				Natural, standing inland water bodies	Lakes
44006	BWF 2030 and BWF 2040	BWF 2030 and BWF 2040		Artificial inland water bodies	Dammed lakes (lakes with a dam, or with a dam wall no more than 10 m away)
44005			3402	Artificial inland water bodies	Harbour basin
IPCC category: Settlements					
41001 to 41010			2101-2352	Settlements	Settlement includes built-up and undeveloped areas that are characterised by human habitation or contribute to habitation.
42001 to 42016			3101-3543	Transport	Transport areas consist of areas, either with or without buildings and structures, that serve and support transports.
41002	FKT 2530 & PEG 3000	FKT 2530 & PEG 3000	2126 & PEG 1300	Settlements: Open areas with photovoltaic plants	"Power station" refers to an area with structures and other facilities used to generate electricity. "Sun" indicates that

ATKIS® Object-type catalogue					
					the power/heating station converts solar energy into another form of energy.
43007	FKT 1100	1100 FKT		Wasteland and vegetation-free areas: Area accompanying a water body	An area accompanying a water body is an area, either with or without buildings and structures, that is allocated to a watercourse.
IPCC category: Other Land					
43007	FKT 1000	FKT 1000	4120	Wasteland and vegetation-free areas: Areas without vegetation	Areas without significant vegetation cover, as a result of special soil characteristics such as unprotruding rocks, sand or ice areas.

6.3.1.2.2 Derivation of LULUCF information

The GHG sampling grid is merged with the above-described maps, and each grid point is assigned all relevant information from the maps. Then, each point is taken through a decision-tree process in which, as a rule, data from the Basis-DLM is used for the period as of 2010. Data are taken from a different year (ideally immediately before or after) only in cases in which no data for that year are available in the Basis-DLM.

The results for Forest Land are compared with the corresponding data from the National Forest Inventory (NFI). The Basis-DLM includes areas where trees grow that do not necessarily conform to the NFI's definition of "Forest Land", which is used in reporting. Nonetheless, the two data sets normally showed excellent agreement with regard to their Forest Land areas. Discrepancies amounted to less than 1%, meaning that the areas result may be considered consistent with the Forest Land definition used in reporting.

The Basis-DLM (until 2012) was expanded in a series of steps up until 2008. As a result, the available surveys for the period prior to 2008 are less extensive than later surveys. This has an impact on three categories: Wetlands, Terrestrial wetlands and Special crops, although changes in methodology also occurred in areas in other categories.

In general, derivation of land uses and land-use changes for the period 1990 to 2000 is problematic. Until the 2025 submission, this resulted in a pronounced underestimation of land-use changes for this period, which in turn led to abrupt trend changes in land developments in the year 2000.

For these reasons the time series for this report was created using Basis-DLM data from 2010, 2015, 2020 and 2024. Land use and land-use changes before 2010 are extrapolated back to 1970 using information from 2010 and 2015. First, the transition probabilities are determined for each land-use change. Next, the transition probabilities are used to select stochastic points at five-year intervals in the inventory model to which the corresponding land-use change is then assigned. This is how land use is determined artificially prior to 2010. A comparison confirmed that extrapolation provides better consistency with available statistics on land use, rather than using Corine Land Cover 1990 and 2000, as well as past versions of Basis-DLM. This applies in particular to the land development trend, but hardly at all when it comes to absolute area values. Due to the various survey methods (e.g. statistical methods (notably: exclusion limits), surveying and remote sensing) and survey scales (approx. 1:1,000-1:250,000) as well as the different survey categories/system nomenclature and corresponding compilation of individual areas, the absolute area values often exhibit major differences.

In accordance with the 2006 IPCC Guidelines, land-use changes since 1970 are taken into account. As a result, the conversion categories are already being filled with area data in a

manner that enables them, as of 1990, to reach a stable dynamic state comprising additions of new change areas and transfers of areas into relevant remaining categories.

6.3.1.3 Errors

The various sources of error involved in the sampling method employed include

- the sampling error,
- inconsistencies between definitions,
- discrepancies between Minimum Mapping Units, and
- errors occurring in georeferencing of data sets.

The error sources a) inconsistencies between definitions, b) discrepancies between Minimum Mapping Units and c) imprecise georeferencing cannot be quantified. Only the sampling error is included in the analysis of uncertainties.

6.3.1.4 Step-by-step implementation

Complete implementation of the above-described system for time-based surveys of land uses and land-use changes throughout Germany calls for extensive preliminary work and continuous supporting efforts. This includes the following:

- The various data sets for different points in time have to be acquired,
- Geometric corrections (of erroneous geometries, etc.) and checks have to be carried out,
- Conversion functions have to be written for converting the original classifications into the categorisation used here,
- The sample points have to be merged with the maps,
- The decision tree has to be programmed and adjusted as necessary depending on the available data and
- The conversion time procedures have to be programmed and adjusted as necessary depending on the available data.

The decision to use this flexible, sample-based system was made in spring 2011, in consultation with the Single National Entity (German Environment Agency - UBA) and the Federal Ministry of Food and Agriculture (BMEL), which is responsible for the forest inventories.

The decision trees for the classification years (one per year) and the “conversion time” procedures were programmed depending on the current data structure.

6.3.1.4.1 Derivation of land uses

At each sample point, data are available (cf. Chapter 6.3.1.2) that make it possible to assign the sample point to a land-use category for the years in question (2010, 2015, 2020 and 2024). The basic table is structured as follows (the table is shown here with three sampling points provided by way of example):

Table 342: Basic table for derivation of land uses

Point ID	Hedge	Roads_dlm22	Org. Soil	Gleise_DLM22	2010 DLM	DLM 2015	DLM 2020	DLM 2024	Hedge	Roads_dlm22	Org. Soil	Gleise_DLM22	2010 DLM
1	0	0	0	crop	crop	set1	set1	set1	0	0	0	crop	crop
1000	0	1	0	gra1	gra1	gra1	gra1	gra1	0	1	0	gra1	gra1
2000	1	0	0	crop	crop	crop	crop	crop	1	0	0	crop	crop

The following land-use-category codes are used in the data sets:

Table 343: Codes in the basic table

Code	Category	Subcategory
crop	$Cropland_{annual}$	$Cropland_{annual}$
croh	Special crop	Hops
crow	Special crop	Vineyards
croo	Special crop	Orchards
cros	Special crop	Short-rotation plantations
crot	Special crop	Tree nurseries
crox	Special crop	Christmas tree plantations
gra1	Grassland	Grassland (in the strict sense)
gra2	Grassland	Woody grassland
gra3	Grassland	Hedges
forl	Forest Land	Forest Land
wett	Wetlands	Terrestrial Wetlands
wetl	Wetlands	Natural standing water bodies
wetr	Wetlands	Natural flowing water bodies
wetp	Wetlands	Peat extraction
wetb	Wetlands	Artificial standing water bodies
wetd	Wetlands	Artificial flowing water bodies
wets	Wetlands	Artificial water bodies used for navigation
set1	Settlements	Buildings and open areas
set2	Settlements	Roads
set3	Settlements	Railway track beds
setp	Settlements	Photovoltaic areas
othl	Other Land	Other Land
dlm0	No information[89]	

The decision trees were applied to this basic table for the respective years 2010, 2015, 2020 and 2024. The Basis-DLM is always used, except in cases in which the Basis-DLM provides no

[89] No land-use information at this point in the Basis-DLM data

information for a given point. In these cases, gradations are relied on from a chronologically near Basis-DLM with data.

Use of the decision trees yields a further table (cf. Table 344) with, in each case, the most likely land uses per sample point and year (2010, 2015, 2020 and 2024) and the best data source.

Table 344: Most probable land use (LU) and their data sources (DB)

Point ID	LU 2010	LU 2015	LU 2020	LU 2024	DB 2010	DB 2015	DB 2020	DB 2024
1	crop	set1	set1	set1	dlm	dlm	dlm	dlm
1000	set2	set2	set2	set2	Roads_DLM22	Roads_DLM22	Roads_DLM22	Roads_DLM22
2000	gra3	gra3	gra3	gra3	Hedge	Hedge	Hedge	Hedge

(For abbreviations, see Table 343)

6.3.1.5 Results from the land-use matrix

The method described here for determining land-use changes and the resulting land-use matrix (cf. Table 345), including a 20-year transition time beginning in 1970, are compliant with reporting requirements pursuant to the UNFCCC, as set forth in the 2006 IPCC Guidelines. Table 346 shows the complete detailed land-use matrix for 2024, by way of example.

Table 345: Areas of the various land-use categories and their transitions, including a 20-year transition time

Year	4.A.1 Forest Land remaining Forest Land [ha]	4.A.2 … LUC to Forest Land [ha]	4.B.1 Cropland remaining Cropland [ha]	4.A.2 … LUC to Cropland [ha]	4.C.1 Grassland remaining Grassland [ha]	4.A.2 … LUC to Grassland [ha]	4.D.1 Wetlands remaining Wetlands [ha]	4.A.2 … LUC to Wetlands [ha]	4.E.1 Settlements remaining Settlements [ha]	4.A.2 … LUC to Settlements [ha]	4.F.1 Other Land remaining Other Land [ha]	4.F.2 … LUC to Other Land [ha]
1990	10,403,254	227,951	11,684,880	1,752,658	5,301,420	1,698,418	777,704	15,062	3,176,557	668,780	83,438	0
1991	10,411,604	228,495	11,670,450	1,745,620	5,296,665	1,689,088	777,760	15,122	3,197,150	676,148	82,020	0
1992	10,419,924	229,040	11,653,664	1,740,925	5,287,952	1,683,745	777,777	15,218	3,217,558	683,698	80,621	0
1993	10,428,234	229,587	11,634,454	1,738,664	5,275,703	1,681,932	777,784	15,320	3,237,633	691,570	79,241	0
1994	10,436,537	230,134	11,612,896	1,738,747	5,259,560	1,684,016	777,784	15,426	3,257,532	699,616	77,874	0
1995	10,444,826	230,678	11,588,824	1,741,357	5,239,431	1,690,086	777,754	15,566	3,276,942	708,135	76,523	0
1996	10,453,112	231,243	11,572,626	1,733,725	5,233,580	1,681,459	777,850	15,624	3,299,515	716,260	75,128	0
1997	10,461,370	231,806	11,553,973	1,728,534	5,223,547	1,677,042	777,884	15,739	3,321,584	724,893	73,750	0
1998	10,469,625	232,368	11,532,984	1,725,682	5,209,864	1,676,271	777,915	15,857	3,343,519	733,643	72,394	0
1999	10,477,864	232,929	11,509,545	1,725,290	5,192,609	1,679,057	777,926	16,003	3,365,007	742,840	71,052	0
2000	10,486,089	233,499	11,483,548	1,727,459	5,171,498	1,685,705	777,910	16,177	3,386,248	752,271	69,718	0
2001	10,494,302	234,088	11,464,098	1,719,757	5,164,100	1,678,822	777,991	16,305	3,410,851	761,459	68,349	0
2002	10,502,489	234,685	11,442,414	1,714,283	5,152,963	1,675,692	778,049	16,448	3,435,018	771,085	66,996	0
2003	10,510,672	235,269	11,418,500	1,711,058	5,137,717	1,676,673	778,102	16,596	3,458,891	780,981	65,663	0
2004	10,518,842	235,854	11,392,083	1,710,317	5,119,010	1,681,130	778,121	16,779	3,482,405	791,236	64,345	0
2005	10,527,000	236,444	11,363,108	1,712,140	5,096,642	1,689,243	778,147	16,964	3,505,619	801,776	63,039	0
2006	10,535,106	237,050	11,339,506	1,703,773	5,087,599	1,685,191	778,260	17,137	3,532,326	812,481	61,693	0
2007	10,543,191	237,662	11,313,374	1,697,935	5,074,709	1,684,995	778,321	17,359	3,558,656	823,551	60,369	0
2008	10,551,264	238,269	11,284,939	1,694,398	5,058,130	1,688,501	778,423	17,541	3,584,680	834,915	59,062	0
2009	10,559,328	238,873	11,253,814	1,693,546	5,037,802	1,695,762	778,451	17,789	3,610,510	846,473	57,774	0
2010	10,567,381	239,483	11,219,947	1,695,439	5,013,704	1,706,793	778,471	18,045	3,635,993	858,371	56,495	0
2011	10,575,259	233,947	11,189,330	1,686,394	5,006,768	1,708,430	778,692	18,387	3,665,818	871,808	55,289	0
2012	10,583,116	228,404	11,156,225	1,679,858	4,996,141	1,713,768	778,845	18,789	3,695,199	885,676	54,101	0
2013	10,590,969	222,855	11,120,245	1,676,192	4,981,960	1,722,678	779,027	19,158	3,724,454	899,653	52,931	0
2014	10,598,809	217,309	11,081,740	1,675,056	4,963,820	1,735,534	779,166	19,567	3,753,272	914,065	51,784	0
2015	10,606,631	211,769	11,040,183	1,676,970	4,942,499	1,751,593	779,269	20,013	3,781,941	928,602	50,652	0
2016	10,613,236	212,817	11,041,310	1,646,166	4,942,651	1,748,846	779,092	21,430	3,812,802	922,590	49,182	0
2017	10,619,825	213,871	11,041,149	1,616,670	4,940,933	1,747,956	778,845	22,911	3,843,403	916,819	47,740	0
2018	10,626,410	214,909	11,039,903	1,588,253	4,937,212	1,749,089	778,586	24,414	3,873,675	911,359	46,312	0
2019	10,632,983	215,942	11,037,324	1,561,158	4,932,006	1,751,734	778,315	25,926	3,903,464	906,365	44,905	0
2020	10,639,557	216,967	11,033,944	1,534,864	4,924,247	1,756,947	778,012	27,468	3,932,903	901,702	43,511	0
2021	10,645,645	217,141	11,044,599	1,484,266	4,946,036	1,740,368	778,155	31,689	3,968,157	890,984	43,082	0
2022	10,651,726	217,301	11,054,009	1,434,909	4,966,739	1,724,931	778,267	35,940	4,003,139	880,488	42,673	0

	4.A.1 Forest Land remaining Forest Land	4.A.2 … LUC to Forest Land	4.B.1 Cropland remaining Cropland	4.A.2 … LUC to Cropland	4.C.1 Grassland remaining Grassland	4.A.2 … LUC to Grassland	4.D.1 Wetlands remaining Wetlands	4.A.2 … LUC to Wetlands	4.E.1 Settlements remaining Settlements	4.A.2 … LUC to Settlements	4.F.1 Other Land remaining Other Land	4.F.2 … LUC to Other Land
2023	10,657,793	217,456	11,062,431	1,386,556	4,986,374	1,710,562	778,315	40,252	4,037,842	870,264	42,277	0
2024	10,663,852	217,608	11,069,768	1,339,305	5,004,400	1,697,826	778,286	44,633	4,072,201	860,354	41,889	0

Table 346: Land-use matrix for 2024: In each case, the number on the diagonal shows the area remaining in the same category for the column in question. The other table cells show the relevant land-use changes (including 20-year transition times)

Initial*Final*	*Forest Land*	*Cropland$_{annual}$*	*Cropland perennial*	*Grassland (in the strict sense)*	*Woody Grassland & Hedges*	*Terrestrial Wetlands*	*Water bodies*	*Peat extraction*	*Settlements*	*Traffic routes*	*Photovoltaics*	*Other Land*	Σ reductions	Σ additions - Σ reductions
Forest Land	**10,663,852**	0	728	0	95	8,187	0	127	78,337	0	0	0	87,474	130,134
Cropland$_{annual}$	104	**10,627,213**	47,815	1,459,583	39,240	443	0	409	377,185	0	16,517	0	1,941,296	- 583,039
Cropland perennial	2	47,688	**347,052**	24,960	8,873	18	0	35	14,104	0	61	0	95,741	- 19,190
Grassland (in the strict sense)	47,886	1,226,982	14,359	**4,271,121**	131,345	26,217	0	2,138	309,767	0	7,669	0	1,766,363	7,364
Woody Grassland & Hedges	146,089	38,751	11,786	156,937	**444,997**	6,746	0	20	51,150	0	1,324	0	412,803	- 200,422
Terrestrial Wetlands	4,624	870	15	6,360	1,305	**99,903**	0	869	443	0	1	0	14,487	38,710
Water bodies	0	0	0	0	0	0	**659,743**	0	0	0	0	0	0	0
Peat extraction	69	3,063	2	1,305	46	11,342	0	**6,429**	161	0	66	0	16,054	- 12,407
Settlements	15,098	40,751	1,843	117,779	27,831	243	0	49	**2,899,007**	0	8,872	0	212,466	622,196
Traffic routes	0	0	0	0	0	0	0	0	0	**1,163,504**	0	0	0	0
Photovoltaics	0	0	0	0	0	0	0	0	0	0	**818**	0	0	34,564
Other Land	3,736	152	3	6,803	3,646	1	0	0	3,515	0	54	**41,889**	17,910	- 17,910
Σ additions	217,608	1,358,257	76,551	1,773,727	212,381	53,197	0	3,647	834,662	0	34,564	0		
Σ Land-use category	10,881,460	11,985,470	423,603	6,044,848	657,378	153,100	659,743	10,076	3,733,669	1,163,504	35,382	41,889		
Area of **Germany**	35,790,122													

Table 347: Annual areas of land-use changes used as a basis for inventory calculations (20-year transition period)

Land-use change [hectares per year]	1990-2000	2001-2005	2006-2010	2011-2015	2016-2020	2021-2024
… to Forest Land						
$Cropland_{annual}$ to Forest Land	7	7	7	4	2	9
Hops to Forest Land	0	0	0	0	0	0
Vineyards to Forest Land	0	0	0	0	0	0
Orchards to Forest Land	0	0	0	0	0	0
Tree nurseries to Forest Land	0	0	0	0	0	0
Christmas tree plantations to Forest Land	0	0	0	0	0	0
Short-rotation plantations to Forest Land	0	0	0	0	0	0
Grassland (in the strict sense) to Forest Land	2,021	2,082	2,119	1,086	3,679	2,848
Woody Grassland to Forest Land	8,020	8,173	8,269	4,189	8,213	8,566
Hedges to Forest Land	0	0	0	0	0	77
Terrestrial Wetlands to Forest Land	188	199	214	115	289	335
Peat extraction to Forest Land	4	4	4	2	5	3
Settlements to Forest Land	1,278	1,297	1,306	661	521	343
Other Land to Forest Land	281	284	287	146	228	38
… to $Cropland_{annual}$						
Forest Land to $Cropland_{annual}$	0	0	0	0	0	0
Hops to $Cropland_{annual}$	338	336	335	334	217	72
Vineyards to $Cropland_{annual}$	128	125	124	122	155	119
Orchards to $Cropland_{annual}$	983	962	945	924	1,543	1,697
Tree nurseries to $Cropland_{annual}$	0	0	0	0	13	0
Christmas tree plantations to $Cropland_{annual}$	1,326	1,296	1,275	1,253	930	899
Short-rotation plantations to $Cropland_{annual}$	0	0	0	0	0	0
Grassland (in the strict sense) to $Cropland_{annual}$	92,385	91,335	90,584	89,716	52,430	42,856
Woody Grassland to $Cropland_{annual}$	2,098	2,059	2,022	1,972	2,579	1,925
Hedges to $Cropland_{annual}$	0	0	0	0	0	183
Terrestrial Wetlands to $Cropland_{annual}$	34	36	36	38	91	34
Peat extraction to $Cropland_{annual}$	150	156	160	164	168	162
Settlements to $Cropland_{annual}$	2,421	2,367	2,324	2,274	3,200	2,124
Photovoltaic areas to $Cropland_{annual}$	0	0	0	0	0	0
Other Land to $Cropland_{annual}$	8	8	8	9	48	1
… to Hops						
Forest Land to Hops	0	0	0	0	0	0
$Cropland_{annual}$ to Hops	330	335	338	343	544	246
Vineyards to Hops	0	0	0	0	0	1
Orchards to Hops	7	7	6	6	5	40
Tree nurseries to Hops	0	0	0	0	0	0
Christmas tree plantations to Hops	1	1	1	1	1	0
Short-rotation plantations to Hops	0	0	0	0	0	0
Grassland (in the strict sense) to Hops	34	35	36	39	33	33
Woody Grassland to Hops	1	1	1	2	4	2
Hedges to Hops	1	1	1	1	2	1
Terrestrial Wetlands to Hops	0	0	0	0	0	0
Peat extraction to Hops	0	0	0	0	0	0
Settlements to Hops	1	1	1	1	1	1
Photovoltaic areas to Hops	0	0	0	0	0	0
Other Land to Hops	0	0	0	0	0	0
… to Vineyards						

Land-use change [hectares per year]	1990-2000	2001-2005	2006-2010	2011-2015	2016-2020	2021-2024
Forest Land to Vineyards	0	0	0	0	0	0
$Cropland_{annual}$ to Vineyards	220	223	226	232	309	369
Hops to Vineyards	0	0	0	0	0	0
Orchards to Vineyards	42	43	45	49	80	175
Tree nurseries to Vineyards	0	0	0	0	0	0
Christmas tree plantations to Vineyards	2	2	2	3	1	1
Short-rotation plantations to Vineyards	0	0	0	0	0	0
Grassland (in the strict sense) to Vineyards	100	100	101	102	140	144
Woody Grassland to Vineyards	38	38	38	39	68	81
Hedges to Vineyards	1	1	1	1	2	2
Terrestrial Wetlands to Vineyards	0	0	0	0	0	0
Peat extraction to Vineyards	0	0	0	0	0	0
Settlements to Vineyards	13	14	15	19	20	27
Photovoltaic areas to Vineyards	0	0	0	0	0	0
Other Land to Vineyards	0	0	0	0	0	0
… to Orchards						
Forest Land to Orchards	0	0	0	0	0	0
$Cropland_{annual}$ to Orchards	1,116	1,123	1,128	1,134	1,392	1,436
Hops to Orchards	4	4	4	4	19	6
Vineyards to Orchards	20	20	19	18	24	19
Tree nurseries to Orchards	0	0	0	0	0	0
Christmas tree plantations to Orchards	137	135	135	137	100	170
Short-rotation plantations to Orchards	0	0	0	0	0	0
Grassland (in the strict sense) to Orchards	426	416	407	400	641	376
Woody Grassland to Orchards	64	63	61	61	78	53
Hedges to Orchards	4	5	5	6	12	2
Terrestrial Wetlands to Orchards	0	0	0	0	1	1
Peat extraction to Orchards	0	0	0	0	0	1
Settlements to Orchards	94	92	90	89	59	31
Photovoltaic areas to Orchards	0	0	0	0	0	0
Other Land to Orchards	0	0	0	0	0	0
… to Tree nurseries						
Forest Land to Tree nurseries	0	0	0	0	0	0
$Cropland_{annual}$ to Tree nurseries	837	794	815	977	921	683
Hops to Tree nurseries	0	0	0	0	0	0
Vineyards to Tree nurseries	2	2	2	2	4	1
Orchards to Tree nurseries	57	50	47	51	53	70
Christmas tree plantations to Tree nurseries	0	0	0	0	0	0
Short-rotation plantations to Tree nurseries	0	0	0	0	0	0
Grassland (in the strict sense) to Tree nurseries	248	246	270	370	328	195
Woody Grassland to Tree nurseries	344	414	607	1,198	435	198
Hedges to Tree nurseries	0	0	0	0	12	14
Terrestrial Wetlands to Tree nurseries	1	1	1	1	1	0
Peat extraction to Tree nurseries	0	0	0	0	0	0
Settlements to Tree nurseries	30	26	25	26	76	63
Photovoltaic areas to Tree nurseries	0	0	0	0	0	0
Other Land to Tree nurseries	0	0	0	0	0	0
… to Christmas tree plantations						
Forest Land to Christmas tree plantations	0	0	0	0	0	0

Land-use change [hectares per year]	1990-2000	2001-2005	2006-2010	2011-2015	2016-2020	2021-2024
$Cropland_{annual}$ to Christmas tree plantations	0	0	0	0	0	0
Hops to Christmas tree plantations	0	0	0	0	0	0
Vineyards to Christmas tree plantations	0	0	0	0	0	0
Orchards to Christmas tree plantations	0	0	0	0	0	0
Tree nurseries to Christmas tree plantations	0	0	0	0	0	0
Short-rotation plantations to Christmas tree plantations	0	0	0	0	0	0
Grassland (in the strict sense) to Christmas tree plantations	0	0	0	0	0	0
Woody Grassland to Christmas tree plantations	0	0	0	0	0	0
Hedges to Christmas tree plantations	0	0	0	0	0	0
Terrestrial Wetlands to Christmas tree plantations	0	0	0	0	0	0
Peat extraction to Christmas tree plantations	0	0	0	0	0	0
Settlements to Christmas tree plantations	0	0	0	0	0	0
Photovoltaic areas to Christmas tree plantations	0	0	0	0	0	0
Other Land to Christmas tree plantations	0	0	0	0	0	0
… to Short-rotation plantations						
Forest Land to Short-rotation plantations	1	6	25	120	0	0
$Cropland_{annual}$ to Short-rotation plantations	7	42	150	558	56	96
Hops to Short-rotation plantations	0	0	0	0	0	0
Vineyards to Short-rotation plantations	0	0	0	0	0	0
Orchards to Short-rotation plantations	0	0	0	0	0	0
Tree nurseries to Short-rotation plantations	0	0	0	0	0	0
Christmas tree plantations to Short-rotation plantations	0	0	1	3	0	0
Grassland (in the strict sense) to Short-rotation plantations	0	2	10	44	92	112
Woody Grassland to Short-rotation plantations	0	0	0	1	0	0
Hedges to Short-rotation plantations	0	0	0	0	0	0
Terrestrial Wetlands to Short-rotation plantations	0	0	0	0	0	0
Peat extraction to Short-rotation plantations	0	0	0	0	0	0
Settlements to Short-rotation plantations	0	0	0	0	0	0
Photovoltaic areas to Short-rotation plantations	0	0	0	0	0	0
Other Land to Short-rotation plantations	0	0	0	0	0	0
… to Grassland (in the strict sense)						
Forest Land to Grassland (in the strict sense)	0	0	0	0	0	0
$Cropland_{annual}$ to Grassland (in the strict sense)	94,405	95,705	98,096	102,699	69,977	69,067
Hops to Grassland (in the strict sense)	17	17	17	18	26	19
Vineyards to Grassland (in the strict sense)	179	176	174	174	233	220
Orchards to Grassland (in the strict sense)	827	869	920	1,003	913	1,251
Tree nurseries to Grassland (in the strict sense)	0	0	0	0	0	0

Land-use change [hectares per year]	1990-2000	2001-2005	2006-2010	2011-2015	2016-2020	2021-2024
Christmas tree plantations to Grassland (in the strict sense)	251	243	238	234	328	302
Short-rotation plantations to Grassland (in the strict sense)	0	0	0	0	0	0
Woody Grassland to Grassland (in the strict sense)	6,650	6,583	6,574	6,621	10,058	14,570
Hedges to Grassland (in the strict sense)	0	0	0	0	0	143
Terrestrial Wetlands to Grassland (in the strict sense)	267	259	251	243	420	625
Peat extraction to Grassland (in the strict sense)	76	74	73	72	130	84
Settlements to Grassland (in the strict sense)	6,397	6,282	6,213	6,157	9,047	8,812
Photovoltaic areas to Grassland (in the strict sense)	0	0	0	0	0	0
Other Land to Grassland (in the strict sense)	378	374	371	368	682	296
… to Woody Grassland						
Forest Land to Woody Grassland	0	0	0	0	86	0
$Cropland_{annual}$ to Woody Grassland	3,010	2,854	2,721	2,678	2,999	2,279
Hops to Woody Grassland	0	0	0	0	0	0
Vineyards to Woody Grassland	98	101	104	110	171	71
Orchards to Woody Grassland	209	210	211	224	506	383
Tree nurseries to Woody Grassland	0	0	0	0	0	0
Christmas tree plantations to Woody Grassland	81	74	68	66	99	78
Short-rotation plantations to Woody Grassland	0	0	0	0	0	0
Grassland (in the strict sense) to Woody Grassland	9,625	9,299	9,040	9,264	11,483	8,313
Hedges to Woody Grassland	0	0	0	0	0	29
Terrestrial Wetlands to Woody Grassland	75	73	69	71	130	118
Peat extraction to Woody Grassland	8	8	7	8	7	4
Settlements to Woody Grassland	1,835	1,728	1,640	1,624	2,472	2,177
Photovoltaic areas to Woody Grassland (in the strict sense)	0	0	0	0	0	0
Other Land to Woody Grassland	487	429	388	365	268	48
… to Hedges						
Forest Land to Hedges	0	0	0	0	0	11
$Cropland_{annual}$ to Hedges	0	0	0	0	0	169
Hops to Hedges	2	2	2	3	2	1
Vineyards to Hedges	2	2	2	3	2	3
Orchards to Hedges	9	9	9	12	21	17
Tree nurseries to Hedges	0	0	0	0	0	0
Christmas tree plantations to Hedges	21	22	22	25	21	14
Short-rotation plantations to Hedges	0	0	0	0	0	0
Grassland (in the strict sense) to Hedges	0	0	0	0	1	98
Woody Grassland to Hedges	0	0	0	0	0	0
Terrestrial Wetlands to Hedges	0	0	0	0	0	1
Peat extraction to Hedges	0	0	0	0	0	0
Settlements to Hedges	0	0	0	0	0	25
Photovoltaic areas to Hedges	0	0	0	0	0	0
Other Land to Hedges	0	0	0	0	0	0
… to Terrestrial Wetlands						
Forest Land to Terrestrial Wetlands	124	137	153	191	411	1,109
$Cropland_{annual}$ to Terrestrial Wetlands	18	20	21	24	23	55
Hops to Terrestrial Wetlands	0	0	0	0	0	0

Land-use change [hectares per year]	1990-2000	2001-2005	2006-2010	2011-2015	2016-2020	2021-2024
Vineyards to Terrestrial Wetlands	0	0	0	0	0	0
Orchards to Terrestrial Wetlands	1	1	1	1	0	0
Tree nurseries to Terrestrial Wetlands	0	0	0	0	0	0
Christmas tree plantations to Terrestrial Wetlands	0	0	0	0	0	2
Short-rotation plantations to Terrestrial Wetlands	0	0	0	0	0	0
Grassland (in the strict sense) to Terrestrial Wetlands	423	484	540	647	1,483	3,614
Woody Grassland to Terrestrial Wetlands	109	126	143	172	394	825
Hedges to Terrestrial Wetlands	0	0	0	0	0	3
Peat extraction to Terrestrial Wetlands	172	174	176	178	443	1,849
Settlements to Terrestrial Wetlands	7	7	7	8	21	32
Photovoltaic areas to Terrestrial Wetlands	0	0	0	0	0	0
Other Land to Terrestrial Wetlands	1	1	0	0	0	0
… to Peat extraction						
Forest Land to Peat extraction	8	8	8	8	8	11
$Cropland_{annual}$ to Peat extraction	49	48	47	46	47	25
Hops to Peat extraction	0	0	0	0	0	0
Vineyards to Peat extraction	0	0	0	0	0	0
Orchards to Peat extraction	0	0	0	0	0	0
Tree nurseries to Water bodies	0	0	0	0	0	0
Christmas tree plantations to Water bodies	1	1	1	1	6	1
Short-rotation plantations to Water bodies	0	0	0	0	0	0
Grassland (in the strict sense) to Peat extraction	198	194	191	187	216	88
Woody Grassland to Peat extraction	1	1	1	1	2	3
Hedges to Peat extraction	0	0	0	0	0	0
Terrestrial Wetlands to Peat extraction	80	78	77	75	122	83
Settlements to Peat extraction	7	7	7	7	31	5
Other Land to Peat extraction	0	0	0	0	0	0
… to Settlements						
Forest Land to Settlements	2,828	3,125	3,336	3,579	4,806	4,854
$Cropland_{annual}$ to Settlements	21,034	23,428	25,169	27,157	13,484	12,165
Hops to Settlements	9	10	10	12	6	7
Vineyards to Settlements	69	76	80	86	74	86
Orchards to Settlements	441	484	512	544	459	469
Tree nurseries to Settlements	0	0	0	0	0	0
Christmas tree plantations to Settlements	126	140	149	161	163	115
Short-rotation plantations to Settlements	0	0	0	0	0	0
Grassland (in the strict sense) to Settlements	14,182	15,660	16,720	17,920	16,928	14,968
Woody Grassland to Settlements	2,107	2,316	2,463	2,633	2,796	2,960
Hedges to Settlements	0	0	0	0	0	45
Terrestrial Wetlands to Settlements	13	15	17	21	133	31
Peat extraction to Settlements	4	5	5	6	14	16
Photovoltaic areas to Settlements	0	0	0	0	0	0
Other Land to Settlements	217	240	254	273	200	23
... to Photovoltaic areas						
Forest Land to Photovoltaic areas	2,828	3,125	3,336	3,579	4,806	4,854
$Cropland_{annual}$ to Photovoltaic areas	21,034	23,428	25,169	27,157	13,484	12,165
Hops to Photovoltaic areas	9	10	10	12	6	7

Land-use change [hectares per year]	1990-2000	2001-2005	2006-2010	2011-2015	2016-2020	2021-2024
Vineyards to Photovoltaic areas	69	76	80	86	74	86
Orchards to Photovoltaic areas	441	484	512	544	459	469
Tree nurseries to Photovoltaic areas	0	0	0	0	0	0
Christmas tree plantations to Photovoltaic areas	126	140	149	161	163	115
Short-rotation plantations to Photovoltaic areas	0	0	0	0	0	0
Grassland (in the strict sense) to Photovoltaic areas	14,182	15,660	16,720	17,920	16,928	14,968
Woody Grassland to Photovoltaic areas	2,107	2,316	2,463	2,633	2,796	2,960
Hedges to Photovoltaic areas	0	0	0	0	0	45
Terrestrial Wetlands to Photovoltaic areas	13	15	17	21	133	31
Peat extraction to Photovoltaic areas	4	5	5	6	14	16
Settlements to Photovoltaic areas	0	0	0	0	0	0
Other Land to Photovoltaic areas	217	240	254	273	200	23

6.3.1.6 Verification

For the inventory, the land-use categories were selected so as to be in accordance with the relevant definitions pursuant to the UNFCCC and the IPCC. In addition to the Basis-DLM from ATKIS®, which serves as the database for the German inventory, there are other independent systems for surveying land areas (unfortunately, it is not possible to use the German InVeKoS data (IACS) in the present context). There is no system, however, that shows land-use changes in a georeferenced format. As a result, verification always has to be carried out by comparing area sums for land-use categories. Data sets used for comparison:

- Area survey based on the type of actual use involved (survey on the basis of the automatic real estate cadastre and the Basis-DLM database of ATKIS®, with various post-processing steps (such as conversion of linear elements into areas); official statistics Statistisches Bundesamt (FS 3, R 3.1.2))
- Agricultural-structure survey (ASE; questionnaire-based survey; agricultural statistics) (Statistisches Bundesamt, FS 3, R 3.1.2)
- Sampling grid of the Agricultural Soil Inventory (Jacobs et al., 2018)

These data sources can be used only to a very limited degree for verification purposes, since

- different export formats are involved: statistical data vs. a map with high spatial resolution. As a result, comparison is restricted to area sums. Land-use changes cannot be derived from the data available in statistics.
- They have differing definitions for important land-use categories - especially for agricultural areas, settlements and other land
- They differ widely in their data collection methods - for example, they exhibit
  - differences of survey scope
  - differences in their spatial resolution
  - differences in their approach: statistical approach vs. wall-to-wall approach (surveying, remote sensing)
  - differences of focus: land cover, land use or a mixed form thereof

- exclusion limits and criteria
- differences in the ways linear elements are recorded and displayed
- differences in the periodicity of their surveys, etc.

As a result, the various survey systems differ – widely, in some cases – in their area data for the same land-use categories. These discrepancies can exceed 10% and have been known for a long time, but are retained in order to maintain consistent time series in each data set. Without being manipulated, the results yielded by the different survey systems hardly lend themselves to comparison on an absolute basis. For this reason, an additional criterion was used for comparison across survey systems: the development of area sums in individual land-use categories since 2000 in the various survey systems and the pertinent trends. Comparisons with this criterion showed excellent agreement between the results of the area surveys and the corresponding values in the Basis-DLM. Consequently, area surveys based on the type of actual use involved may be considered consistent with the corresponding data in the inventory.

The three surveys can be compared only with respect to the total agricultural area involved. All three show the applicable trend very accurately. A comparison of individual aspects of the agricultural area, between the agricultural statistics (ASE) and the corresponding values in the land-use matrix (from the Basis-DLM in AKTIS®) on which the inventory is based, shows a considerably more diffuse picture at both national and federal state levels. Along with outstanding agreement in the trend, sharp discrepancies in the curve progressions are also apparent. These discrepancies are clearly seen to depend on the numbers of areas that are subject to exclusion criteria in the relevant reference areas in the official statistics.

This was confirmed by an additional test. In it, data of the Basis-DLM were compared with data of the German Agricultural Soil Inventory (BZE-LW) (Jacobs et al., 2018) and with data of the Agricultural Structural Survey (ASE) (Statistisches Bundesamt, FS 3, R 3.1.2). The BZE-LW used a nationwide, systematic, complete-coverage sampling grid (8 x 8 km) to survey soil quality on agriculturally used land. The land uses involved were verified on site, for all points of the grid. Differences between the Agricultural Soil Inventory (BZE-LW) and the Basis-DLM arise solely through the survey methods used. Whereas the Agricultural Soil Inventory explicitly lists areas with grassland crop rotation as such and then, in post-processing, assigns these areas completely to Cropland (in the ASE, such areas are mapped as Cropland), the Basis-DLM records the current use – i.e. either Grassland or Cropland – at the time of the survey. When the Grassland values/Cropland values of the Basis-DLM are adjusted to the relevant values in the Agricultural Soil Survey with suitable area offsets in the pertinent other category, the two survey systems' results show excellent agreement, while the Agricultural Structure Survey tends to underestimate the agricultural area, especially with regard to Cropland (as a result of exclusion criteria, Table 348). With regard to the small difference between the total area represented in the Agricultural Soil Survey and that represented in the Basis-DLM, it should be noted that statistical survey systems with relatively coarse resolution often overestimate the sizes of small areas (cf. Jacobs et al. (2018)).

Table 348: Distribution of agriculturally used land areas pursuant to the German Agricultural Soil Inventory (BZE-LW), the Digital Basic Landscape Model of ATKIS® (Basis-DLM) and the Agricultural Structural Survey (ASE). The reference area is the total area covered by the BZE-LW, in [%]

	BZE-LW	B-DLM_GL_an	B-DLM_AL_an	ASE
Cropland	71.9	71.0	71.9	59.6
Grassland	26.4	26.4	25.5	23.5
Special crops	1.6	1.3	1.3	1.0
Total area represented	100.0	98.8	98.8	84.1

6.3.2 Information about approaches used in connection with natural disturbances, if applicable

Germany did not select the option "natural disturbances." Natural disturbances that occur are not considered separately; instead, they enter into the change calculations for the relevant pools. For this reason, no relevant information is available for this chapter.

6.3.3 Information about the approaches used in reporting on wood products

Germany uses the production approach to estimate CO_2 emissions and their removals in HWPs. Additional information is presented in Chapter 6.10.

6.4 Forest Land (4.A)

6.4.1 Category description (4.A)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
L/T	4 A, Forest Land	0	CO_2	-26,920.55	-2.09	1,648.08	0.24	-106.12
-/-	4 A, Forest Land	0	CH_4	32.44	0.01	26.91	0.01	-17.04
-/-/2	4 A, Forest Land	0	N_2O	435.49	0.04	465.46	0.07	6.88

Gas	Pool	Method used	Source for the activity data	Emission factors used
CO_2	Mineral soils	Tier 3	NS/M	CS/M
N_2O	Mineral soils	Tier 3	NS/M	CS/M
CO_2	Organic soil	Tier 2	NS/M	D
N_2O	Organic soil	Tier 2	NS/M	D
CH_4	Organic soil	Tier 2	NS/M	D
CO_2	Biomass	Tier 3	NS/M	CS/M
CO_2	Dead wood	Tier 3	NS/M	CS
CO_2	Litter	Tier 3	NS/M	CS/M
N_2O	Forest fire	Tier 2	Q	CS/D
CH_4	Forest fire	Tier 2	Q	CS/D

The categories Forest Land remaining Forest Land (4.A.1) and Land converted to Forest Land (4.A.2) are key categories for CO_2 emissions and removals in terms of emissions level and trend, and key categories for N_2O pursuant to Approach 2 analysis.

In the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006a) and in the official Common Reporting Format (CRF) tables for GHG inventories submitted to the UNFCCC Secretariat, the category Forest Land is subdivided into Forest Land remaining Forest Land and Land converted to Forest Land. Land converted to Forest Land occurs as a result of succession, reforestation and afforestation on land previously used for other purposes. Pursuant to the 2006 IPCC Guidelines, when these land-use changes occur, calculations must take a 20-year conversion period into account on the basis of data as of the year 1970 (cf. Chapter 6.3.1). Consequently, before it can be placed in the category Forest Land remaining Forest Land, Land converted to Forest Land has to remain in the relevant conversion category for 20 years. Forest Land remaining Forest Land refers to a) areas that, in the year for which the inventory is being prepared, remain Forest Land, and b) areas that, at the end of a 20-year conversion period, are removed from the relevant conversion category (Land converted to Forest Land (4.A.2)) and added to the category Forest Land remaining Forest Land.

Reporting in the category *Forest Land* covers CO_2 emissions/removals from mineral and organic soils, above-ground and below-ground biomass, litter, dead wood and wildfires. It also covers nitrous oxide emissions from wildfires, from drainage of organic soils and from mineralisation in mineral soils, and it covers methane emissions from wildfires and from drainage of organic soils.

In 2024, the total emissions from forests amounted to 2,141 kt CO_2 equivalents. Table 349 lists the emissions for the category Forest Land, by pools and GHG, and with the pertinent uncertainties included.

Table 349: Emissions in the category Forest Land for the year 2024

Category	Gas	Emission	2.5% percentile	97.5% percentile	2.5% percentile	97.5% percentile
		[kt CO_2-eq.]			%	
$Forest_{total}$ [1]		2,140.5	1,881.1	2,458.4	12.12	14.85
Mineral soils	CO_2 [2]	2,175.0	1,416.3	3,358.1	34.88	54.4
	$N_2O_{indirect}$ [3]	63.5	0.1	171.5	99.9	170.27
	N_2O_{direct} [3]	144.2	36.1	282.3	74.97	95.77
Organic soils	CO_2 [2]	2,995.6	2,411.5	3,678.9	19.5	22.81
	CH_4 [4]	24.8	8.0	51.1	67.59	106.23
	N_2O [4]	256.7	0.3	536.9	99.9	109.2
Biomass	CO_2 [2]	1,773.0	1,632.3	1,913.9	7.94	7.94
Litter	CO_2 [2]	IE	IE	IE	IE	IE
Dead wood	CO_2 [2]	-5,295.6	-4,002.1	-6,589.0	24.43	24.43
Forest fires	CO_2 [5]	IE	IE	IE	IE	IE
	CH_4 [5]	2.1	0.38	3.89	82.12	82.12
	N_2O [5]	1.1	0.48	1.76	57.01	57.01

1 Sum of the emissions from CRT tables 4.A, 4.(II).A, 4.(III).A, 4.(IV).A

2 CRT Table 4.A

3 CRT Table 4.(III).A

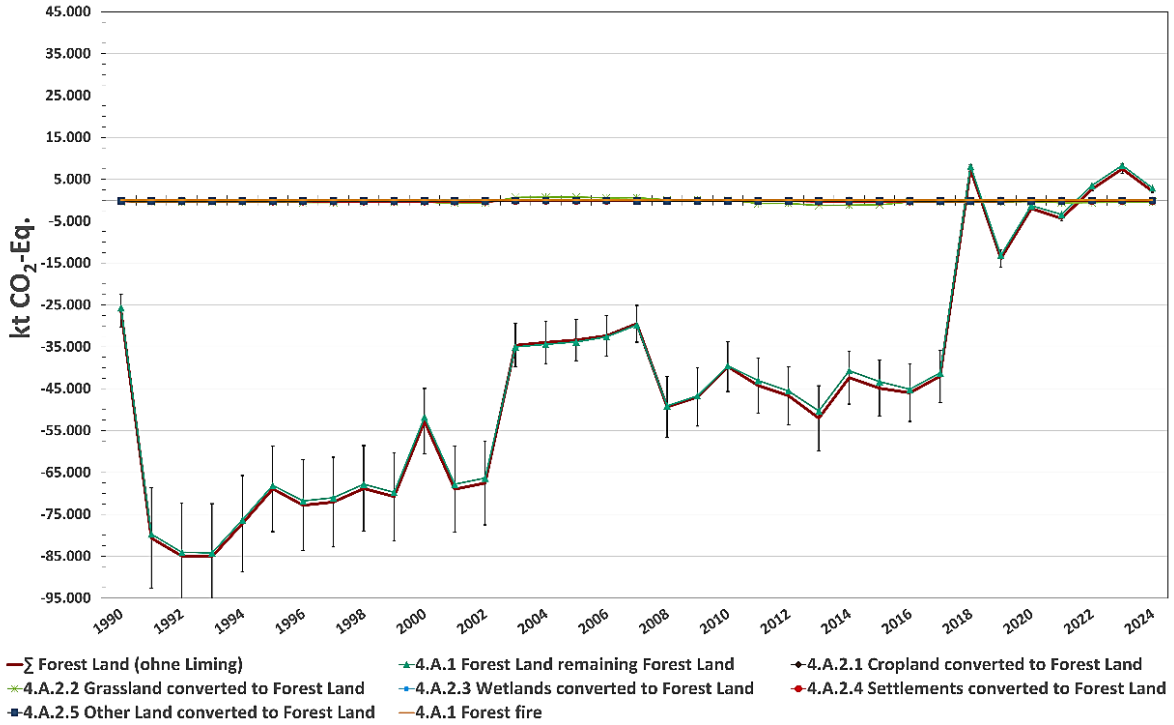
4 CRT Table 4.(II).A

5 CRT Table 4.(IV).A

In the category Forest Land (2024), the most important factor for removals is the pool dead wood (-5,295.6 kt CO_2-eq.). The sources are the pools biomass (1,773.0 kt CO_2-eq.), mineral soils

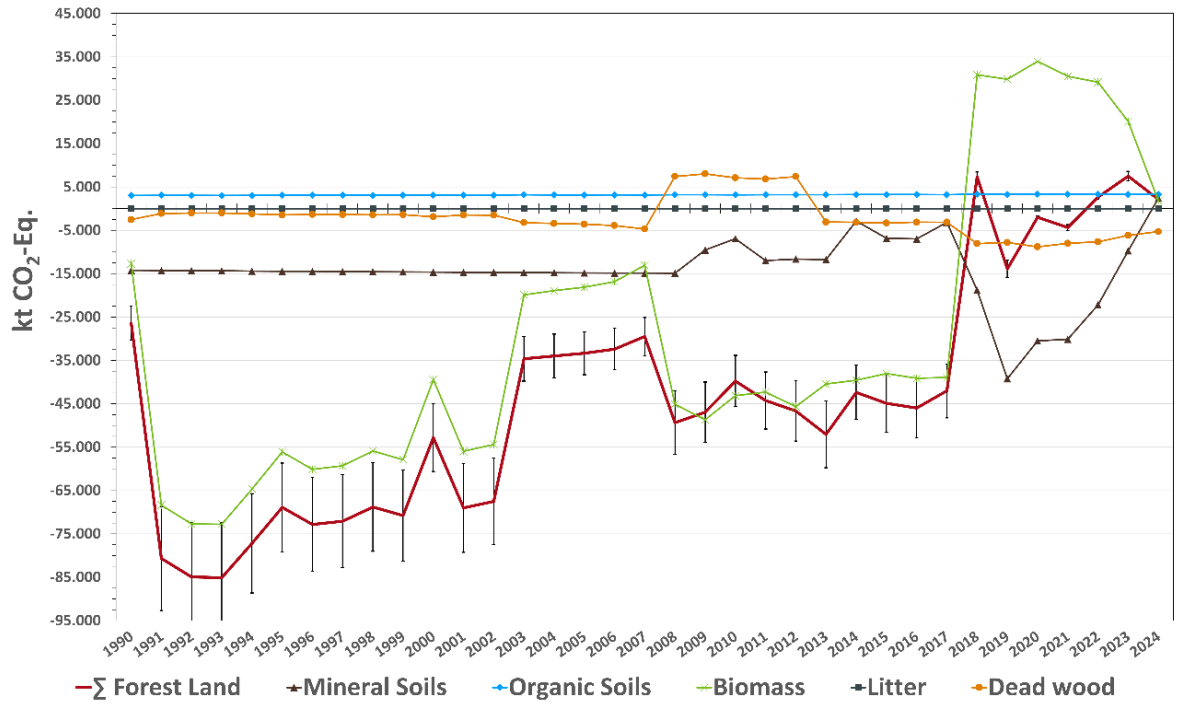
including litter (IE) (2,382.7 kt CO_2-eq.) and organic soils (3,277.0 kt CO_2-eq.). Forest fires contribute only a small share of emissions, at 3.3 kt CO_2-eq.

Figure 78: GHG emissions (sum of CO_2, CH_4 and N_2O) [kt CO_2-eq.] as a result of land use and land-use change from Forest Land, 1990-2024, by subcategory



Source: own illustration, Thünen-Institut

Figure 79: GHG emissions (sum of CO_2, CH_4 and N_2O) [kt CO_2-eq.] as a result of land use and land-use change from Forest Land, 1990-2024, by pool



Source: own illustration, Thünen-Institut

6.4.2 Methodological issues (4.A)

6.4.2.1 Sources of data

The following data sources were used to determine forest areas and land-use changes that have occurred; to estimate the relevant emission factors for soil, biomass, litter and dead wood; to calculate carbon stocks and stock changes at various times and over various periods; and to calculate emissions from wildfires, drainage and mineralisation:

- National Forest Inventory 1987 (NFI 1987)
- National Forest Inventory 2002 (NFI 2002)
- National Forest Inventory 2012 (NFI 2012)
- National Forest Inventory 2022 (NFI 2022)
- Inventory Study 2008 (Inventurstudie; IS08)
- Carbon Inventory 2017 (CI 2017)
- Datenspeicher Waldfonds (Forest Fund Database)
- Logging statistics of the Thünen Institute of Wood Research (also used for HWP)
- Forest Soil Inventory I (Bodenzustandserhebung im Wald I; BZE I-Wald)
- Forest Soil Inventory II (Bodenzustandserhebung im Wald II; BZE II-Wald)
- Official topographic-cartographic information system (Amtliches Topographisch-Kartographisches Informationssystem) (ATKIS®)

- CORINE Land Cover (CLC)
- Soil map for the Federal Republic of Germany 1:1,000,000 (Bodenübersichtskarte der Bundesrepublik Deutschland; BÜK 1000)
- Map of Germany's organic soils (Wittnebel et al., 2023)
- Forest-fire statistics of the Federal Republic of Germany
- Climate data of the German Meteorological Service

6.4.2.1.1 National Forest Inventory and intermediary inventories, Forest Fund Database and logging data

The National Forest Inventory surveys the state of forests, and of forest production potential, on a large scale throughout Germany, using a standardised sampling procedure. The National Forest Inventory is a terrestrial sampling inventory that uses permanently marked sample points in a 4 km x 4 km basic grid whose resolution has been increased on a regional basis at the request of the federal states[90]. The first National Forest Inventory (NFI 1987) covered only the territory of the Federal Republic of Germany, in its pre-1990 borders, and West Berlin. It was carried out in the period 1986 to 1989 (sample year 1987). The second National Forest Inventory (NFI 2002) was carried out in the period 2001 to 2003 (sample year 2002), as a repeat inventory in the old German federal states and as a first inventory in the new German federal states (BMELV, 2005; Polley, 2001). The surveys of the third National Forest Inventory (NFI 2012) were carried out from 2011 to 2012 (sample year 2012), and those of the fourth National Forest Inventory (NFI 2022) from 2021 to 2022, as repeat inventories, throughout the entire national territory.

In addition to being collected in the National Forest Inventories (NFI), forest-condition data were collected in the years 2008 and 2017 on a subsample of the NFI that consisted of an 8 by 8 km grid. For the most part, the Inventory Study 2008 (IS08) and the Carbon Inventory 2017 (CI 2017) use the same methods that are used in the National Forest Inventory (BMELF, 2008; Riedel et al., 2019; Schwitzgebel et al., 2009).

The Forest Fund Database Datenspeicher Waldfonds (DSWF) contains complete-coverage forestry-management data for the territory of the former GDR until 1993. These data were collected at regular intervals and updated annually using growth models, as well as following implementation and change notifications from forestry operations (BMELF, 1994).

The logging data are derived from national logging statistics (Statistisches Bundesamt, FS 3, R 3.3.1). These statistics underestimate the annual roundwood harvest by about 30% and are therefore calibrated using data from forest inventories on the removal of solid wood (Rüter (2017)) (cf. also Chapter 6.10.2.1).

6.4.2.1.2 Forest Soil Inventory (BZE-Wald)

Carbon emissions from forest soils were determined using the stock difference method and the YASSO soil carbon model. Yasso calculates the quantity of organic carbon in the soil, the changes in that quantity and the heterotrophic soil respiration (cf. also Chapter 6.4.2.5). The input data consisted of data from the BZE I-Wald and BZE II-Wald Forest Soil Inventories. The Forest Soil Inventory I (BZE I-Wald) was carried out from 1987 to 1992, while the Forest Soil Inventory II (BZE II-Wald) was carried out from 2006 to 2008. In both inventories, samples were taken of the

[90] For more information: http://www.bundeswaldinventur.de

total organic layer, hereafter "litter", pursuant to the 2006 IPCC Guidelines, as well as of mineral soils.

Descriptions of the inventory structure, and of the sampling procedure, are presented in Chapter 6.4.2.5.3.2.

6.4.2.2 Biomass (CRF 4.A)

6.4.2.2.1 Forest Land remaining Forest Land

The changes in biomass carbon stocks are calculated with the Tier 3 stock-difference method (Equation 2.8, 2006 IPCC Guidelines (IPCC (2006a))). In the process, only those forest areas are taken into account that were forest land at both points in time (Forest Land remaining Forest Land). Afforested and deforested areas (Land converted to Forest Land and Forest Land to Land) are not taken into account and are calculated separately in each case using the stock difference method.

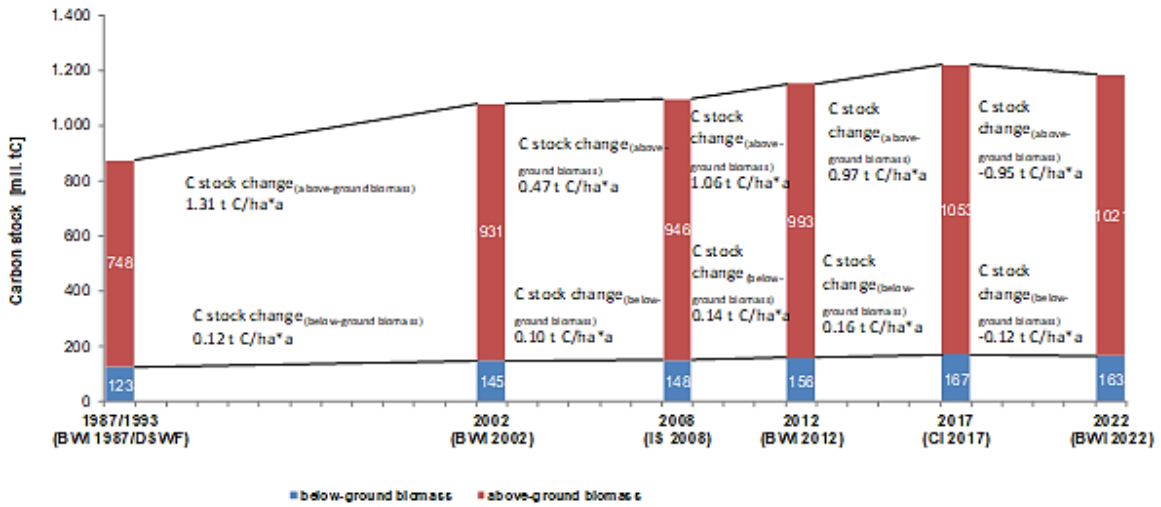
A stratification takes place in Forest Land in line with the major forest areas and federal states. The stock-difference method is applied to each stratum and each inventory period. As a result, average emission factors are obtained for each stratum in the periods between the respective inventories.

The periodical emission factors are calibrated on the basis of the annual quantity of logged wood. For each year and stratum, this procedure produces an EF that is adjusted to the quantity of logged wood. A description of the method is provided in Chapter 6.4.2.2.9 and (Röhling et al., 2016). At the end, a pan-German IEF is calculated for each year for the area shares of the strata.

For the years after the last National Forest Inventory, the matrix model (Rock et al., 2025) is used to quantify forest development during the inventory period from 2012 to 2022 .

Figure 80 shows the carbon stocks and changes for the various inventory time points and periods. These values highlight the changes in forest biomass carbon stocks, even though they include only carbon stocks in the category Forest Land remaining Forest Land (not including Land converted to Forest Land). The carbon-stock change values are the Germany-wide EFs for the relevant period.

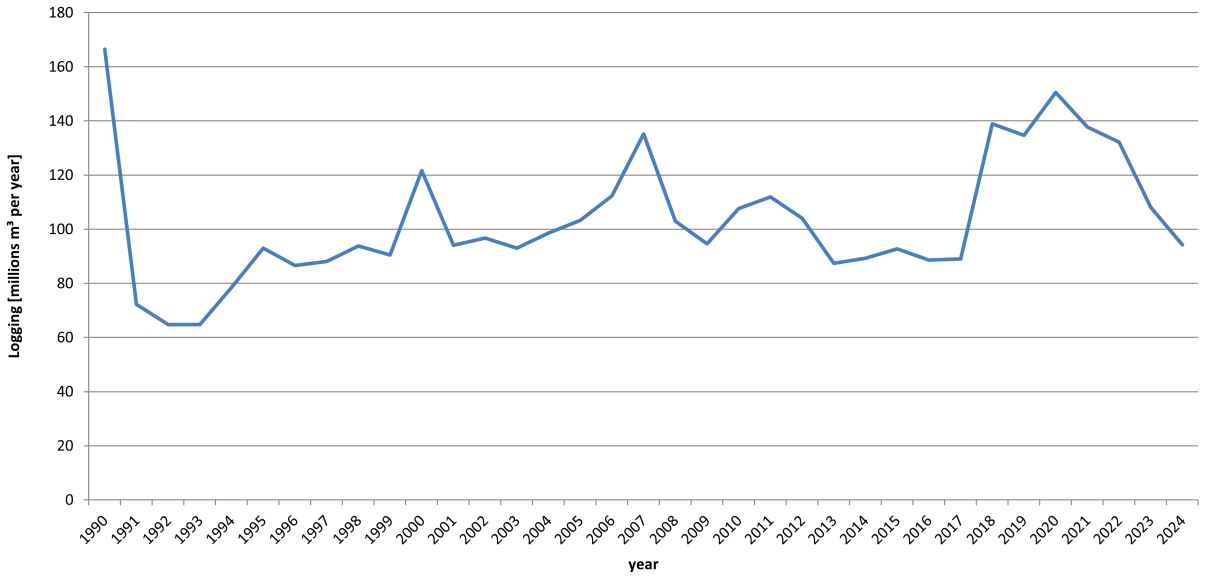
Figure 80: Soil organic carbon stocks and carbon-stock changes in below-ground and above-ground biomass in forests for the years 1987/1993, 2002, 2008, 2012, 2017 and 2022



Source: own illustration, Thünen-Institut

Figure 81 shows the relevant logging statistics for Germany. The method used to derive these statistics is described in Chapter 6.10.2.1 and in (Rüter, 2017). The annual emission factors, which are shown in Tabelle 349, were derived from the logging recalculation.

Figure 81: Quantities of wood logged in Germany



Source: own illustration, Thünen-Institut

Table 350: Emission factors for above-ground and below-ground biomass on Forest Land remaining Forest Land, in [t C*ha]

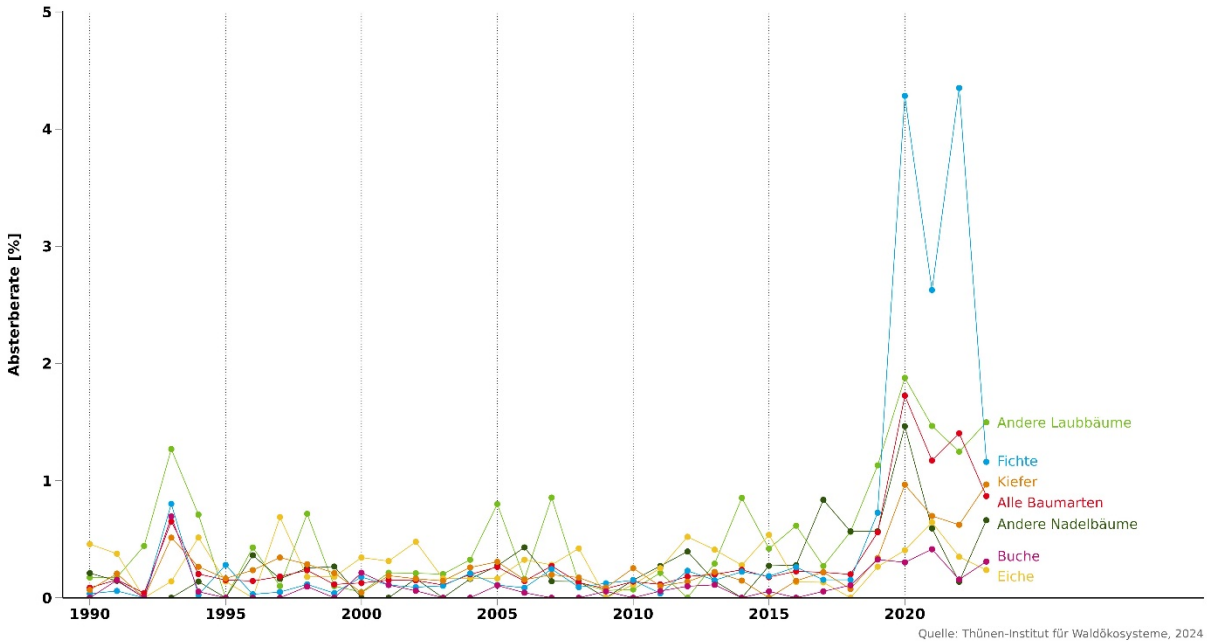
Year	EF above-ground biomass [t C*ha]	EF below-ground biomass [t C*ha]	Total EF biomass [t C*ha]
1990	0.28	0.03	0.30
1995	1.31	0.12	1.44
2000	0.91	0.09	1.00
2005	0.38	0.10	0.48
2006	0.35	0.09	0.44
2007	0.27	0.07	0.35
2008	1.02	0.14	1.16
2009	1.10	0.15	1.25
2010	0.97	0.13	1.11
2011	0.93	0.13	1.06
2012	1.01	0.14	1.15
2013	0.84	0.16	1.00
2014	0.82	0.16	0.98
2015	0.79	0.15	0.94
2016	0.83	0.16	0.99
2017	0.83	0.16	0.98
2018	-0.71	-0.09	-0.81
2019	-0.69	-0.09	-0.78
2020	-0.78	-0.10	-0.89
2021	-0.71	-0.09	-0.8

Year	EF above-ground biomass [t C*ha]	EF below-ground biomass [t C*ha]	Total EF biomass [t C*ha]
2022	-0.68	-0.09	-0.77
2023	-0.47	-0.06	-0.53
2024	-0.05	-0.01	-0.06

The very low emission factors in the years 1990 and 2007 stand out. They correlate with the large quantities of timber cut in these years as a result of storm events that damaged very large numbers of trees. In 1990, Germany was hit by a series of hurricanes that damaged about 70 million m^3 of timber. In 2007, hurricane Kyrill struck, leaving behind about 37 million m^3 of windthrow/damaged trees.

Forest, and spruce in particular, covering an area of more than 540,000 ha, died off in the period from 2018 to 2022 (BMEL, 2024c). This is confirmed by the 2024 Forest Condition Report (BMEL, 2024a). Figure 82 shows the dieback rates by tree species since 1990. From 2018, the dieback rates have increased for all tree species, and especially for spruce. For the reasons given, the loss of stocks exceeds the growth, and there is a reduction in carbon stocks in Forest Land. This is reflected in negative emission factors from 2018 (cf. Table 350). Some of these losses can be found in dead wood stocks in mineral soils (litter) and in harvested wood products. In addition, some of the damaged wood was exported.

Figure 82: Development of dieback rates by tree species since 1990 (2024 Forest Condition Report)



Source: own illustration, Thünen-Institut

6.4.2.2.2 Land converted to Forest Land

The changes in biomass carbon stocks on Land converted to Forest Land are calculated following the Tier 3 method given by Equation 2.16 of the 2006 IPCC Guidelines. In that approach, the stock changes are determined as the difference between the biomass stocks before and after conversion (cf. also Chapter 6.1.2.2.3). In the CRF, the biomass stocks from the previous use that are lost are entered under losses, while the biomass increase on Land converted to Forest Land is entered under gains.

The National Forest Inventory (NFI) differentiates between forest land that has been afforested (Land converted to Forest Land), forest land that was already forest (Forest Land remaining Forest Land) and forest land that has been deforested (Forest Land to Land). The pertinent change calculation is carried out separately for the categories afforestation, Forest Land remaining Forest Land and deforestation. The stock changes calculated in this context (using the stock-difference method) refer only to afforestation areas.

To obtain emission factors for the category Land converted to Forest Land, an individual-tree calculation was carried out on the basis of the NFI 1987, NFI 2002, IS2008, NFI 2012 and NFI 2022 inventories. For the period until 2002, only trees in the old German federal states were taken into account since the NFI 1987 inventory was carried out only there. As of the year 2002, calculations were carried out on a nationwide basis. The biomass carbon stocks were calculated for each area on which conversion from a given land use to Forest Land took place, and then all the resulting stocks were aggregated within the category Land converted to Forest Land. The stocks of initial land-use categories were deducted and thus taken into account.

For the new German federal states in the period 1990 to 2002, it was not possible to derive timber stocks for Land converted to Forest Land directly by comparing two inventories. For this reason, the relevant values for the old German federal states were used for that period.

It must be remembered that afforested areas remain in this land-use category for 20 years. On the areas added each year, the carbon-stock losses from initial land uses must be taken into account in the year in which conversion takes place; these losses are immediately accounted for as emissions.

Table 351 shows the emission factors for the annual increase in the above-ground and below-ground biomass on afforestation areas, without reference to previous uses. The different emission factors in the inventory periods can be attributed to different growth conditions in areas in which afforestation took place at various times between the forest inventories. This applies to different site conditions, different choice of tree types, planting or natural rejuvenation, different climatic conditions, different management of resources, etc. Taken in combination with uneven spatial distribution in terms of afforestation across the whole of Germany, over time this leads to differences in the respective periodical emission factors.

Table 351: Emission factors for above-ground and below-ground biomass on Land converted to Forest Land in [t C*ha]

Period	1990-2002	2003-2007	2008-2012	2013-2024
EF, above-ground biomass	2.82	1.42	1.96	2.67
EF, below-ground biomass	0.58	0.21	0.37	0.55

6.4.2.2.3 Derivation of individual-tree biomass

The above-ground biomass is estimated by means of biomass functions derived from the data of the NFI. Additional information is presented in Bösch and Kändler (2013) and in Chapter 6.4.2.2.4. The below-ground biomass is also derived using allometric equations. The equations being used for this purpose are representative of national circumstances (cf. Chapter 6.4.2.2.5).

Above-ground carbon stocks in the old German federal states as of 1987 were calculated on the basis of data from the NFI 1987 (some 230,000 measured trees). For the new German federal states, data on forest-management plans until 1993 are available in aggregated form in the Forest Fund Database (Datenspeicher Waldfonds), which can be used for calculations of carbon stocks. The NFI 2002 survey, in which some 377,000 trees were measured, provides the database for the 2002 sampling year. The data of the NFI 2012, covering some 537,000 trees,

and of NFI 2022 with 521,000 trees, are now also available. The NFI data are supplemented with data from the Inventory Study 2008 (repeat surveys of some 83,000 trees) and the Carbon Inventory 2017 (repeat surveys of some 96,000 trees). These data sources provide such a good basis for calculation of the estimated carbon-stock changes that it was possible to use the stock difference method IPCC (2006a)) instead of the gain-loss method IPCC (2006a)).

6.4.2.2.4 Conversion into above-ground individual tree biomass

The some 1,600 trees covered by the study of Bösch and Kändler (2013) included only the species spruce, pine, beech and oak. All other tree species, except for soft hardwoods species, were included in these four species groups. If the study had also included the soft hardwoods in the beech group and then applied the corresponding functions and coefficients, it would have considerably overestimated the biomass of that group. For this reason, for soft hardwoods a more suitable allometric equation of the same type was used that was adapted using "pseudo-observations" based on the tables in Grundner and Schwappach (1952).

The biomass allometric equations based on the tree species groups are divided into three parts:

- Trees >= 10 cm diameter at breast height (DBH)
- Trees >= 1.3 m height and < 10 cm DBH, and
- Trees < 1.3 m height

For trees less than 1.3 metres in height (where DBH cannot be measured), differentiating between the five tree species groups mentioned above is no longer useful. For this reason, trees are differentiated only in terms of whether they are coniferous or broadleaf trees. In conversion areas, the functions have been smoothed by way of statistical procedures. This prevented any jumps between the functions that might otherwise have occurred.

The following section presents the equations used for deriving above-ground biomass from the NFI data, as well as the equations' coefficients broken down by tree species groups.

Trees with at least 10 cm DBH

Equation 62:

$$Y_{BIOM_0} = b_0 e^{b_1 \frac{DHB}{DHB+k_1}} e^{b_2 \frac{D03}{D03+k_2}} H^{b_3}$$

- where Y_{BIOM_0} = Above-ground biomass in kg per individual tree,
- $b_{0,1,2,3}$ and $k_{1,2}$ = Coefficients of the Marklund function,
- DBH = Diameter at breast height in cm,
- D03 = Diameter in cm at 30% of tree height,
- H = Tree height in m.

Table 352: Coefficients of biomass function for trees >= 10 cm DBH

Tree species	b_0	b_1	b_2	b_3	k_1	k_2	RMSE%
Spruce	0.75285	2.84985	6.03036	0.62188	42.0	24.0	11.2
Pine	0.33778	2.84055	6.34964	0.62755	18.0	23.0	15.6
Beech	0.16787	6.25452	6.64752	0.80745	11.0	135.0	18.8

Tree species	b_0	b_1	b_2	b_3	k_1	k_2	RMSE%
Oak	0.09428	10.26998	8.13894	0.55845	400.0	8.0	12.1
Soft hardwoods	0.27278	4.19240	5.96298	0.81031	13.7	66.8	50.0[91]

Trees > 1.3 m height and < 10 cm DBH

Equation 63:

$$Y_{BIOM_0} = b_0 + \left(\frac{b_s - b_0}{d_s^2} + b_3(DBH - d_s)\right) DBH^2$$

- Y_{BIOM_0} = Above-ground biomass in kg per individual tree,
- $b_{0,s,3}$ = Coefficients of the function,
- DBH = Diameter at breast height in cm,
- d_s = Diameter-validity boundary for this function = 10 cm.

Table 353: Coefficients of biomass function for trees >= 1.3 m height and < 10 cm DBH

Tree species	b_0	b_s	b_3
Spruce	0.41080	26.63122	0.01370
Pine	0.41080	19.99943	0.00916
Beech	0.09644	33.22328	0.01162
Oak	0.09644	28.94782	0.01501
Soft hardwoods	0.09644	16.86101	-0.00551

Trees < 1.3 m height

Equation 64:

$$Y_{BIOM_0} = b_0 \, H_1^b$$

- Y_{BIOM_0} = Above-ground biomass in kg per individual tree,
- $b_{0,1}$ = Coefficients of the function,
- H = Tree height in m.

In the NFI, heights of trees smaller than 1.3 m are recorded only in terms of two basic classes: 20-50 cm and 50-130 cm, and thus the mid-range values of these classes, 35 and 90 cm, have been used in the function as standard values.

Table 354: Coefficients of biomass function for trees < 1.3 m height

Tree species	b_0	b_1
Spruce	0.23059	2.20101
Beech	0.04940	2.54946

[91] No RMSE% is available for this function, so the IPCC default value of 50% was used.

No inventory data were available for the new German federal states for the year 1990. The only available data source is the Datenspeicher Waldfonds Forest Fund Database of 1993, which surveyed the stocks and the forested areas in the new German federal states using a consistent method. For this reason, raw wood stocks were converted into biomass using the methods described in Burschel et al. (1993). In a first step of the relevant process, the raw wood volume is multiplied by the applicable root percentage (Table 355); this yields the pertinent below-ground volume. Then the raw wood volume and the below-ground volume are multiplied by a volume expansion factor (Table 356). The product of that multiplication is then the applicable total tree wood volume. The branch volume is obtained by subtracting the raw wood volume and the below-ground volume from the tree wood volume. Then, the various volumes are multiplied by the bulk density using specific bulk density values pursuant to Pistorius et al. (2007). All relevant values are listed in the following tables.

Table 355: Root percentages and bulk densities for conversion of Forest Fund Database data

Tree species	Root percentage (up to 20 years old)	Root percentage (> 20 years)	RMSE%	Bulk density (roundwood and roots)	Bulk density (branch wood)	RMSE%
Spruce	100	30	50	0.38	0.49	18.8
Fir	100	25	50	0.36	0.49	22.7
Douglas fir	100	25	50	0.41	0.49	20.7
Pine	100	25	50	0.43	0.49	27.2
Larch	100	25	50	0.49	0.49	18.2
Beech	100	25	50	0.56	0.54	13.7
Oak	100	25	50	0.57	0.57	19.8
Hard hardwoods	100	25	50	0.56	0.57	15.0
Soft hardwoods	100	25	50	0.46	0.54	8.7

Table 356: Volume expansion factors for conversion of raw wood volume and below-ground volume into the tree wood volumes of the Forest Fund Database data

Tree species	0 to 20 years	21 to 40 years	41 to 60 years	61 to 80 years	81 to 100 years	101 to 120 years	121 to 140 years	141 to 160 years	> 160 years	RMSE%
Spruce	4	1.65	1.51	1.45	1.45	1.45	1.46	1.47	1.48	50
Fir	4	1.52	1.44	1.44	1.38	1.41	1.41	1.42	1.41	50
Douglas fir	4	1.65	1.51	1.45	1.45	1.45	1.46	1.47	1.48	50
Pine	4	1.51	1.42	1.40	1.36	1.34	1.34	1.34	1.33	50
Larch	4	1.51	1.42	1.40	1.36	1.34	1.34	1.34	1.33	50
Beech	4	1.69	1.47	1.41	1.38	1.39	1.39	1.38	1.39	50
Oak	4	1.58	1.41	1.39	1.37	1.35	1.34	1.35	1.34	50
Hard hardwoods	4	1.69	1.47	1.41	1.38	1.39	1.39	1.38	1.39	50
Soft hardwoods	4	1.69	1.47	1.41	1.38	1.39	1.39	1.38	1.39	50

No uncertainties are known for the root percentage and the volume expansion factor. For this reason, the IPCC default value of 50% has been used.

6.4.2.2.5 Conversion into below-ground biomass

As of the 2015 submission, biomass functions based on peer-reviewed articles are used. This addresses the need for consistency between the method used to derive above-ground biomass and that used to derive below-ground biomass, as well as the need for overall clarity and transparency. The Thünen Institute has developed a separate biomass function for derivation of below-ground biomass for pine. All biomass functions chosen are of the form of Equation 65.

Equation 65:

$$Y_{BIOM_u} = b_0 \, DBH^{(b_1)}$$

- Y_{BIOM_u} = Below-ground biomass, in kg per individual tree
- $b_{0,1}$ = Coefficients of the below-ground biomass function.
- DBH = Diameter at breast height in cm

Table 357: Coefficients, parameters, uncertainties and sources for the biomass functions used, by tree species

Tree species	b_0	Parameter	b_1	RMSE %	Region	Source
Spruce	0.003720	DBH [cm]	2.792465	34.6	Solling	(Bolte et al., 2003)
Pine	0.006089	DBH [cm]	2.739073	26.3	Barnim	(Neubauer & Demant, 2016)
Beech	0.018256	DBH [cm]	2.321997	49.0	Solling	(Bolte et al., 2003)
Oak	0.028000	DBH [cm]	2.440000	50.0[92]	Northeast France	(Drexhage & Colin, 2001) in (Bolte et al., 2003)
Soft hardwoods (root biomass)	0.000010	DBH [mm]	2.529000	9.6	South Sweden	(Johansson & Hjelm, 2012)
Soft hardwoods (root-stump biomass)[93]	0.000116	DBH [mm]	2.290300	15.9	South Sweden	(Johansson & Hjelm, 2012)

The log functions available in the literature (cf. Equation 83) were intentionally not used. “Back transformation” of log error values for further use in the error budget was either unfeasible or, in cases in which the original measurements were available, yielded values as high as they were in the original scale units.

Like the Thünen Institute’s own pine function (Neubauer & Demant, 2016), the function provided by Drexhage and Colin (2001) in Bolte et al. (2003) for oak is unique in the European context. The selected functions for beech and spruce cover a considerably broader area of DBH distribution, especially for larger diameters, than the comparable studies of Wutzler et al. (2008) and Wirth et al. (2004). The functions thus have a considerably smaller extrapolation region, which prevents upward “drifting” of biomass values (cf. Figure 83).

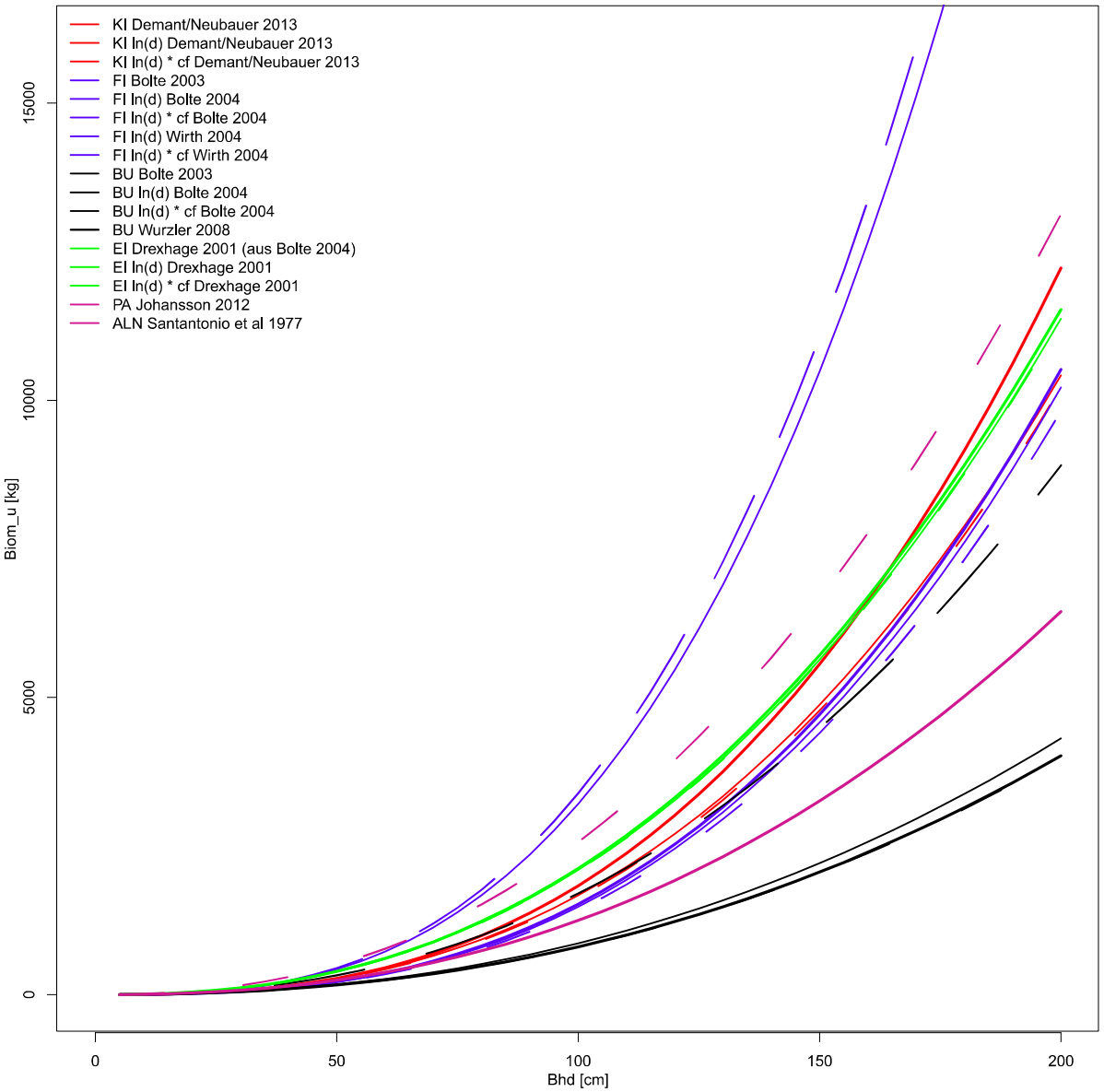
[92] For this function, no figure for RMSE% is available. Therefore, the IPCC default value of 50% has been used.

[93] The mean RMSE% for both functions (root-stump biomass + root biomass) is 24.2%.

At the same time, the chosen functions for spruce and beech were derived from data of a small region, the "Solling" region. By contrast, the functions of Wutzler et al. (2008) and Wirth et al. (2004) include data from a range of studies, both geographically and methodologically diverse.

This comparison of the chosen functions for spruce, beech and soft hardwoods (in each case, the unbroken line in Figure 83) with functions from other publications shows that the chosen functions always produce conservative estimates of biomass stocks. The rates of change between two states are thus also low compared to the corresponding values produced by other functions. Since carbon accumulates in the category of below-ground biomass throughout the entire period covered by the report, the estimates of the sequestration rate may be considered conservative.

Figure 83: Comparison of different functions for derivation of below-ground biomass



Source: own illustration, Thünen-Institut

6.4.2.2.6 Conversion of individual-tree biomass to carbon

A value of 0.5 has been applied for the conversion of biomass to carbon stocks. Wirth et al. (2004) report that the differences between compartments within a single tree species are larger

than the differences between tree species. They obtain a range of 0.50 to 0.56 g C g^{-1} in conifers. The relative standard error for carbon content in wood is given by Burschel et al. (1993) as 1 to 2%; Weiss et al. (2000) use 2%. Overall, therefore, 0.5 g C g^{-1}, with a relative standard error of ±2%, seems appropriate as a good assumption for mean carbon content.

6.4.2.2.7 State estimator for 1987, 2002, 2008, 2012, 2017 and 2022

Some German federal states use sampling grids smaller than 4 by 4 km. In addition, some federal states have increased the density of their sampling grids between the inventories. For this reason, extrapolation to the national level must be conducted in a stratified manner, using sampling strata defined by with grids of homogeneous densitiy. This section presents the procedures for scaling up the values "raw wood stocks", "biomass" and "carbon" in the framework of the stratified sampling plan for given time periods. The relevant states for the years 1987, 2002, 2008, 2012, 2017 and 2022 have been calculated. The upscaling procedures for different domains (all of Germany, various regions (old/new federal states) and different LULUCF/ARD categories) are identical.

The NFI is designed as a cluster sample. The cluster with four cluster points (sample points) is the smallest sampling unit. Along the boundaries of the inventory area or of sampling strata, incomplete clusters of varying sizes will be found, i.e. the number of sample points (cluster points in forest and non-forest) within these clusters can vary between 1 and 4. For each cluster *c* located within stratum *l*, the local sampling density (*Y*) must be calculated first:

Equation 66:

$$Y_{lc} = \frac{\sum_{m=1}^{M} I_{l,c,m} Y_{l,c,m}}{M_{l,c}}$$

- *Y* = Local sampling density
- *l* = Stratum
- *c* = Cluster
- *m* = Sample point
- *M* = Number of sample points

The estimator of means for stratum *l* with respect to the sampling density for both Forest Land and non-Forest Land is thus obtained as follows:

Equation 67:

$$\hat{\bar{Y}}_l = \frac{\sum_{c_l=1}^{C_l} M_{l,c} Y_{lc}}{\sum_{c_l=1}^{C_l} M_l}$$

- $\hat{\bar{Y}}$ = Weighted average of the local sampling density
- *l* = Stratum
- *c* = Cluster
- *C* = Number of clusters

- *M* = Number of sample points
- *Y* = Local sampling density

The estimator of means for a given value throughout all sampling strata is the mean of the individual stratum estimators, weighted with the area proportions for the various strata:

Equation 68:

$$\hat{\bar{Y}}_{st} = \sum_{l=1}^{L} \hat{\bar{Y}}_l \frac{\lambda(U_l)}{\lambda(U)}$$

- $\hat{\bar{Y}}_{st}$ = Estimator of the total
- *l* = Stratum
- *U* = Area
- *λ* = Estimate

The estimator of the total is obtained by multiplying the estimator of means throughout all strata by the total area *λ(U)*.

Equation 69:

$$\hat{Y}_{st} = \hat{\bar{Y}}_{st} \lambda(U)$$

- $\hat{Y}_{st}$ = Estimator of the total
- *st* = State
- *U* = Area
- *λ* = Estimate

The (forest-)area-related mean value is defined as the quotient or ratio estimator; it is obtained as follows:

Equation 70:

$$\hat{R}_{st} = \frac{\hat{Y}_{st}}{\lambda(U_{Wald})}$$

- $\hat{R}_{st}$ = Ratio estimator
- $\hat{Y}_{st}$ = Total state estimator
- U_{Wald} = Forest area
- *λ* = Estimate

6.4.2.2.8 Estimator for stock changes pursuant to the stock-difference method

To calculate the changes between two time points (as in the periods 1987-2002, 2002-2008, 2008-2012, 2012-2017, 2017-2022), the continuous forest inventory (CFI) method was used, i.e. only those cluster points that were included at both times were used for upscaling. The change estimate is thus based on the difference between the two estimators of the total. At the stratum level, the total change is estimated as follows:

Equation 71:

$$\hat{G}_l = \hat{Y}_l^{(t_2)} - \hat{Y}_l^{(t_1)}$$

- $\hat{G}_l$= Total change in stratum
- l = Stratum
- t = Time
- $\hat{Y}$ = Estimation of state

The total change throughout all strata for a given domain is estimated in the manner described in Equation 71. The estimated total change is calculated by means of Equation 72. The change in the area-related mean estimator is determined by:

Equation 72:

$$\hat{G}_{R\,st} = \hat{R}_{st}^{(t_2)} - \hat{R}_{st}^{(t_1)}$$

- $\hat{G}_{R_{st}}$ = Total change over all strata
- t = Time
- $(\hat{R}_{st})$ = Ratio estimator

6.4.2.2.9 Derivation of the annual change estimates

Since the National Forest Inventory is a periodically recurring inventory, only average EFs can be determined for the years in the periods. To allow for variability in the periods, the logging factor method was used (Röhling et al., 2016). The carbon losses caused by the wood harvest influence the carbon-stock change. The higher the quantity of harvested wood in a given year in comparison to the periodic average, and the higher the resulting carbon losses, the more the EF is adjusted to the wood harvest. For the logging factor method (LFM), the following equations are used:

Equation 73:

$$EF_{LFM} = EF * (1 + F_1)$$

- EF_{LFM} = Annual emission factor corrected to the quantity of logged wood (tC/ha*a)
- EF = Average emission factor for the inventory period (tC/ha*a)
- F_1 = Correction factor

Equation 74:

$$F_1 = \frac{(L_{fp} - L_{fa})}{L_{fp}}$$

- F_1 = Correction factor
- L_{fa} = Annual quantity of logged wood (m³)
- L_{fp} = Periodic quantity of logged wood (m³)

6.4.2.3 Dead wood (CRF 4.A)

6.4.2.3.1 Forest Land remaining Forest Land

The changes in dead wood carbon stocks are calculated with the Tier 3 stock-difference method (Equation 2.19, IPCC (2006a)).

The carbon stocks in dead wood were calculated with data from the NFI 2002 (BMELV, 2005), the 2008 Inventory Study, the NFI 2012, the CI 2017 and the NFI 2022. The NFI 1987 did not include any surveys of dead wood, meaning that no dead wood data are available for that time. The terrestrial survey used for the NFI 2002 included only fallen dead wood with a thicker-end diameter of at least 20 cm, standing dead wood with a diameter of at least 20 cm at breast height (DBH), and stumps with either a height of at least 50 cm or a cut-surface diameter of at least 60 cm (Polley, 2001). In the 2008 Inventory Study, the NFI 2012 Inventory Study, the CI 2017 and the NFI 2022, the survey threshold for dead wood objects was reduced to a diameter of at least 10 cm at the thicker end in accordance with requirements for climate reporting (BMELF, 2008). In all four forest inventories, trees were subdivided into three main tree species groups: conifers, deciduous trees (except for oaks) and oaks. The degree of decomposition of dead wood was divided into four classes (BMELF, 2008), (Polley, 2001).

The periodical emission factors for the inventory periods are calibrated based on the annual quantity of logged wood. For each year, this procedure produces an EF that is adjusted to the pertinent quantity of logged wood. A description of the method is provided in (Röhling et al., 2016).

For reporting pursuant to the 2006 IPCC Guidelines, the applicable dead wood-stock ratio between the 10 cm and 20 cm survey limits was determined from the data collected in the Inventory Study 2008. Under the assumption that this ratio was the same at the time of the NFI 2002, the dead wood stocks from the 10 cm survey limit upward were estimated for the year 2002. The biomass of the dead wood stocks for the various relevant decomposition classes was determined with the wood density figures pursuant to Fraver et al. (2002) for conifers, and with the wood density figures pursuant to Müller-Using and Bartsch (2009) for deciduous trees. To calculate the bulk density of deciduous wood, the dead wood objects in the deciduous (other than oak) and oak tree species groups were combined. An overview of the biomass expansion factors used and their errors, by tree species class and degree of decomposition, is presented in Table 358.

Table 358: Biomass expansion factors (BEFs) and their errors (RMSE%) for the various tree species classes and degrees of decomposition (NDH = conifers (Nadelbäume), LBH = deciduous trees (Laubbäume), EI = oak (Eiche))

Type of dead wood	Degree of decomposition		BEF	RMSE%	Source
NDH	1	Just died	0.372	17.2	(Fraver et al.)
NDH	2	Onset of decomposition	0.308	27.9	(Fraver et al.)
NDH	3	Advanced decomposition	0.141	35.5	(Fraver et al.)
NDH	4	Heavily rotted	0.123	25.2	(Fraver et al.)
LBH	1	Just died	0.58	12.1	(Müller-Using & Bartsch)
LBH	2	Onset of decomposition	0.37	43.2	(Müller-Using & Bartsch)
LBH	3	Advanced decomposition	0.21	33.3	(Müller-Using & Bartsch)
LBH	4	Heavily rotted	0.26	65.4	(Müller-Using & Bartsch)
EI	1	Just died	0.58	12.1	(Müller-Using & Bartsch)
EI	2	Onset of decomposition	0.37	43.2	(Müller-Using & Bartsch)
EI	3	Advanced decomposition	0.21	33.3	(Müller-Using & Bartsch)
EI	4	Heavily rotted	0.26	65.4	(Müller-Using & Bartsch)

The annual carbon stock change in dead wood was calculated using Equation 75 (Eq. 2.19, IPCC (2006a)). The average EFs for the inventory periods on the Forest Land remaining Forest Land are summarised in Table 359.

Equation 75:

$$\Delta C_{FF_{DW}} = \frac{A * \left(B_{t_2} - B_{t_1}\right)}{T} CF$$

where:

- ΔC_{FFDW} = Annual change in carbon stocks in dead wood on Forest Land remaining Forest Land
- A = Area of forest land remaining forest land
- B_{t1} = Dead wood stocks at time t_1 (beginning of the period) for Forest Land remaining Forest Land
- B_{t2} = Dead wood stocks at time t_2 (end of the period) for Forest Land remaining Forest Land
- $T=(t_2-t_1)$ = Time period between the two estimates
- CF = Carbon conversion factor (standard value = 0.5)

Table 359: Dead wood emission factors for Forest Land remaining Forest Land, in [t C*ha]

	1990-2002	2003-2007	2008-2012	2013-2017	2018-2024
EF	0.037	0.097	-0.188	0.101	0.113

6.4.2.3.2 Land converted to Forest Land

The annual changes in carbon stocks in dead wood on Land converted to Forest Land were calculated using Equation 2.19 of the 2006 IPCC Guidelines (IPCC, 2006a). That equation is identical to the equation for calculating changes in dead wood carbon stocks on forest land remaining forest land (cf. Equation 75). The data of the NFI 2002, NFI 2012 and CI 2017 and NFI 2022 were available for determination of dead wood carbon stocks on Land converted to Forest Land. The 2008 Inventory Study did not collect data on Land converted to Forest Land and the NFI 1987 did not collect data on dead wood. The average EFs for the inventory periods on the Land converted to Forest Land are summarised in Table 360.

Table 360: Dead wood emission factors for Land converted to Forest Land, in [t C*ha]

	1990-2007	2008-2012	2013-2017	2018-2024
EF	0.034	0.229	0.101	0.113

6.4.2.4 Litter (CRF 4.A)

6.4.2.4.1 Forest Land remaining Forest Land

As a result of constraints tied to the model used, emissions from litter are calculated together with emissions from mineral soils. For this reason, the notation key IE (included elsewhere) is entered in the appropriate spaces in the CRF. The changes in carbon stocks for mineral soils, including litter, is calculated using overlap method and a Tier 3 approach (IPCC, 2006a).

For litter, the descriptions in Chapter 6.4.2.5.1 for mineral soils apply. The methods are described in detail in Chapters 6.4.2.5.3 ff. and the results are described in Chapters 6.4.2.5.4 ff.

6.4.2.4.2 Land converted to Forest Land

For Land converted to Forest Land, the calculation is also model-based and carried out together with the mineral soil. For this reason, the notation key IE (included elsewhere) is used. For Land converted to Forest Land, and as with Forest Land remaining Forest Land, the carbon stocks of mineral soils and litter, which serve as the final stocks in the change calculation, using a combination of two methods (overlap method) based on a Tier 3 approach (Equation 2.25, (IPCC, 2006a)).

For litter, the descriptions in Chapter 6.4.2.5.2 for mineral soils apply. The methods are described in detail in Chapters 6.4.2.5.3 ff. and the results are described in Chapters 6.4.2.5.4 ff.

The carbon-stock changes in mineral soils, including litter on Land converted to Forest Land, are calculated in accordance with the methods described in Chapter 6.1.2.1.

6.4.2.5 Mineral soils (CRF Table 4.A)

6.4.2.5.1 Forest Land remaining Forest Land

The changes in carbon stocks in mineral soils are calculated using the overlap method with a Tier 3 approach (2006 IPCC Guidelines – Equation 2.25, IPCC (2006a)).

For the period 1990 to 2008, the carbon stocks and carbon-stock changes in mineral soils were calculated with the "stock difference" method; for the period as of 2008, they were calculated with results from modelling with Yasso15. The introduction of the new method was accompanied by a regionalisation of the relevant soils (cf. also Chapter 6.1.2.1.3). The data needed for this are based on the nationwide Forest Soil Inventories (BZE I-Wald and BZE II-Wald; cf. Chapter 6.4.2.1.2 and Grüneberg et al. (2014)). The methods are described in detail in Chapters 6.4.2.5.3 ff. and the results are described in Chapters 6.4.2.5.4 ff.

The third Forest Soil Inventory (BZE III-Wald) is currently being carried out. The results of the BZE III-Wald inventory will improve the method used.

6.4.2.5.2 Land converted to Forest Land

For the Land converted to Forest Land, the calculation of carbon stocks for mineral forest soils, which are included as final stocks for the change calculation, is carried out using a combination of two methods (overlap method) according to a Tier 3 approach, as for the remaining forest areas. (Equation 2.25, (IPCC, 2006a)).

The methods are described in detail in Chapters 6.4.2.5.3 ff. and the results are described in Chapters 6.4.2.5.4 ff.

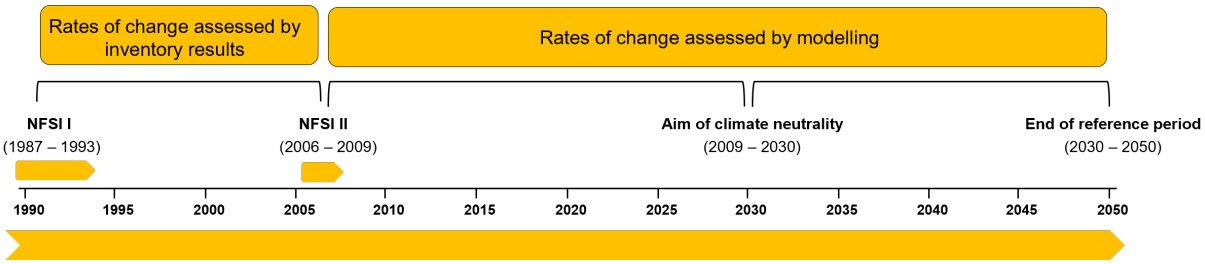
The carbon-stock changes in mineral soils on Land converted to Forest Land are calculated in accordance with the methods described in Chapter 6.1.2.1.

6.4.2.5.3 Materials and methods

6.4.2.5.3.1 Introduction

The data for calculating the annual rates of change of organic carbon stocks in the humus layer and in mineral soil comes from the nationwide Forest Soil Inventory (BZE Wald). The Yasso15 soil carbon model (Yärvenpää et al., 2018, Tuomi et al., 2009) takes account of the findings of the BZE-Wald Forest Soil Inventory and provided a basis for predicting rates of change until the year 2050 (Figure 84). The model results reflect the annual changes in organic soil carbon stocks down to a mineral soil depth of 30 cm.

Figure 84: Chronology of data collection in the Forest Soil Inventory and of soil carbon modelling using the data collected in the Inventory



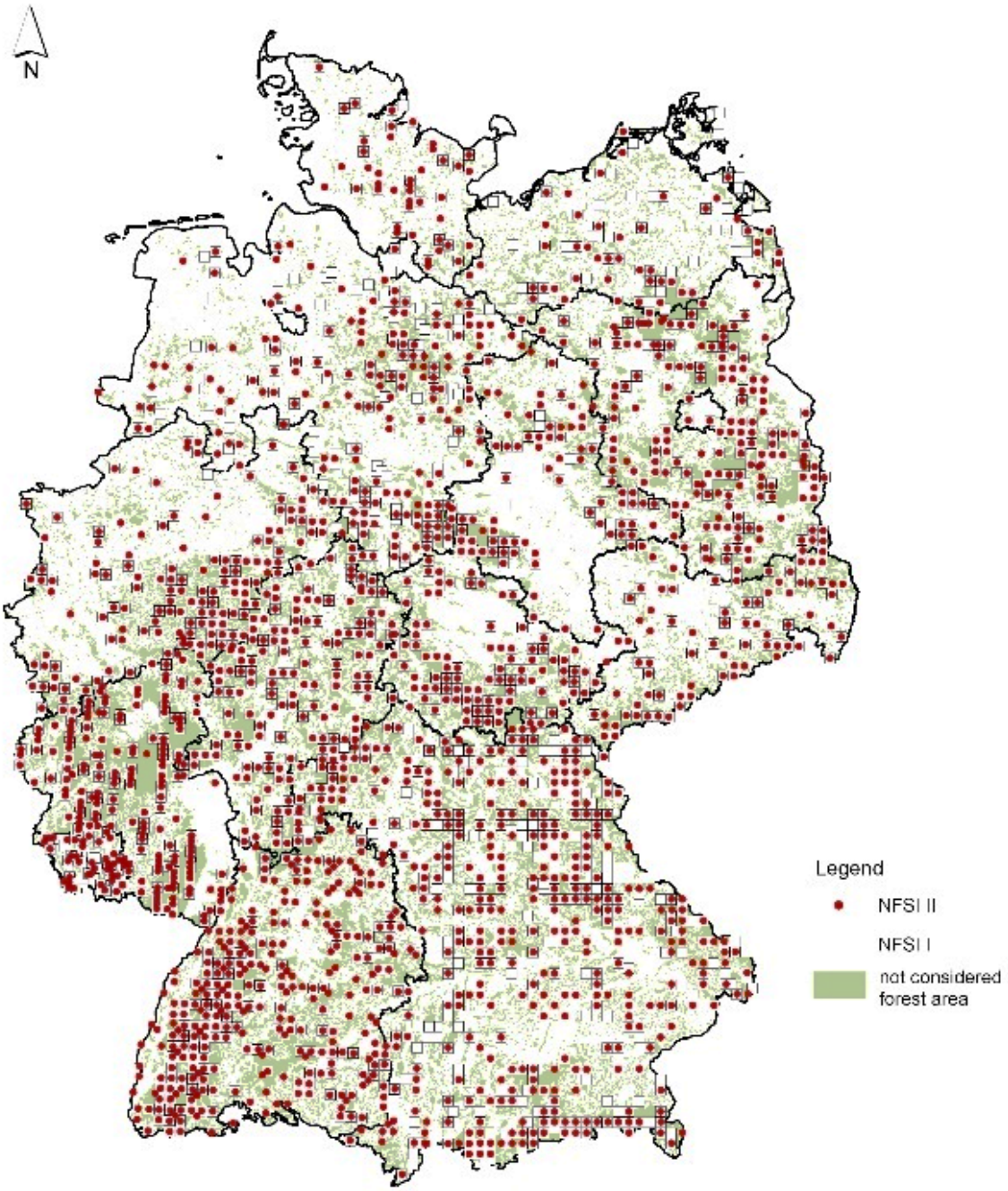
Source: own illustration, Thünen-Institut

6.4.2.5.3.2 Inventory design, and sampling

The Forest Soil Inventory (BZE Wald) is part of an environmental monitoring system for the country's forests. With a nationwide, representative and systematic 8 x 8 km sampling grid, the Forest Soil Inventory (BZE Wald) covers Germany's entire forested area. Data is collected by the German federal states in accordance with the Federal Republic of Germany's federal structure. The first inventory, the Forest Soil Inventory I (BZE I-Wald), was carried out on the basis of a specialised manual developed specifically for this purpose ("Arbeitsanleitung für bodenkundliche Außenaufnahmen, BMELV, 1990). In the second inventory, the Forest Soil Inventory II (BZE II-Wald), a similar manual – improved, agreed upon by a working group and oriented especially to the soil mapping guide used in Germany (Bodenkundliche Kartieranleitung; Ad-hoc-Arbeitsgruppe Boden, 1982, 1994, 2005) – was then used (Wellbrock et al., 2006). The first inventory took place in the years 1987 to 1993 and included a total of 1,936 sampling points (Figure 85). The repeat inventory (BZE II-Wald) was carried out between 2006 and 2008. It included resampling of some of the points that were covered in the first inventory, and it added additional points. The present analysis considered data from a total of

1,865 points from the BZE I-Wald inventory, and from 1,813 points from the BZE II-Wald inventory. In cases where a BZE point was resampled, the results entered into the analysis as a paired data record. In cases where the repeat sampling covered a different point, the results entered into the analysis as an unpaired data record. While 624 BZE points were not resampled in the BZE II, 577 new points were sampled for the first time. The points from the first inventory that were not resampled second time in the BZE II entered into the analysis as unpaired samples together with the points that the BZE II sampled for the first time.

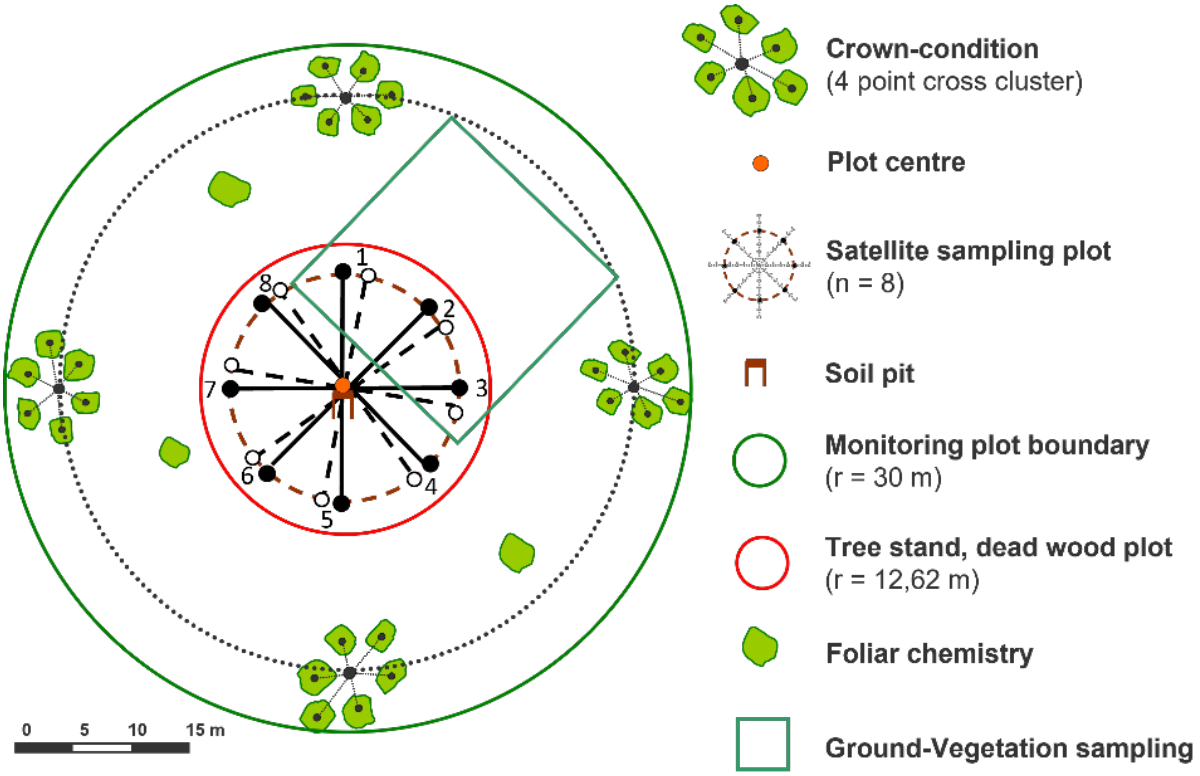
Figure 85: Spatial distribution of inventory points in the first and second Forest Soil Inventories (BZE-Wald)



Source: own illustration, Thünen-Institut

The standard procedure for sampling of BZE soil points is to take soil profiles of satellite points around BZE midpoints. In each case, profiling ditches are dug within a 30 m radius around the BZE midpoint. In each initial instance of sampling of satellite points, eight holes were drilled, to a depth of 90 cm, at a distance of 10 m from the BZE midpoint. Radially, the holes were spaced at angular intervals of 50 gradians. During resampling at the same sites, holes were again drilled on the same circle, at the same distance from the midpoint, but at points shifted by 10 gradians (Figure 86).

Figure 86: Layout of sampling points in the Forest Soil Inventory (BZE-Wald)



Source: own illustration, Thünen-Institut

The resulting soil profiles were described in accordance with the guide, with the description covering the parent substrate of the soil development and the relevant soil types, and other characteristics such as structure, texture and colour. In each case, the organic surface layer was also sampled at the eight satellite points using a sampling frame, sampling ring or special drill bit. The organic soil horizons from all eight satellites were combined to produce a composite mixed sample. The Forest Soil Inventory I (BZE I Wald) did not account for branches, cones and green vegetation fractions, while the repeat inventory only excluded branches and cones with diameters >20 mm.

In both inventories, the chemical parameters of mineral soils were determined by sampling the upper 30 cm of satellite points, with a combination used to produce composite samples. To estimate the fine soil fractions, it is essential to take samples of the mineral soil that are representative of its volume. This sampling takes account of the mass and weight of volume-based fine earth and coarse earth fractions. A study of a partial collection of BZE samples, for example, found that estimated fine earth fractions differed significantly from measured values (Wirth et al., 2004). For true-to-volume sampling to determine physical soil parameters, samples were taken from the soil profile's front wall using a sampling ring. Estimates – for example, of bulk densities – were permitted only in cases in which sampling with sampling rings was not

feasible owing to high rock concentrations. At some sites, sampling of soil physics was carried out using core soundings.

6.4.2.5.3.3 Sample preparation and laboratory analysis

Although the soil analyses were carried out in various laboratories, the comparability of the methods used was ensured by way of ring analyses (König & Wolff, 1993). The relevant laboratory methods were used based on the manual Forstliche Analytik (GAFA, 2006). The organic layer was dried for 48 hours at 60°C, then passed through a sieve <2 mm and finally ground to a fine powder for analysis. The mineral soil samples were prepared by drying at 40°C for 48 hours, followed by sieving <2 mm and final analysis-grade grinding. The carbon analysis processes used with the BZE I samples included Wösthoff carmhography, indirect analysis by loss on ignition at 550°C and wet combustion with $K_2Cr_2O_7$ and H_2SO_4. The nitrogen was analysed by either gas chromatographic elemental analysis or Kjeldahl digestion with subsequent photometric or titrimetric nitrogen analysis. All of the laboratory methods used were entered into the subsequent analysis. It should be noted, however, that >79% of the samples were analysed solely by gas chromatographic elemental analysis. In the subsequent inventory, the total carbon and total nitrogen in the samples were determined solely by way of gas chromatographic elemental analysis. While the inorganic carbon concentration in mineral soils was determined using the Scheibler method (Schlichting & Blume, 1966), the organic carbon concentration in carbonate-containing soils was determined as the difference between total carbon and inorganic carbon.

6.4.2.5.3.4 Calculation of organic soil carbon stocks

The organic carbon stocks (C) in the humus layer were calculated as a function of the sampled area within the sampling frame or sampling ring (F), as well as of the weight (W) and of the carbon concentration (C_{coc}) of the collected sample (Equation 76):

Equation 76:

$$\boldsymbol{C = F * W * C_{coc}}$$

For determination of the organic carbon stocks of the upper 30 cm of mineral soils, the first step was to determine the fine earth fractions (FEFs) using a function employing data on the fine soil bulk density (BD) and the volume of the coarse soil fraction (CSV) (Equation 77) or the coarse soil stocks (CSS) and the total soil bulk density (BDg) (Equation 78).

Equation 77:

$$\boldsymbol{FES_i = BD_{FE_i} * \left(1 - \frac{CSV_i}{100}\right)}$$

Equation 78:

$$\boldsymbol{FES_i = BD_g * 100 - CSS_i}$$

The organic carbon stocks (C) are obtained by multiplying the fine earth fractions by the organic carbon concentrations (Equation 79).

Equation 79:

$$\boldsymbol{C = FES * C_{coc}}$$

6.4.2.5.3.5 Calculation of the annual rates of change of organic soil carbon stocks

Spatially referenced data from the Forest Soil Inventories were correlated with geodata sets available on a complete-coverage basis. All sites were placed in groups in accordance with the classification schemes of the geodata sets. To make it possible to determine the organic carbon stocks of mineral soils, all BZE sites were allocated to certain soil groups within the German federal states. For each point, the relevant forest type within the German federal states served as a means of grouping the point with others for the calculation of the organic carbon stocks of the humus layer. German federal states forest areas were included in the classification scheme so that it would be possible to take account of federal state-specific deviations from the standard grid used in the BZE-Wald Forest Soil Inventory. The CORINE land coverage data of the years 1990 and 2006 were used for the determination of the distribution of forests in Germany and for differentiation of forest types by the categories deciduous, coniferous and mixed forest (EEA, 2010a), (EEA, 2010b). The area-referenced calculation of the national annual carbon storage rate is based on a forest area, without taking organic soils into account, of 10.2 million ha (UBA et al., 2012). In addition, soil substrate groups were formed, and their distribution was taken from the national soil map to a scale of 1:1,000,000 (BGR, 1998). The soil map contains 72 soil units that are categorised by parent substrates oriented to the revised FAO legend (FAO, 1990). Each BZE point was allocated, based on its soil-based chemical and physical characteristics, and its soil classification, to the relevant dominant soil unit. BZE points were allocated to a total of 52 of the 72 dominant soil units. With a view to obtaining more representative and statistically more significant groups, these dominant soil units were grouped into 16 new soil substrate groups in accordance with their soil characteristics and soil-based chemical and physical characteristics (Table 361). The analysis did not take into account of organic and anthropogenic soils, however, due to the great breadth of heterogeneous characteristics found in these soils. Also, more extensive aggregation of soil substrate groups, solely based on soil substrate, was carried out (soils with low or high base saturation, formed from solid or loose rock), to permit area-weighting of the humus layer, in combination with the forest type (deciduous, coniferous or mixed forest).

Table 361: Soil substrate groups based on aggregated legend units of the soil map to a scale of 1:1,000,000 (BÜK 1.000).

ID	Soil substrate groups	Legend unit
1	Soils from nutrient-poor sands	17, 25, 28, 31, 33, 34
2	Soils from sandy-to-loamy terrace or riverine deposits	10, 11, 12, 16
3	Soils from calcareous, loamy-clayey terrace or riverine deposits	8, 9, 13, 14, 15
4	Soils from sandy-loamy sediment deposits (without damming or groundwater impacts)	18, 19, 20, 21, 24, 26, 27, 30, 32
5	Soils from sandy-loamy sediment deposits (with damming or groundwater impacts)	22, 23, 29
6	Soils of loess areas (without damming or groundwater impacts)	35, 36, 37, 39, 40, 41, 42, 43, 45, 46
7	Soils of loess areas (with damming or groundwater impacts)	38, 44, 47, 48
8	Soils from redistribution products of limestone, dolomite, marl and clay weathering	49, 50, 51, 52, 67
9	Soils from alkaline and intermediary magmatic rock	53, 54
10	Soils from acidic magmatic and metamorphic rock	55, 57

ID	Soil substrate groups	Legend unit
11	Soils from acidic sedimentary rock	58, 59, 60, 61, 63
12	Soils from loess-containing covering layers over acidic sedimentary rock or magmatic and metamorphic rock	56, 62, 64, 65, 66
13	High-mountain soils	68
14	Peatland	6, 7
15	Tide-influenced soils	2, 3, 4, 5
16	Initial soils	1, 69

For the paired sample, the annual rates of carbon-stock change in the humus layer (for the aggregated soil substrate groups and forest types) and in the mineral soil (for the soil substrate groups) were determined from the differences between the averaged carbon stocks at the relevant survey times (Figure 87). The stocks, therefore, refer to the time that has passed between the inventories (Equation 59):

Equation 80:

$$rC_m = \frac{1}{n}\sum_{i=1}^{n}\frac{(CII_i - CI_i)}{\Delta t_1}$$

where rC_m is the change in the carbon stocks in mineral soil or in the humus layer, in category m (soil substrate groups or aggregated soil substrate groups within the given federal state), CIi is the soil carbon stocks determined in the BZE I-Wald Forest Soil Inventory, CIIi is the soil carbon stocks determined in the BZE II-Wald inventory, and Δt_1 is the time between the two inventories for BZE point i.

Annual carbon-stock changes with respect to unpaired samples (Figure 87) were calculated based on averaged carbon stocks for the soil substrate groups for mineral soils, and of aggregated soil substrate groups and forest types for the humus layer, taking account of the averaged time points for the relevant inventories (Equation 81):

Equation 81:

$$rC_m = \frac{\left(\frac{1}{nII}\sum_{i=1}^{nII} CII_i - \frac{1}{nI}\sum_{i=1}^{nI} CI_i\right)}{\left(\frac{1}{nII}\sum_{i=1}^{nII} tII_i - \frac{1}{nI}\sum_{i=1}^{nI} tI_1\right)}$$

To make it possible to estimate the average annual rate of change of the carbon stocks for Germany, the soil substrate groups (for mineral soils) and the aggregated soil substrate groups and forest types (for the humus layer) were intersected with the relevant forest areas (Equation 82):

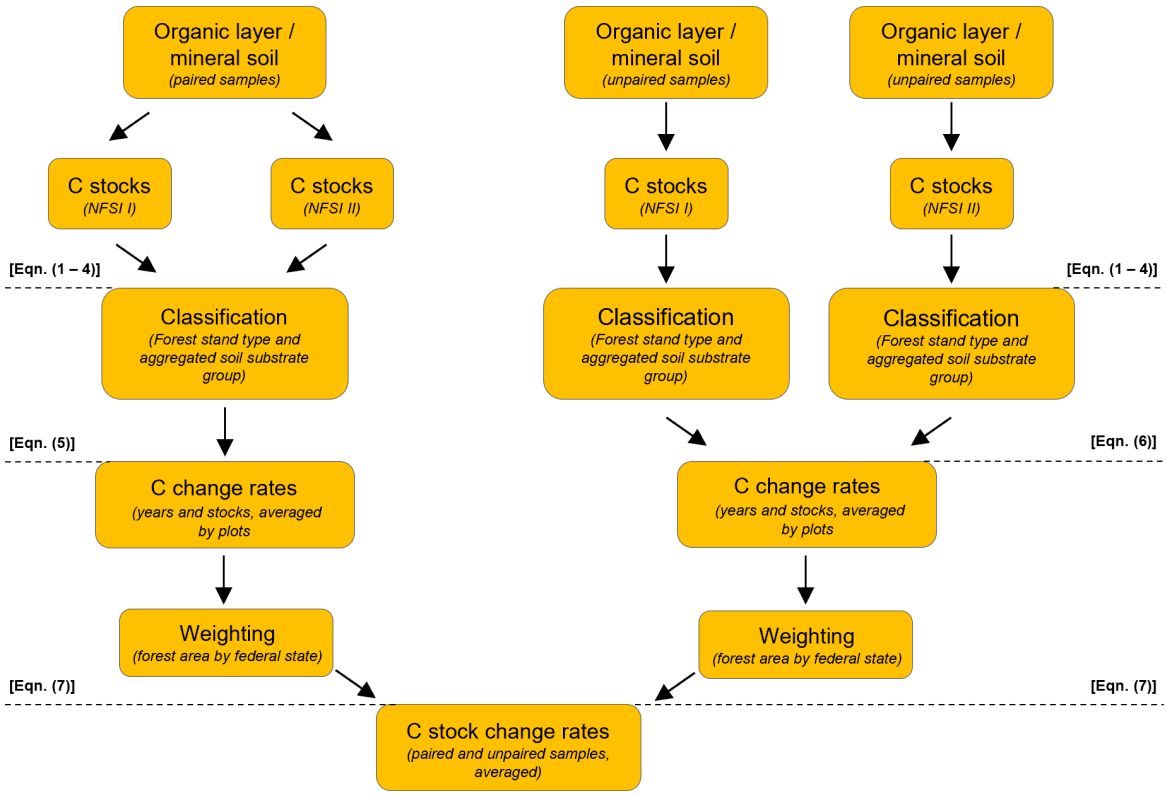
Equation 82:

$$rC_m = \frac{1}{\sum_{m=1}^{k} A_m}\sum_{m=1}^{k} rC_m * A_m$$

where A_m is the forest area in category m (soil substrate groups or aggregated soil substrate groups within the given federal state). In the process, a minimum random-sample size of n=5 was assumed. The area data were taken from a GIS-based intersection of the BÜK 1.000 German soil map and the grid-based CORINE land cover map. This approach made it possible to calculate area-weighted average values in order to account for any federal state-specific differences within the BZE grid.

Also, the determination of site-based and area-based percentages for each inventory made it possible to assess the representativeness of samples with respect to scaling at the soil substrate-group level. In this approach, the forest area for the aggregated soil substrate groups and forest types (humus layer) and soil substrate groups (mineral soils) was referenced to the total forested area within the given federal state. In addition, the number of BZE points for the aggregated soil substrate groups and forest types (humus layer) and soil substrate groups (mineral soils) was linked with the total number of inventory points within the federal states. However, the area-based and point-based percentages for the two inventories did not differ significantly.

Figure 87: Overview of calculation of the annual rates of change of organic carbon in the humus layer and in mineral soils



Source: own illustration, Thünen-Institut

6.4.2.5.3.6 Soil carbon modelling

The Yasso15 soil carbon model ((Järvenpää et al., 2018), (Tuomi et al., 2009)) was used to model all of the BZE Wald points separately (for the period from 1988 to 2001 for BZE I-Wald Forest Soil Inventory and 2004 to 2008 for BZE II-Wald Forest Soil Inventory) up to 2070 in a series of monthly steps. The values measured in BZE I-Wald were taken as the starting values and, only if no data from the first inventory were available, the modelling used the values measured for the BZE II-Wald Forest Soil Inventory. The model results relate to the changes in organic soil carbon stocks down to a mineral soil depth of 30 cm. Until simulation year 2023, the climate data

required for the modelling (mean monthly air temperatures and monthly precipitation) were calculated from data of the German Meteorological Service (DWD), which are currently available with a resolution of 1 km^2 and adjusted using spatial interpolation between the four nearest data points around each BZE point. In the process, the spatial intervals, and the squares of the geodetic elevation differences, were entered as inverse proportions into the calculation, as weighting factors. From simulation year 2024, climate projection data of IPCC Scenario RCP4.5 were used ((IPCC, 2014; Meinshausen et al., 2011)). These data are available for Germany in six variants at a resolution of 5 x 5 km^2, in each case scaled down using various regional climate models (Dalelane et al., 2018). These data were used for the modelling with Yasso in six rows of partial simulations, and the final result was formed from the median of the six partial simulations. The spatial interpolation for the climate projection data was carried out using the same method as for the measured climate data. The data on carbon inputs into the soil at the relevant BZE points and data on the corresponding simulation years were derived in accordance with (Ziche et al., 2019). In addition, the harvest factors responsible for annual variations in organic input were updated up to the year 2024. From simulation year 2025, averages from 2014 to 2023 were used.

Yasso15 was executed with the Sorcering modelling framework (Scherstjanoi & Dechow, 2024) in the R software environment (v.4.2.1, (The R Core Team, 2025)). Dead wood, which is considered an important input source for forest soils, required separate consideration during modelling. In Yasso15 it has special properties as an input quantity, but is not used as the modelled state quantity, meaning that it is no longer possible to simulate the share of dead wood separately in the modelled organic carbon. As a result, the entire data set for organic carbon is modelled, then the quantity of dead wood is subtracted. This approach was applied while initialising and performing the simulations. The simulations with Yasso were initiated with a 3,000-year model spin-up that was carried out for all BZE points. Before the simulations were commenced, the quantity ratios between the Yasso model pools that were obtained at the end of the spin-up were transferred to the sum of a) the measured BZE starting values for organic soil carbon stocks and b) the newly calculated values for dead wood. This generated starting values for the simulation. To determine this quantity of dead wood, additional separate spin-up runs were performed with wood input only and without wood input. The results of these runs and the characteristics of the wood input were used to derive the quantity of non-decomposed dead wood across the distributions among the five Yasso15 model pools (Scherstjanoi et al., in prep.). The same approach was used in subsequent simulations for dead wood.

For the determination of the model uncertainties, the simulations were repeated hundreds of times, with stochastically varying model sizes:

1. The Yasso15 developers prepared a list of 10,000 model parameter sets using Bayesian methods and Markov chain Monte Carlo sampling. From that list, a random selection was made in each stochastic repetition.
2. Distributions already generated by (Ziche et al., 2019) for each carbon entry to account for uncertainties were used to create 100 sets of input data through random sampling. After elimination of implausible values (doubling or halving of carbon stocks between the inventories), a total of 1,672 points remained for the modelling. Of these, 1,189 points belonged to the BZE I Wald collective.

The model results for each output year were transferred to the corresponding classes of the soil substrate groups to provide a basis for a nationwide cartographic depiction.

6.4.2.5.3.7 Uncertainties analysis

The uncertainties for the calculated carbon stocks in the humus layer and in the mineral soils result from the individual uncertainties for the measured variables (Equation 83) (law of error propagation, ISO/IEC Guide 98–3: 2008):

Equation 83:

$$S_y^2 = \left(\sum_{i=1}^{n} \frac{\partial y}{dx_1} S_{x1}\right)^2 + 2 \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \frac{\partial_y}{d_{x_i}} \frac{\partial y}{dx_j} cov(x_i, x_j)$$

where

$$y = \int (x_1, \ldots, x_n)$$

- $s_{x_i} = Standardabweichung\ vom\ Mittelwert\ x_1$,
- $cov(x_i,x_j)$ = covariance of x_i and x_j,
- $\frac{\partial_y}{d_{\sim}} \frac{\partial_y}{d_{\sim}}$ = partial discrepancy for y, with respect to x_i and x_j

To begin with, the uncertainties arising from the sampling variance were calculated. The variance in the organic soil carbon stocks was determined individually for each category with respect to the humus layer (forest type and federal state) and mineral soils (soil substrate group and federal state). In each of these categories, the standard error and the average values of FESI, FESII, C_{orgI}, C_{orgII}, Δ_t; the covariance between these variables; and the number of samples, were included in accordance with Equation 80, Equation 81 and Equation 82. In the case of the unpaired sample collective, the covariance of the variables between the inventories played no role. As a next step, the variances of the individual categories were combined. This made it possible to calculate an area-weighted total variance (Equation 84):

Equation 84:

$$S^2{}_{rC} = \frac{\sum_{m=1}^{k} A^2 m c^2 rCm}{\left(\sum_{m=1}^{k} A_m\right)^2}$$

where

- $S^2{}_{rC}$ = Total variance
- $c^2{}_{rCm}$ Variance of category m
- A_i = Area of category m.

To evaluate the input variables' influence on the overall sampling variance, each term of Equation 60 was calculated separately and expressed as a percentage of the sum of the absolute values (Schrumpf et al., 2011). For this evaluation, only fine earth fractions of BZE points were used that have been repeatedly sampled, however. Along with the sampling variance, uncertainties tied to various measurement techniques result. The uncertainties for the carbon analyses were quantified using the results of ring analyses between the various laboratories. With the findings, it was possible to estimate the uncertainties for the carbon analyses carried out by the laboratories. With respect to the ring tests of the laboratories, for the determination of the carbon concentrations of the BZE II-Wald (Forest Soil Inventory II) samples, the standard deviation for all average values was estimated based on a) the repeatability standard deviation

as a combined intra-laboratory standard deviation within the laboratories, and b) the inter-laboratory standard deviation. This, in turn, made it possible to calculate the reproducibility standard deviation (Equation 85), which is a suitable measure for estimation of measurement uncertainties.

Equation 85:

$$S^2_R = S^2_L + S^2_r$$

where

- S_R = Reproducibility standard deviation,
- S_r = Repeated standard deviation,
- S_L = Standard deviation between the laboratories

The reproducibility standard deviations of the ring tests between the laboratories ranged between 0.9 mg/g and 2.9 mg/g for mineral soils with and without carbonate. For the humus layer, a reproducibility standard deviation of 20.2 mg/g resulted. Consequently, all values were within a range of 5% around the sample mean. For carbonate-containing soil samples, a variation coefficient of 18% resulted. The variation coefficients published by (Wolff & Riek, 1997) with respect to evaluations of ring analyses for the BZE I-Wald Forest Soil Inventory ranged between 5 and 10% for the humus layer and between 5 and 20% for mineral soil. Uncertainties also arise as a result of analysis method changes made between the first and second forest inventories. For 40 soil samples whose organic carbon concentration was determined in the BZE I-Wald inventory by wet combustion with a potassium dichromate solution ($K_2Cr_2O_7$), repeat analysis was carried out with the dry combustion method that was used in the BZE II-Wald inventory. The average organic carbon concentration in the humus layer was 309.9 ± 11.9 mg/g for the BZE I Wald inventory (wet combustion) and 320.8 ± 12.6 mg/g for the BZE II Wald (dry combustion). The root mean square error (RMSE) was 54.3 mg/g. In mineral soil, however, the organic carbon concentration decreased from 12.2 ± 1.0 mg/g to 11.3 ± 1.1 mg/g, and the RMSE was 2.8 mg/g. Regression analysis of the carbon concentrations in both data collectives was carried out. The variance homogeneity of the carbon concentrations of mineral soil was ensured by a log transformation. For both data collectives, the F statistics showed neither a significant deviation from 0 nor a significant deviation of the regression coefficient from 1. Consequently, no systematic error was detected as a result of the change in measurement methods. For estimation of the uncertainties of the fine earth fractions, only BZE points were selected that were available as paired sample points and for which measured values from both inventories were available. The fine earth fractions were assumed to have remained the same between the two inventories. And a comparison of the fine earth fractions showed no significant differences between the inventories. The measurement uncertainty for fine earth fractions can be determined as the mean deviation plus the deviation of the fine earth fractions (standard error). The uncertainties for category m were obtained by combining the variances of the annual carbon-stock changes with the measurement uncertainties for the analysis methods (Equation 86):

Equation 86:

$$u^2{}_{rCm} = S^2{}_{rCm} + \left(\frac{C_{org_m}}{(\Delta t_m)} MD_{FES}\right)^2 + \left(\frac{FESI}{(\Delta t_m)} S_{C_{org_{RI}}}\right)^2 + \left(\frac{FESII}{(\Delta t_m)} S_{C_{org_{RII}}}\right)^2$$

where

- $S^2{}_{rCm}$ = Sample variance of soil carbon stocks in category m,
- MD_{FES} = Mean deviation of fine earth fractions (+ standard error) between the two inventories,
- C_{org_m} = Mean organic carbon concentration in category m,
- $S_{C_{org_{RI}}} S_{C_{org_{RII}}}$ = Uncertainties for determination of the carbon concentrations during the two inventories (I, II),
- $FESI_m$, $FESII_m$ = Fine earth fractions in category m
- Δt_m = Average time between the two inventories in category m

The area-weighted total uncertainty was determined with Equation 84.

6.4.2.5.3.8 Statistics

All statistical analyses were carried out with SAS 9.2. (SAS Institut, Carry, NC, USA). The data were all considered to be unpaired and all were tested for normal distribution (Shapiro-Wilk test) and variance homogeneity (Levene test). Where data were not normally distributed, they were converted into a normal distribution by taking the square root or applying a log transformation. This made it possible to test them statistically. For statistical tests, the type-I two-way ANOVA test and the Tukey-Kramer test were used; the significance level was α= 0.05. To clear the samples of statistical outliers, non-normal, atypical and distortionally trending observations were eliminated. The outliers were removed by eliminating values located outside of the double standard deviation (x±2σ) of the units aggregated by forest type or soil substrate group. Also, the soil carbon stocks of paired samples were tested for outliers using simple linear regression. This was done by eliminating leverage values for 3(p+1)/n and studentised residuals outside of the value range ±√n-k-1.

6.4.2.5.4 Results

6.4.2.5.4.1 Inventory-based rates of change of carbon stocks in litter

Between the time of the BZE I-Wald Forest Soil Inventory and the repeat inventory, the carbon stocks stored in litter in Germany decreased from 19.0 ± 0.33 t/ha to 18.8 ± 0.3 t/ha. The annual carbon loss, therefore, amounted to 0.02 ± 0.02 tC/ha/a. The changes were not significant since the standard error and the rate of change were of a similar magnitude, and since the total uncertainty, at 0.03 tC/ha, is of an even higher magnitude. With regard to the aggregated soil substrate groups, the humus layer on soils with solid rock as the parent material, and with a high degree of base saturation, stores the smallest quantities of carbon, while the layer on loose sediment soils with low base saturation has the largest carbon storage capacity (Table 362). The humus layer carbon stocks also varied considerably with respect to forest type. Layers under deciduous forests on alkaline-rich soils with solid rock as the parent material had the lowest carbon storage capacities, while layers under coniferous forests on alkaline-poor soils with loose substrates as the parent material had the highest storage capacities. The humus layer carbon stocks exhibited significant differences both between the aggregated soil substrate groups and between the different forest types (ANOVA; P<0.001). And this applies to both inventories. On

the other hand, the changes between the inventories were undirected. This applied both to the aggregated soil substrate groups and to the different forest types (ANOVA; P<0.001). Carbon stocks increased in loose sediments with low base saturation and under coniferous forests, but they tended to decrease in soils over solid rock in all forest types (Tukey; P<0.05).

Table 362: Mean humus layer carbon stocks and their changes for various aggregated soil substrate groups and various forest types as determined by the BZE I-Wald and BZE II-Wald Forest Soil Inventories

Aggr. soil substrate groups	Forest type	C stocks, BZE I Wald		C stocks, BZE II Wald		rC	rC (UC)
		n	[t/ha]	n	[t/ha]	[t/ha/a]	[t/ha/a]
1 Loose sediments with low base saturation	Coniferous forest	148	26.2 ± 1.2 [1)]	152	28.5 ± 1.0 [1)]	0.15 ± 0.08	0.11
	Mixed forest	5	19.6 ± 7.2	5	11.2 ± 5.7	-0.62 ± 0.15	0.23
2 Loose sediments with high base saturation	Deciduous forest	100	8.0 ± 0.6	102	5.9 ± 0.5	-0.14 ± 0.04	0.07
	Coniferous forest	216	21.5 ± 0.8	183	24.9 ± 1.0	0.23 ± 0.07	0.09
	Mixed forest	77	17.1 ± 1.2	79	17.2 ± 1.6	0.00 ± 0.11	0.10
3 Solid rock with low base saturation	Deciduous forest	116	10.7 ± 0.8 [1)]	106	8.3 ± 0.6 [1)]	-0.18 ± 0.06	0.07
	Coniferous forest	342	26.4 ± 0.7 [1)]	334	25.5 ± 0.7 [1)]	-0.08 ± 0.05	0.07
	Mixed forest	187	18.9 ± 0.9 [1)]	180	16.2 ± 1.0 [1)]	-0.17 ± 0.06	0.08
4 Solid rock with high base saturation	Deciduous forest	79	5.7 ± 0.4 [1)]	95	4.5 ± 0.3 [1)]	-0.09 ± 0.03	0.03
	Coniferous forest	77	14.3 ± 0.6 [1)]	50	9.6 ± 0.9 [1)]	-0.30 ± 0.06	0.08
	Mixed forest	74	10.4 ± 0.7 [1)]	78	6.1 ± 0.5 [1)]	-0.28 ± 0.05	0.08

[1)] Based on a significance level of α = 0.05 determined by Type I two-way variance analysis (ANOVA) with subsequent Tukey's HSD test and with inventories compared using aggregated soil substrate groups

6.4.2.5.4.2 Inventory-based rates of change of carbon stocks in mineral soils

The estimated mean organic carbon stocks in Germany's mineral soils to a depth of 30cm increased from 55.6 ± 3.4 t/ha during the BZE I Wald Forest Soil Inventory to 61.8 ± 3.7 t/ha during the BZE II Wald inventory. As determined by the calculation procedure used, this increase amounted to annual storage of 0.41 ± 0.03 tC/ha. The variance analysis showed significant increase in stocks (ANOVA; P<0.001) along with a total uncertainty of 0.11 tC/ha. Similarly, significant differences emerged between the soil substrate groups (ANOVA; P<0.001), and the interactions between the class variables indicate that the carbon stocks are texture-dependent. This was reflected in lower stocks in soils with sandy substrates compared to moderate carbon accumulation in loamy soils in lowland areas and in soils with solid rock in mountainous regions and low mountain ranges (Table 363). Despite low carbon stocks, the sandy soils of the lowlands in particular showed high increases (Tukey, P<0.05). Large, distribution-independent stocks were found especially in carbonate-containing soils. The solid-rock soils of hilly and upland areas, and in Alpine regions, exhibited moderate rates of accumulation (Tukey, P<0.05). No carbon stock changes were found in carbonate rock soils. The results show that significant positive changes occurred in locations with low initial stocks, while soils with high stocks exhibited no significant changes.

Table 363 Carbon stocks and their changes, in the upper 30 cm of mineral soils and in various soil substrate groups, as determined by the BZE I-Wald and BZE II-Wald Forest Soil Inventories

soil substrate groups	C stocks, BZE I Wald		C stocks, BZE II Wald		rC	rC (UC) 1)
	n	[t/ha] 2)	n	[t/ha] 2)	[t/ha/a]	[t/ha/a]
1	201	52.8 ± 1.6 3)	187	65.5 ± 6.8 3)	0.95 ± 0.12	0.24
2	56	60.5 ± 2.6	62	65.0 ± 4.9	0.02 ± 0.20	0.31
3	20	67.3 ± 3.2	25	68.1 ± 2.4	0.20 ± 0.33	0.88
4	105	66.4 ± 1.8	87	64.1 ± 4.5	0.14 ± 0.12	0.29
5	77	33.4 ± 1.6 3)	75	52.8 ± 2.2 3)	1.19 ± 0.14	0.21
6	34	24.6 ± 1.6 3)	34	43.7 ± 1.8 3)	1.35 ± 0.19	0.24
7	126	55.8 ± 1.5 3)	109	63.0 ± 2.2 3)	0.47 ± 0.12	0.20
8	110	76.3 ± 2.4	106	79.1 ± 0.8	-0.17 ± 0.16	0.83
9	36	77.1 ± 4.9	43	68.3 ± 1.0	-0.71 ± 0.28	1.39
10	55	56.7 ± 2.1	63	60.8 ± 0.8	0.19 ± 0.14	0.56
11	39	51.3 ± 3.2	39	54.6 ± 0.9	0.38 ± 0.17	0.36
12	187	59.5 ± 1.7 3)	163	62.5 ± 2.2 3)	0.11 ± 0.10	0.31
13	222	54.7 ± 1.4 3)	233	60.1 ± 4.1 3)	0.44 ± 0.08	0.23
14	245	50.5 ± 1.2 3)	257	55.3 ± 3.2 3)	0.35 ± 0.08	0.18
15	30	51.8 ± 2.9	30	49.0 ± 0.9	-0.26 ± 0.20	0.64
16	34	84.4 ± 6.2 3)	26	104.5 ± 0.5 3)	0.40 ± 0.46	2.40

1) UC, uncertainties

2) ± Standard error determined

3) On the basis of a significance level of α = 0.05, determined by Type I two-way variance analysis (ANOVA) with subsequent Tukey's HSD test, and with inventories compared by soil substrate group

In forests, the carbon stock changes are particularly pronounced in topsoils when compared with the relevant subsoils. In accordance with this result, the repeat inventory found significant changes in all depth layers (ANOVA; $P<0.001$). Also, the stocks varied significantly in all depth layers between the soil substrate groups (ANOVA; $P<0.001$). In addition, significant interactions were seen between the class variables. This supports the validity of carrying out evaluation via classification since the soil substrate groups, in terms of the magnitude of the changes seen in all depth layers, account for an adequate portion of the variance. In the repeat inventory, the uppermost depth layer exhibited a stock increase in nearly all soil substrate groups. The magnitude of the increase decreased with increasing depth, however. Here as well, lowland sandy soils exhibited the largest carbon stock increases in all depth layers. In most of the soil substrate groups, the increases were less pronounced in the depth layers below the uppermost depth layer. Along with the lowland sandy soils, the nutrient-poor soils in hilly and upland areas also exhibited an increase in lower depth layers.

6.4.2.5.4.3 Modelled rates of change of organic soil carbon stocks

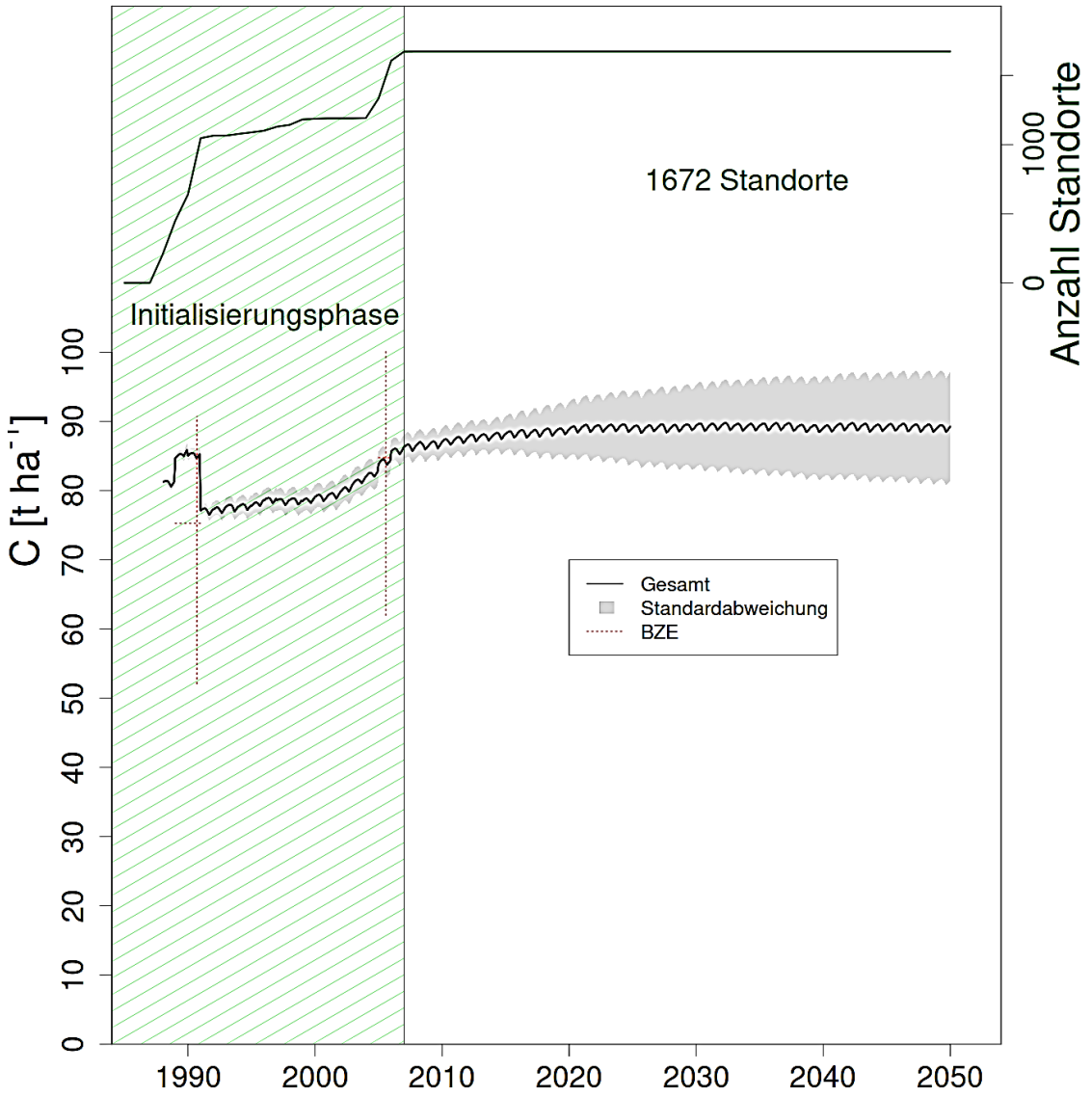
The average soil carbon stocks modelled with Yasso are shown in Figure 88. From this modelling, the following clearly emerges:

1. The model results reflect the trend seen between the BZE I-Wald and BZE II-Wald Forest Soil Inventories,
2. the trend flattens out from the year 2020, and

3. the mean model results fluctuate at the beginning of the simulations.

The major increases in soil carbon-stocks between 2018 and 2023 are attributable to an increase in salvage logging during that time. The initial large leaps at the beginning of the simulations are due to a change in the scope of the survey and the fact that it cannot be assumed that the few hundred simulations started before 1991 are representative of Germany (green line in Figure 88). This is only fully the case following the completion of the initialisation phase from 2008. The average modelled rates of change of the soil carbon stocks of the BZE points within the relevant new dominant soil units were determined for each simulation year. Since the number of sites is incomplete in the initialisation phase, the model results were linearly and backwardly interpolated after the soil substrate groups for the period before 2008 had been stratified. To this end, the annual storage rate for the period between the two inventories was calculated for each soil substrate group and then used as a factor for linear extrapolation. Taking the relevant results into account, rates of change of about 0.43 tC/a resulted for the period 1970 to 2030, and rates of about 0.35 tC/a result for the period 1970 to 2050.

Figure 88: Mean modelled soil carbon stocks, in [t ha^{-1}]



Source: own illustration, Thünen-Institut

The upper line (green) shows the results from the initial survey of the 1,672 sites, while the lines in red show BZE measurements (vertical axis: 1st to 3rd quantile of the measurements; horizontal axis: 1st to 3rd quantile of the survey years). The range of uncertainty is limited by the 15th and 85th percentiles, in turn highlighting the influence of parameter and model input uncertainties.

6.4.2.6 Organic soils (CRF 4.A)

This chapter solely discusses CO_2 emissions from organic soils. These emissions are entered in CRF 4.A under "organic soils". The methods applied for N_2O and CH_4 greenhouse gas emissions are described in Chapter 6.1.2.2. Those emissions are reported in CRF 4(II).

6.4.2.6.1 Forest Land remaining Forest Land

The areas covered by organic soils were determined by a georeferencing procedure where the map of organic soils (Karte organischer Böden) is overlaid with ATKIS® data. The process differentiates between drained and non-drained organic soils. For Forest Land remaining Forest Land, the organic soils area for the year 2024 is 262,797 ha. A detailed description of the method used to derive organic soil areas and the drained fractions of those areas is presented in Chapter 6.1.2.2.1.

The method used to derive the emission factor is described in Chapter 6.1.2.2.2, while the method used to derive the implied emission factor (IEF) is described in Chapter 6.1.2.2.3. Table 364 summarises the implied emission factors for organic forest soils.

Table 364: Implied emission factors (IEFs) (carbon) for organic soils, in [t CO_2 ha^{-1}]

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024
IEF	10.57	10.55	10.57	10.56	10.55	10.60	10.60	10.56	10.61	10.54	10.55

6.4.2.6.2 Land converted to Forest Land

For Land converted to Forest Land, the organic soils area for the year 2024 is 21,086 ha (cf. Chapter 6.1.2.2.1). The emission factors presented in Table 364 are also used for organic soils on Land converted to Forest Land. Those annual emissions are being reported for all years since the relevant conversions. The manner in which greenhouse gas emissions from organic soils are derived for all land-use categories is described in Chapter 6.1.2.2.

Table 365: Implied emission factors (IEFs) (carbon) for Land converted to Forest Land on organic soils, in [t CO_2 ha^{-1}]

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024
IEF	10.57	10.57	10.57	10.57	10.54	10.56	10.58	10.54	10.60	10.51	10.53

6.4.2.7 Other GHG emissions from forests

6.4.2.7.1 Nitrous oxide emissions from nitrogen fertilisation (CRF 4(I))

No nitrogen fertilisation in forests takes place in Germany. Therefore, CRF 4(I) reports this activity as "NO" (not occurring; cf. also Chapter 6.1.2.5).

6.4.2.7.2 Drainage and rewetting of organic and mineral soils (CRF 4(II))

The derivation of GHG emissions from organic and mineral soils related to drainage and rewetting is described for all land-use categories in Chapter 6.1.2.6. The CO_2 emissions for forests are entered in CRF 4.A and marked "IE" (included elsewhere) in CRF Table 4(II) (cf. also

Chapter 6.4.2.6). The pertinent CH_4 and N_2O emissions, on the other hand, are presented in CRF 4(II). Table 366 summarises the implied emission factors for organic forest soils.

No rewetting of mineral soils in forests occurs; in CRF 4(II), the source is marked "NO" (not occurring).

Table 366: Implied emission factors (IEFs) (methane and nitrogen) for organic soils

	Methane [kg CH_4 ha^{-1}]	Nitrogen [kg N_2O ha^{-1}]
1990	3.09	2.32
1995	3.09	2.16
2000	3.10	2.26
2005	3.11	2.24
2010	3.11	2.11
2015	3.12	2.47
2020	3.12	2.5
2021	3.12	2.24
2022	3.12	2.59
2023	3.12	2.10
2024	3.12	2.17

6.4.2.7.3 Direct nitrous oxide emissions related to nitrogen mineralisation and immobilisation (CRF 4(III))

The manner in which direct N_2O emissions from mineralisation and immobilisation of mineral soils are determined is described in Chapter 6.1.2.7. The pertinent CH_4 and N_2O emissions, on the other hand, are presented in CRF 4(III).

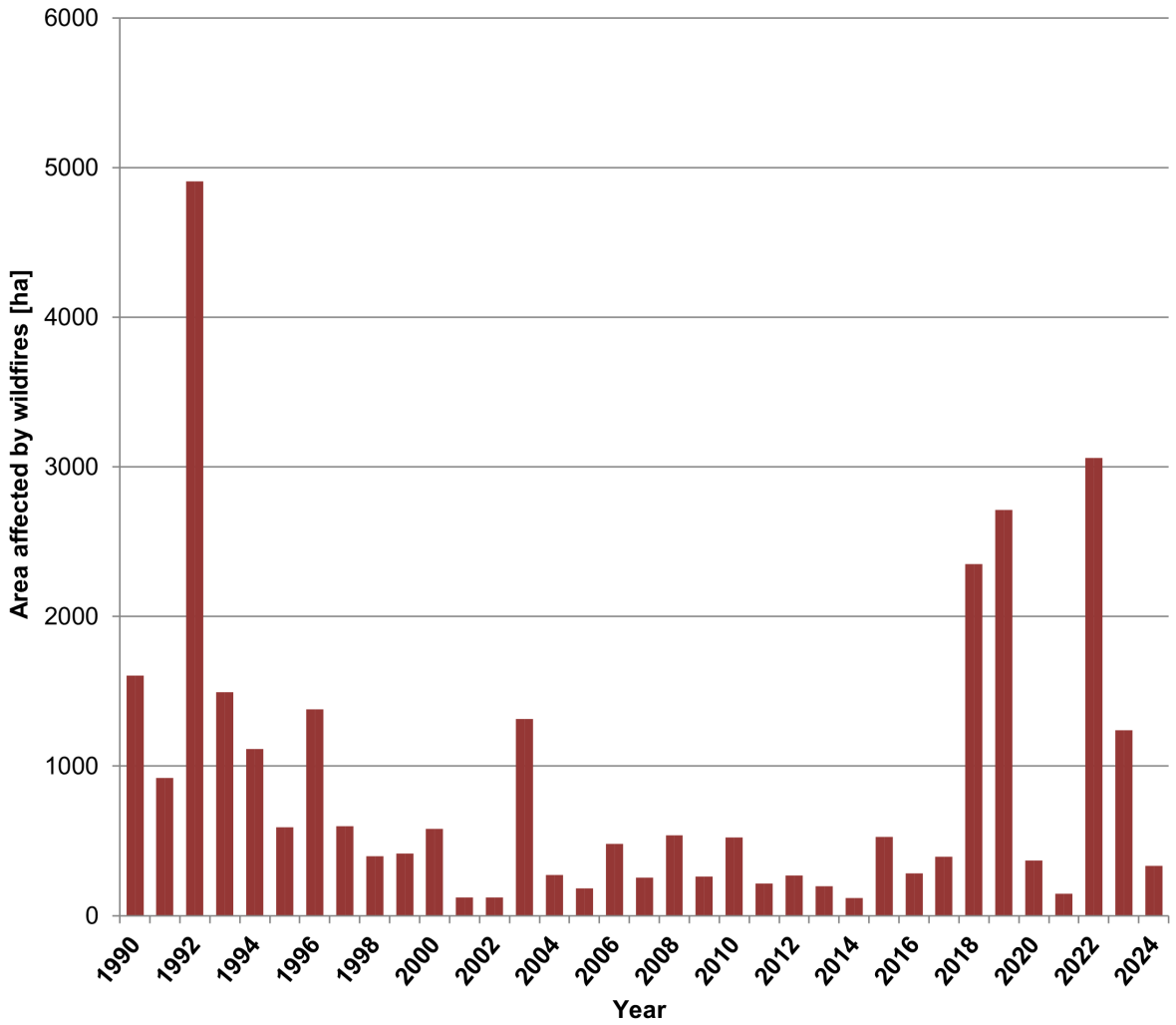
6.4.2.7.4 Indirect nitrous oxide emissions from cultivated soils (CRF 4(IV))

The manner in which indirect N_2O emissions related to losses of organic soil substance resulting from land-use changes and cultivation measures are determined is summarised for all land-use categories in Chapter 6.1.2.8. The pertinent CH_4 and N_2O emissions, on the other hand, are presented in CRF 4(IV).

6.4.2.7.5 Wildfires (CRF 4(V))

While in other countries "prescribed burning" is an accepted method for clearing land or for managing ecosystems, no prescribed/controlled burning of biomass is carried out in Germany's managed forests. In CRF 4 (IV), therefore, NO is entered in the category "Controlled Burning". Due to Germany's climatic situation, and the measures taken in Germany to prevent wildfires, fires occur relatively rarely. This conclusion is confirmed by relevant wildfire statistics (BLE, 2024) and their data on areas affected by wildfires (cf. Figure 89). The mean forest area affected annually by wildfires in the period 1990-2024 was 866 ha. In some years, unreasonably high summer temperatures resulted in larger burned areas. This was the case, for example, in 1996, 2003, 2018, 2019 and 2022. An unusually large burned area, about 4,908 ha, was measured in 1992, which had an extremely warm summer.

Figure 89: Areas affected by wildfires between 1990 and 2024 (pursuant to BLE, 2024)



Source: own illustration, Thünen-Institut

Along with CO_2, wildfires emit a range of other greenhouse gases (CO, CH_4, N_2O, NOx and NMVOC). The CO_2 emissions resulting from biomass combustion have already been taken into account as part of changes of biomass stocks (CRF Sector 4.A.1 Forest Land remaining Forest Land) using the stock difference method. For this reason, they are listed as IE (included elsewhere). The emissions of other greenhouse gases were calculated using Equation 87 (Equation 2.27, IPCC (2006a)).

Equation 87:

$$L_{fire} = A*B*C*D*10^{-6}$$

- L_{fire} = Quantity of GHG emitted by fire [t]
- A = Wildfire burned area [ha]
- B = Mass of fuel present on the relevant site (biomass) [kgTM ha^{-1}]
- C = Combustion efficiency
- D = Emission factor [$g(kgTM)^{-1}$]

The NMVOC emissions were calculated with the pertinent equation pursuant to the 2016 EMEP/EEA Emission Inventory Guidebook (EMEP/EEA, 2023).

Equation 88:

$$M(C) = 0.45 * A * B * \alpha * \beta$$

- 0.45 = Average fraction of carbon in fuel wood
- A = Area burnt [m^2];
- B = Average total biomass of fuel material per unit area [kg m^{-2}];
- α = Fraction of average above-ground biomass relative to the total average biomass B;
- β = Burning efficiency (fraction burnt) of the above-ground biomass.

The data on areas affected by wildfires in the period 1990 to 2024 have been taken from the wildfire statistics maintained by the Federal Agency for Agriculture and Food (BLE, 2025). In determination of the relevant areas, no distinction is made between Land converted to Forest Land and Forest Land remaining Forest Land. For this reason, the emissions from Land converted to Forest Land are reported within the section for the category Forest Land remaining Forest Land and listed as "IE" in CRF 4(IV).

The data available for determination of the biomass and dead wood pools include the data for 1990 from the NFI 1987 and DSWF; the data for 2002 from the NFI 2002; the data for 2008 from the IS08; the data for 2012 from the NFI 2012; the data for 2017 from the CI 2017, and the data for 2022 from the NFI 2022. The mean above-ground biomass for each year was derived by linear interpolation between 1990, 2002, 2008, 2012, 2017 and 2022, and by extrapolation from the year 2023. The biomass of the litter pool was calculated from the data of the BZE I-Wald (1990) and BZE II-Wald (2006) Forest Soil Inventories. In the procedure used, the annual biomass is obtained by linear interpolation between 1990 and 2006, and by extrapolation as of 2016.

Pursuant to the expert assessment carried out by König (2007), 80% of the wildfires in Germany remain on the ground surface and 20% rise into tree crowns. In accordance with Table 2.6 (IPCC, 2006a), a combustion efficiency (mass loss through direct combustion) of 0.15 was used for fires remaining on the surface, and an efficiency of 0.45 was used for fires rising to tree crowns. The emission factors for CH_4, N_2O, CO and NO were taken from Table 2.5 (IPCC, 2006a). The emission factor for NMVOC was taken from the 2016 EMEP/EEA Emission Inventory Guidebook (EEA, 2016).

Germany suffers relatively little wildfire damage in terms of burned area, and thus the relevant CH_4, N_2O, CO, NO and NMVOC gas emissions are low. The complete time series for greenhouse gases resulting from wildfires is shown in Table 367.

Table 367: Greenhouse gases emitted by wildfires

Year	Above-ground biomass	Dead wood	Litter	Wildfire burned area	Emitted gases [t]				
	[t ha^{-1}]			[ha]	CH_4	N_2O	CO	NOX	NMVOC
1990	170.9	14.0	38.0	1,606	353.31	19.54	8,043.39	225.52	710.40
1991	171.0	13.7	38.0	920	202.18	11.18	4,602.83	129.05	406.50
1992	171.2	13.3	38.0	4,908	1,077.45	59.60	24,529.28	687.74	2,166.40
1993	171.4	12.9	37.9	1,493	327.41	18.11	7,453.88	208.99	658.30

Year	Above-ground biomass	Dead wood	Litter	Wildfire burned area	Emitted gases [t]				
	[t ha^{-1}]			[ha]	CH_4	N_2O	CO	NOX	NMVOC
1994	171.5	12.5	37.9	1,114	244.04	13.50	5,555.84	155.77	490.70
1995	171.7	12.1	37.9	592	129.55	7.17	2,949.36	82.69	260.50
1996	171.9	11.8	37.9	1,381	301.89	16.70	6,872.92	192.70	607.00
1997	172.0	11.4	37.8	599	130.81	7.24	2,977.93	83.49	263.00
1998	172.2	11.0	37.8	397	86.60	4.79	1,971.60	55.28	174.10
1999	172.4	10.6	37.8	415	90.43	5.00	2,058.81	57.72	181.80
2000	172.6	10.2	37.8	581	126.47	7.00	2,879.27	80.73	254.30
2001	172.7	9.9	37.7	122	26.53	1.47	603.96	16.93	53.30
2002	172.9	9.5	37.7	122	26.52	1.47	603.81	16.93	53.30
2003	173.6	9.1	37.7	1315	286.09	15.83	6,513.03	182.61	575.20
2004	174.4	8.7	37.7	274	59.76	3.31	1,360.47	38.14	120.20
2005	175.1	8.3	37.6	183	40.01	2.21	910.97	25.54	80.50
2006	175.8	8.0	37.6	482	105.34	5.83	2,398.16	67.24	211.80
2007	176.6	7.6	37.6	254	55.93	3.09	1,273.33	35.70	112.50
2008	177.3	7.2	37.6	539	118.01	6.53	2,686.58	75.32	237.30
2009	179.3	6.8	37.5	262	167.04	9.24	3,802.89	106.62	335.90
2010	181.2	6.4	37.5	522	115.99	6.42	2,640.59	74.04	233.20
2011	183.2	6.1	37.5	214	47.89	2.65	1,090.30	30.57	96.30
2012	185.2	5.7	37.5	269	60.53	3.35	1,377.95	38.63	121.70
2013	187.0	5.9	37.4	199	45.17	2.50	1,028.30	28.83	90.80
2014	188.9	6.0	37.4	120	27.52	1.52	626.42	17.56	55.30
2015	190.7	6.2	37.4	526	121.53	6.72	2,766.84	77.57	244.40
2016	192.6	6.4	37.4	283	66.01	3.65	1,502.77	42.13	132.70
2017	194.4	6.6	37.3	395	92.86	5.14	2,114.11	59.27	186.70
2018	193.0	6.8	37.3	2349	549.51	30.40	12,510.23	350.75	1,104.90
2019	191.5	7.0	37.3	2711	630.80	34.90	14,360.80	402.64	1,268.30
2020	190.1	7.2	37.3	368	85.08	4.71	1,936.93	54.31	171.10
2021	188.6	7.3	37.2	148	34.02	1.88	774.42	21.71	68.40
2022	187.2	8.4	37.2	3058	702.52	38.86	15,993.49	448.42	1,412.50
2023	185.7	8.8	37.2	1,240	283.57	15.69	6,455.79	181.00	570.20
2024	184.3	9.1	37.2	334	76.37	4.22	1,738.66	48.51	152.82

6.4.3 Uncertainties and time series consistency (4.A)

Various uncertainties have to be taken into account in the calculation of carbon stocks. The actual uncertainties, however, can only be approximated using pragmatic approaches.

The uncertainties described in the following chapters are included in a total error budget for the LULUCF sector that is presented in Chapter 6.1.2.10.

With regard to the uncertainties in the carbon conversion factor, cf. Chapter 6.4.2.2.6.

When aggregated, error estimates (U) for values (1, …, i, …, I) propagate themselves in two different ways. When two values are added or subtracted, the error propagation is additive (cf. Equation 89):

Equation 89:

$$U = \frac{\sqrt{\sum_i (U_i x_i)^2}}{\sum_i x_i}$$

- U = Total uncertainty

- U_i = Uncertainty for target value
- x_i = Quantity of target value

On the other hand, when two values are multiplied or divided, the errors for the two values propagate themselves multiplicatively (cf. Equation 90).

Equation 90:

$$U = \sqrt{\sum_i (U_i)^2}$$

- U = Total uncertainty
- U_i = Uncertainty for target value

6.4.3.1 Uncertainties in estimation of areas affected by land-use changes

The land-use changes are determined by a sample-based system, meaning it was possible to calculate the sampling errors for each LULUCF category. The sampling error is calculated in accordance with the formulae in Chapter 6.4.3. Once validation has been completed, all other error sources can be ruled out (cf. also Chapter 6.3.1.3). All areas have been recorded significantly.

6.4.3.2 Uncertainties in estimation of emission factors of living and dead biomass

Since biomass cannot be directly measured, a number of error sources enter the processes of deriving forest biomass and carbon stocks and of deriving changes in forest biomass and carbon stocks. The errors in the biomass functions and carbon conversion factor are listed and discussed in Chapters 6.4.2.2.4, 6.4.2.2.5 and 6.4.2.2.6. The errors in biomass conversion factors for dead wood, broken down by tree species and degrees of decomposition, are given in Chapter 6.4.2.3.

The specific errors for the tree species groups are added to the uncertainties for the above-ground and below-ground biomass and then aggregated to yield an error figure for the total biomass. As the biomass stocks at the first time point are subtracted from the stocks at the second time point, the uncertainty for the biomass change is obtained by addition. The error for the total biomass change is multiplied by the error for the carbon conversion factor and by the sampling error. The sampling error is derived from the variance in the sample.

The following tables show the uncertainties for the individual error sources and for the resulting emission factor.

Table 368: Uncertainties in emission factors for living biomass on Forest Land remaining Forest Land, for various periods

1987-2002	Error % (biomass conversion)						Error % (C)	SE %	RMSE%
Old German federal states	Spruce	Pine	Beech	Oak	Softwood$_{F}$ oliage	All			
Biomass$_{above-ground}$	7.96	11.06	13.39	8.62	36.07	7.04	2.00	6.47	9.77
Biomass$_{below-ground}$	24.52	18.63	34.86	35.60	17.41	13.53	2.00	6.24	15.03
Emission factor						6.67	2.00	5.68	8.76
1993-2002	**Error % (biomass conversion)**						**Error % (C)**	**SE %**	**RMSE%**

1987-2002	Error % (biomass conversion)						Error % (C)	SE %	RMSE%
New German federal states	Spruce	Pine	Beech	Oak	$Softwood_{Foliage}$	All			
$Biomass_{above-ground}$	11.34	24.66	17.35	12.93	37.15	9.03	2.00	5.43	10.73
$Biomass_{below-ground}$	30.38	27.74	38.90	43.94	22.49	16.82	2.00	5.93	17.97
Emission factor						8.16	2.00	5.51	10.05
2002-2008	**Error % (biomass conversion)**						**Error % (C)**	**SE %**	**RMSE%**
Germany	**Spruce**	**Pine**	**Beech**	**Oak**	**$Softwood_{Foliage}$**	**All**			
$Biomass_{above-ground}$	7.95	11.05	13.30	8.57	35.39	13.69	2.00	23.30	27.10
$Biomass_{below-ground}$	24.47	18.60	34.67	35.39	17.15	18.28	2.00	13.50	22.82
Emission factor						11.71	2.00	18.83	22.17
2008-2012	**Error % (biomass conversion)**						**Error % (C)**	**SE %**	**RMSE%**
Germany	**Spruce**	**Pine**	**Beech**	**Oak**	**$Softwood_{Foliage}$**	**All**			
$Biomass_{above-ground}$	7.95	11.04	13.30	8.57	35.39	6.19	2.00	8.36	10.59
$Biomass_{below-ground}$	24.47	18.60	34.65	35.38	17.15	12.64	2.00	8.93	15.60
Emission factor						5.99	2.00	7.40	9.52
2012-2017	**Error % (biomass conversion)**						**Error % (C)**	**SE %**	**RMSE%**
Germany	**Spruce**	**Pine**	**Beech**	**Oak**	**$Softwood_{Foliage}$**	**All**			
$Biomass_{above-ground}$	7.94	11.05	13.30	8.56	35.39	6.73	2.00	7.62	10.36
$Biomass_{below-ground}$	24.47	18.61	34.67	35.38	17.15	12.33	2.00	6.31	14.00
Emission factor						6.33	2.00	6.54	9.10

Table 369: Uncertainties in emission factors for living biomass on afforestation areas, for various periods

1987-2002	Error % (biomass conversion)						Error % (C)	SE %	RMSE%
Old German federal states	Spruce	Pine	Beech	Oak	$Softwood_{Foliage}$	All			
$Biomass_{above-ground}$	11.23	15.62	18.80	12.10	50.00	18.63	2.00	19.37	26.95
$Biomass_{below-ground}$	34.60	26.30	49.00	50.00	24.23	17.31	2.00	18.92	25.72
Emission factor						15.99	2.00	-16.52	22.99
2002-2008	**Error % (biomass conversion)**						**Error % (C)**	**SE %**	**RMSE%**
Germany	**Spruce**	**Pine**	**Beech**	**Oak**	**$Softwood_{Foliage}$**	**All**			
$Biomass_{above-ground}$	11.23	15.62	18.80	12.10	50.00	26.79	2.00	48.70	55.62
$Biomass_{below-ground}$	34.60	26.30	49.00	50.00	24.23	18.68	2.00	44.38	48.20
Emission factor						21.86	2.00	-39.98	45.57
2008-2012	**Error % (biomass conversion)**						**Error % (C)**	**SE %**	**RMSE%**
Germany	**Spruce**	**Pine**	**Beech**	**Oak**	**$Softwood_{Foliage}$**	**All**			
$Biomass_{above-ground}$	11.23	15.62	18.80	12.10	50.00	20.13	2.00	18.05	27.11
$Biomass_{below-ground}$	34.60	26.30	49.00	50.00	24.23	17.82	2.00	20.10	26.94
Emission factor						17.48	2.00	-15.67	23.48
2012-2017	**Error % (biomass conversion)**						**Error % (C)**	**SE %**	**RMSE%**

1987-2002	Error % (biomass conversion)						Error % (C)	SE %	RMSE%
Germany	Spruce	Pine	Beech	Oak	$Softwood_{Foliage}$	All			
$Biomass_{above-ground}$	11.23	15.62	18.80	12.10	50.00	17.88	2.00	38.43	42.43
$Biomass_{below-ground}$	34.60	26.30	49.00	50.00	24.23	16.30	2.00	37.11	40.58
Emission factor						15.24	2.00	-32.55	35.95

Table 370: Uncertainties in emission factors for living biomass on deforestation areas, for various periods

1987-2002	Error % (biomass conversion)						Error % (C)	SE %	RMSE%
Old German federal states	Spruce	Pine	Beech	Oak	$Softwood_{Foliage}$	All			
$Biomass_{above-ground}$	11.23	15.62	18.80	12.10	50.00	9.41		17.45	19.93
$Biomass_{below-ground}$	34.60	26.30	49.00	50.00	24.23	16.90		19.68	26.02
Emission factor						8.63	2.00	15.13	17.42
2002-2008	**Error % (biomass conversion)**						**Error % (C)**	**SE %**	**RMSE%**
Germany	**Spruce**	**Pine**	**Beech**	**Oak**	**$Softwood_{Foliage}$**	**All**			
$Biomass_{above-ground}$	11.23	15.62	18.80	12.10	50.00	9.13	2.00	23.98	25.73
$Biomass_{below-ground}$	34.60	26.30	49.00	50.00	24.23	16.59	2.00	23.32	28.69
Emission factor						8.47	2.00	21.06	22.70
2008-2012	**Error % (biomass conversion)**						**Error % (C)**	**SE %**	**RMSE%**
Germany	**Spruce**	**Pine**	**Beech**	**Oak**	**$Softwood_{Foliage}$**	**All**			
$Biomass_{above-ground}$	11.23	15.62	18.80	12.10	50.00	12.58	2.00	22.66	26.00
$Biomass_{below-ground}$	34.60	26.30	49.00	50.00	24.23	24.07	2.00	20.98	31.99
Emission factor						11.63	2.00	20.17	23.29
2012-2017	**Error % (biomass conversion)**						**Error % (C)**	**SE %**	**RMSE%**
Germany	**Spruce**	**Pine**	**Beech**	**Oak**	**$Softwood_{Foliage}$**	**All**			
$Biomass_{above-ground}$	11.23	15.62	18.80	12.10	50.00	10.06	2.00	28.69	30.47
$Biomass_{below-ground}$	34.60	26.30	49.00	50.00	24.23	19.01	2.00	27.57	33.55
Emission factor						9.37	2.00	25.52	27.18

Table 371: Uncertainties of emission factors for dead wood, for various periods

	Error % (biomass conversion)													Error % (C)	SE %	RMSE %
Germany	EI1	EI2	EI3	EI4	L1	L2	L3	L4	N1	N2	N3	N4	All			
Remaining Forest Land 2008-2012	8.59	30.60	24.09	47.41	8.63	30.58	23.76	47.01	12.95	19.81	25.08	17.85	8.59	2.00	26.37	27.80
Remaining Forest Land 2012-2017	8.91	30.73	23.82	52.92	8.89	30.83	23.61	46.96	12.37	19.75	25.08	18.00	10.03	2.00	22.56	24.77
Afforestation 2008-2012	0.00	0.00	0.00	0.00	0.00	0.00	33.33	65.38	17.20	27.92	35.46	25.20	18.81	2.00	41.38	45.50
Afforestation 2012-2017	0.00	0.00	0.00	0.00	0.00	0.00	0.00	65.38	0.00	0.00	0.00	0.00	65.38	2.00	98.02	117.84
Deforestation 2008-2012	0.00	0.00	0.00	0.00	12.07	43.24	33.33	65.38	0.00	27.92	35.46	25.20	19.82	2.00	46.73	50.80
Deforestation 2012-2017	0.00	0.00	0.00	0.00	0.00	43.24	33.33	65.38	17.20	27.92	35.46	25.20	16.58	2.00	49.56	52.30

where N = conifers (Nadelholz), L = deciduous trees (Laubholz), but not including oak, EI = oak (Eiche) and 1 – 4 = degree of decomposition

6.4.3.3 Uncertainties in estimation pertaining to emission factors of litter and mineral soils

Chapter 6.4.2.5.3.7 describes a holistic view of the uncertainties in mineral soil and litter. The following chapters focus on specific aspects of the calculation of uncertainties.

6.4.3.3.1 Sampling error

In soil sampling, proper separation of litter and mineral soil can be challenging since the conversion category between the two compartments is not always unambiguously identifiable. This is even more problematic because the carbon concentration of the litter differs considerably from that in the underlying mineral soil. In sampling, imprecise or improper separation of litter from mineral soil can thus have major impacts on the carbon stocks measured in the relevant horizon or depth layer.

6.4.3.3.2 Small-scale variability

Due to the high spatial variability in litter and mineral soil, and because carbon stocks maintain spatial continuity only over short distances, determining carbon stocks in these compartments is subject to a high degree of uncertainty. For litter in a beech forest, Schöning et al. (2006) calculated stocks of 4.0 t C ha^{-1}, with a variation coefficient of 38%. In mineral soil (0-36 cm), they found carbon stocks of 64.0 t C ha^{-1}, with variation coefficients between 30% and 43%. Similar values were recorded by Liski (1995). He showed that carbon stocks under spruce within a given horizon were spatially independent as of a distance of 8 m.

6.4.3.3.3 Representativeness of points within strata

One problem in carrying out analysis in accordance with dominant soil units resulted from the different degrees to which classes were represented. Small classes lack statistical validity with respect to a major basic totality. Where no comparison between Forest Soil Inventory I and Forest Soil Inventory II (BZE I-Wald and BZE II-Wald) data was possible due to a lack of data, it was not possible to include the relevant forested dominant soil unit area in the calculation. In addition, it was not possible to have all dominant soil units represented since some are found only on small areas of Germany's territory. Overall, as a result of these difficulties, 4.3% of the forest area was not taken into account in this context.

6.4.3.3.4 Sampling error

The carbon stock changes for litter were calculated based on stratified unpaired samples. A sampling error of 0.02 t C ha^{-1} a^{-1}, or 100%, was obtained.

In the calculation of carbon stock changes in mineral soils, the overall sample was divided into a set of paired and a set of unpaired samples. In addition, stratification was carried out, by dominant soil units and the two sample sets. Overall, the sampling error for mineral soils amounted to 0.037 t C ha^{-1} a^{-1}, or 9%.

6.4.3.3.5 Quantification of methodologically related uncertainties

Another source of uncertainty, in addition to the sampling variance, consists of discrepancies in individual measurements which originate in measuring methods and processes. A group of several samples taken independently at the same location would exhibit fluctuations in both the carbon concentration and fine soil fraction throughout a range determined by the precision of the measuring equipment and the methods being used. This fluctuation range in the measurement of carbon concentrations was quantified on the basis of the results of ring analyses (Blum & Heinbach, 2006, 2007b). In the ring analyses for BZE II-Wald, the repeatability standard deviation was determined as the mean within-laboratory standard deviation (DIN ISO 5725 2, (Normung, 2022)) of several carbon measurements, and the reference

standard deviation was determined as the standard deviation of the mean values of the measurements. The reproducibility standard deviation was calculated from those standard deviations. The reproducibility standard deviation serves as a suitable estimate of the measurement uncertainty. The reproducibility standard deviations for mineral soil measurements were as follows: 0.9 g kg^{-1} for (i.e. for measurements in) lime-free soils, 2.9 g kg^{-1} for calcareous soils and 20.2 g kg^{-1} for organic surface layers. With regard to the Forest Soil Inventory I (BZE I-Wald), the values provided by Wolff and Riek (1997) were used, including coefficients of variation ranging from 5 to 20% for carbon measurements in mineral soils and from 5 to 10% for carbon measurements in organic surface layers. The mean values of these coefficients were used in each case. No ring analyses results were available as a basis for the calculation of the uncertainties of fine soil fractions. For this reason, all the BZE points where fine soil fraction results were available at both relevant inventory time points were selected. The mean deviation between these two measurements was then calculated. The mean deviation was 193 ± 35 t ha^{-1}. For conservative error estimation, it was assumed that the fine soil fractions did not change between the two inventories and that the mean deviation plus its spread serves as a measure of the uncertainty in the measurement of fine soil fractions. The uncertainty in the annual carbon change rate was expanded to include the uncertainties in the relevant individual measurements.

The uncertainties in estimation of the annual carbon change rate in mineral soils were as follows: for the sampling variance, 0.037 t C ha^{-1} a^{-1}; for the laboratory analysis for carbon determination at the time of the BZE I-Wald, 0.058 t C ha^{-1} a^{-1}; for this analysis at the time of the BZE II-Wald, 0.056 t C h^{-1} a^{-1}; and for determination of fine soil fractions, 0.05 t C ha^{-1} a^{-1}. These uncertainties yielded a total uncertainty of 0.11 t C ha^{-1} a^{-1}. The total uncertainty in estimation of the annual carbon change rate in the organic surface layer was 0.035 t C ha^{-1} a^{-1}.

6.4.3.4 Time series consistency

The following conditions are applied to the consistency of the time series:

- Throughout the entire time series, the emissions were calculated a) either with the same method or with methods that yield the same results within an overlap range (overlap method); and b) either with the same data sources or with mutually consistent data sources.
- If any changes are made in a method, recalculations should be carried out with the new method throughout the entire time series.
- New data, such as data from repeat inventories, must be consistent with earlier data.
- If new data becomes available that leads to an improvement in the inventory, a recalculation should be carried out throughout the entire time series.
- If any errors are identified in estimates, they must be corrected and the entire pertinent time series recalculated.

These conditions have been systematically applied to all time series of the submission. Any large differences between corresponding values of two successive years of a time series are due to data periodicity within consistent time series. This is because the same method and the same data sets have been used for all years of these time series.

6.4.4 Category-specific QA/QC and verification (4.A)

The QC/QA measures carried out for the entire LULUCF sector are set forth in Chapter 6.1.3.

The data sources used in preparation of this inventory fulfil the review criteria of the QSE manual for data sources (QSE-Handbuch für Datenquellen). Quality assurance for input data (ATKIS®, BÜK, official statistics, wildfire statistics; cf. Chapter 6.4.2.1) is the responsibility of the relevant data administrators (cf. the documentation in the inventory description).

Complete error analysis was carried out for the LULUCF sector, and an attempt was made to quantify all existing sources of error. This included error calculations from the forest categories for biomass, dead wood, litter, mineral soils, organic soils and wildfires, and the greenhouse gases CO_2, N_2O and CH_4. In Chapter 6.1.2.10, a total error budget is presented that summarises the results of error analysis.

6.4.4.1 Biomass and dead wood

The estimates of carbon stocks and carbon-stock changes in the biomass and dead wood pools at the various relevant times are based on the upscaling that was carried out at the Thünen Institute for Forest Ecosystems (TI-WO) using data from the NFIs, the 2008 Inventory Study and the 2017 Carbon Inventory. In the process, the stocks on a nationwide, permanent, systematic sample grid are repeatedly measured. In every case, a distinction is made between Forest Land remaining Forest Land, afforestation, and deforestation, with calculations carried out separately for each area. In the 2022 NFI, some 521,000 trees were surveyed on a total of around 80,000 sample plots. The stock changes are derived from the stocks. In each case, the stock change is the net change between the stocks of relevant individual inventory years. It includes growth, the wood harvest and losses from natural disturbances such as storms and mortality. Extensive quality controls are carried out for the purpose of substantiating the results:

- quality checks during field surveys
- quality checks for the collected data sets
- plausibility checks

With regard to the quality assurance developed for the NFI, refer to the literature for the National Forest Inventory (BMELV, 2005) and to https://bundeswaldinventur.de and https://bwi.info.

6.4.4.2 Litter and mineral soils

In order to achieve a consistent laboratory-analysis standard in the analysis of sampling carried out in the framework of the forest soil inventories, a ring analysis was initiated. To this end, all laboratories underwent a quality test carried out by the forestry analysis auditors' committee (Gutachterausschuss Forstliche Analytik) (Blum and Heinbach (2006), (Blum & Heinbach, 2007a)). To ensure the comparability of the applicable laboratory methods, only laboratories that participated successfully in the ring analysis were permitted to carry out analysis. Germany also participated in a similar ring analysis at the European level (Cools et al., 2006).

To harmonise laboratory measurements and topographical surveys, rules for determining relevant parameters were defined for participating laboratories in the framework of the BZE II Forest Soil Inventory. This was done with a view to preventing any discrepancies resulting from use of different analysis equipment or methods (König et al. (2005), Wellbrock et al. (2006)). Previous ring analyses served as the basis for approving analytics laboratories. A similar approach was taken with regard to field sampling. On the basis of various preliminary studies, suitable sampling methods were defined, specified and described in a field-sampling manual (Wellbrock et al., 2006).

Additional information is presented in Chapter 6.4.2.5.3.7.

6.4.4.3 Comparison with results of other countries

A comparison with the results of other countries can yield a basic context for understanding the circumstances prevailing in Germany. In the category 'Land converted to Forest Land' in particular, the methods and procedures used to deal with conversion time (transition time) vary widely, meaning that results in this area tend not to lend themselves directly to comparison.

The following tables present an intra-European comparison of implied emission factors (IEFs) for various pools. The comparison data for the carbon stock changes of other countries are obtained from the national inventory reports of countries neighbouring Germany. The emission factors for 2023 have been obtained from the 2025 submission to the UN Climate Secretariat; the 2024 data for Germany have been obtained from the 2026 submission.

Table 372: Carbon-stock changes in living biomass in forests of various countries (Germany, for 2023 & 2024; other countries, for 2023), in [t C ha^{-1} a^{-1}]

	4.A.1 - Forest Land remaining Forest Land	4.A.2 - Land converted to Forest Land	4.A.2.1. - Cropland converted to Forest Land	4.A.2.2. - Cropland converted to Forest Land	4.A.2.3. - Wetlands converted to Forest Land	4.A.2.4. - Settlements converted to Forest Land	4.A.2.5. - Other Land converted to Forest Land
Belgium	0.521	3.821	3.948	3.591	4.169	4.624	NO
Denmark	1.257	2.501	2.494	2.575	2.725		
France	0.247	0.711	0.963	0.444	1.054	1.124	1.000
United Kingdom	0.738	0.736	0.758	0.733	NO	0.726	NO
Netherlands	1.042	3.474	3.681	3.289	3.822	3.906	3.780
Austria	-0.252	1.080	1.078	1.080	1.081	1.079	1.079
Poland	1.026	0.907	0.742	1.461	NO	NO	NO
Switzerland	0.181	0.419	-0.247	0.443	0.025	-0.205	0.437
Czech Republic	0.272	2.349	2.494	2.575	2.725		
Germany, 2023	-0.630	0.640	3.290	0.470	-1.730	2.450	4.160
Germany, 2024	-0.062	0.790	2.620	0.590	-0.250	3.430	3.170

Positive: carbon removal by sink; negative: carbon emission by source; Source: (UNFCCC, 2023c)

Table 373: Carbon-stock changes in dead wood in forests of various countries (Germany, for 2023 & 2024; other countries, for 2023), in [t C ha^{-1} a^{-1}]

	4.A.1 - Forest Land remaining Forest Land	4.A.2 - Land converted to Forest Land	4.A.2.1. - Cropland converted to Forest Land	4.A.2.2. - Cropland converted to Forest Land	4.A.2.3. - Wetlands converted to Forest Land	4.A.2.4. - Settlements converted to Forest Land	4.A.2.5. - Other Land converted to Forest Land
Belgium	NA	0.04	0.037	0.048	0.032	0.012	NO
Denmark	0.029	0.002	0.002	0.002	0.002		
France	0.164	0.211	0.245	0.172	0.334	0.258	0.385
United Kingdom	0.295	0.022	0.023	0.022	NO	0.022	NO
Netherlands	0.099	0.13	0.132	0.129	0.128	0.137	0.123
Austria	0.067	0.057	0.053	0.059	0.062	0.054	0.056
Poland	0.086	NA, NO	NA	NA	NO	NO	NO
Switzerland	-0.019	0.202	0.275	0.191	0.387	0.455	0.24
Czech Republic	-0.122	0.063	0.002	0.002	0.002		
Germany, 2023	0.26	0.09	0.09	0.08	0.09	0.09	0.07
Germany, 2024	0.13	0.1	0.1	0.1	0.02	0.1	0.13

Positive: carbon removal by sink; negative: carbon emission by source; Source: (UNFCCC, 2023c)

Table 374: Carbon-stock changes in litter in forests of various countries (Germany, for 2023 & 2024; other countries, for 2023), in [t C ha^{-1} a^{-1}]

	4.A.1 - Forest Land remaining Forest Land	4.A.2 - Land converted to Forest Land	4.A.2.1. - Cropland converted to Forest Land	4.A.2.2. - Cropland converted to Forest Land	4.A.2.3. - Wetlands converted to Forest Land	4.A.2.4. - Settlements converted to Forest Land	4.A.2.5. - Other Land converted to Forest Land
Belgium	NA	0.159	0.147	0.19	0.126	0.048	NO
Denmark	0.123	0.512	0.506	0.566	0.618		
France	0.004	0.394	0.393	0.404	0.206	0.368	0.176
United Kingdom	0.044	0.032	0.022	0.034	NO	0.029	NO
Netherlands	0.055	1.14	1.14	1.14	1.14	1.14	1.14
Austria	IE, NA	1.214	1.15	1.256	0.951	1.238	1.222
Poland	NO	NA, NO	NA	NA	NO	NO	NO
Switzerland	-0.268	0.747	0.576	0.751	0.718	0.64	0.732
Czech Republic	-0.031	0.271	0.506	0.566	0.618		
Germany, 2023	IE	IE	IE	IE	IE	IE	IE
Germany, 2024	IE	IE	IE	IE	IE	IE	IE

Positive: carbon removal by sink; negative: carbon emission by source; Source: (UNFCCC, 2023c)

Table 375: Carbon-stock changes in mineral soils of various countries (Germany, for 2023 & 2024; other countries, for 2023), in [t C ha^{-1} a^{-1}]

	4.A.1 - Forest Land remaining Forest Land	4.A.2 - Land converted to Forest Land	4.A.2.1. - Cropland converted to Forest Land	4.A.2.2. - Cropland converted to Forest Land	4.A.2.3. - Wetlands converted to Forest Land	4.A.2.4. - Settlements converted to Forest Land	4.A.2.5. - Other Land converted to Forest Land
Belgium	NA	0.795					
Denmark	NA	0.155	0.212	0.167	NO		
France	0.005	0.537	1.073	0.001	0.188	1.48	0.205
United Kingdom	0.437	-0.886	-0.913	-0.896	NO	-0.887	NO
Netherlands	NA	0.26		-0.071			
Austria	-0.276	0.658	0.989	-0.76	NO	2.717	2.203
Poland	0.072	0.469					
Switzerland	0.018	2.112					
Czech Republic	0.039	0.27	0.212	0.167	NO		
Germany, 2023	0.003	0.483	1.156	0.323	-0.614	2.212	3.928
Germany, 2024	-0.067	0.503	1.161	0.376	-0.417	1.29	3.75

Positive: carbon removal by sink; negative: carbon emission by source; Source: (UNFCCC, 2023c)

Table 376: Carbon-stock changes in organic soils of various countries (Germany, for 2023 & 2024; other countries, for 2023), in [t C ha^{-1} a^{-1}]

	4.A.1 - Forest Land remaining Forest Land	4.A.2 - Land converted to Forest Land	4.A.2.1. - Cropland converted to Forest Land	4.A.2.2. - Cropland converted to Forest Land	4.A.2.3. - Wetlands converted to Forest Land	4.A.2.4. - Settlements converted to Forest Land	4.A.2.5. - Other Land converted to Forest Land
Belgium	NO	NO					
Denmark	-1.357	-1.738	-1.378	-1.378	-1.378		
France	NO	NO	NO	NO	NO	NO	NO
United Kingdom	0.094	-2.145	-2.108	-2.147	NO	-2.153	NO

	4.A.1 - Forest Land remaining Forest Land	4.A.2 - Land converted to Forest Land	4.A.2.1. - Cropland converted to Forest Land	4.A.2.2. - Cropland converted to Forest Land	4.A.2.3. - Wetlands converted to Forest Land	4.A.2.4. - Settlements converted to Forest Land	4.A.2.5. - Other Land converted to Forest Land
Netherlands	-0.875	-0.882	0	-0.884	0		
Austria	IE,NO	NO	NO	NO	NO	NO	NO
Poland	-0.68	-0.68					
Switzerland	-0.078	-0.078					
Czech Republic	NO	NO	-1.378	-1.378	-1.378		
Germany, 2023	-2.89	-2.87	-2.86	-2.87	-2.88	-2.84	-2.89
Germany, 2024	-2.88	-2.87	-2.91	-2.87	-2.87	-2.8	-2.89

Positive: carbon removal by sink; negative: carbon emission by source; Source: (UNFCCC, 2023c)

6.4.5 Category-specific recalculations (4.A)

This year's submission includes category-specific recalculations for the entire period 1990-2024. The emissions were recalculated in order to take account of new and improved data sources, changes in methods, and error corrections made as part of ongoing inventory improvements. The measures listed in Chapter 6.1.3.4.2, Table 338 affected the results of the emissions calculations for the Forest Land land-use category:

In Table 377 (areas) and Table 378 (emissions), the results of the current recalculations for the Forest Land category are compared with the corresponding results in the previous year's submission.

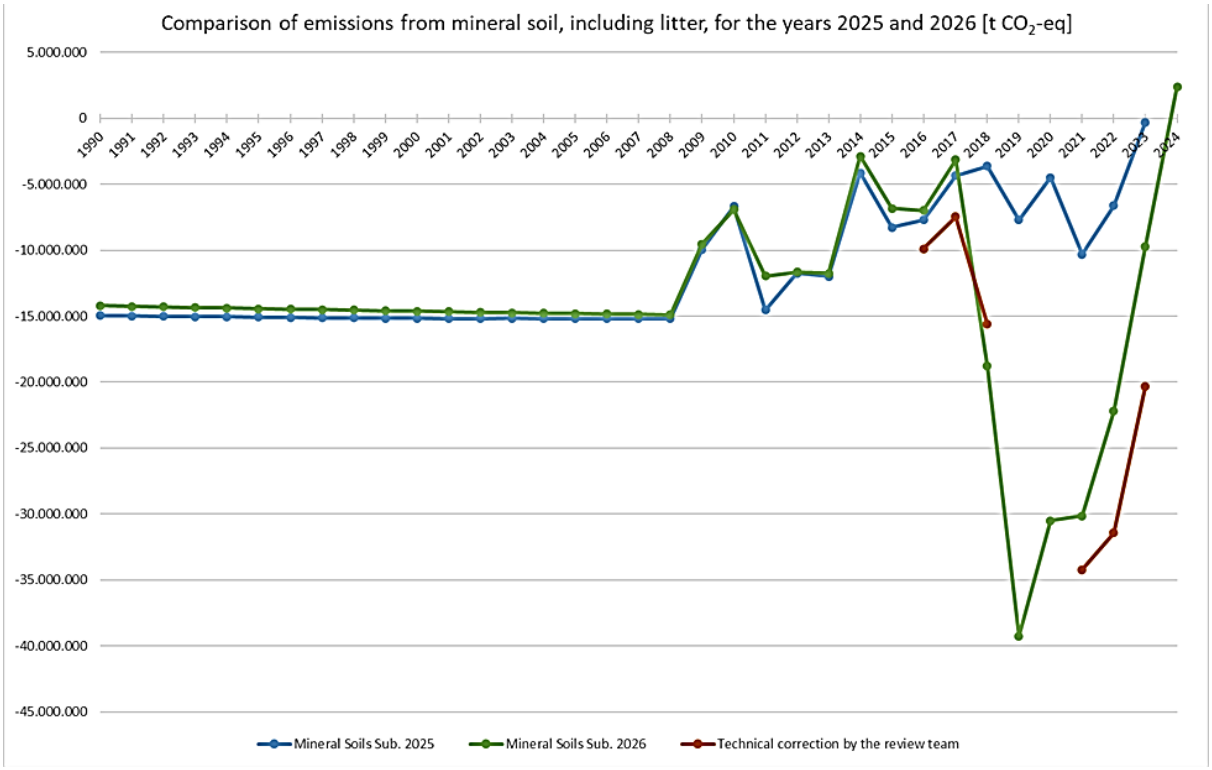
The slight differences between the area data of the current and previous year's submissions (< 1% throughout the entire time series) are due mainly to correction algorithms. They became necessary in connection with updating the map data to determine activity data as a result of integrating the newly added data of the last time series year. It is assumed that the most recent data is of highest quality and therefore the previous time series is adjusted if necessary (cf. also Chapters 6.3.1 ff).

The differences affecting GHG emissions are mainly due to the modification of the input data for the computer-aided modelling using YASSO15 to calculate the emissions from mineral soils and litter.

The European Commission's review of the inventory in the 2025 submission identified the following issue: "The changes in the mineral SOC stock in 4A1 are estimated using the Yasso model. To apply the model, the federal state estimates the annual carbon inputs up to the year 2013 that include, among other things, mortality and harvest. For the years after 2014, a constant input was used, based on the average inputs between 2009 and 2013. Due to the significant changes in mortality and harvest in German forests since 2013, this extrapolation is highly likely to distort mineral stock changes in recent years." The review team therefore calculated a technical correction, the results of which are given in Figure 90.

In this submission, we adapted the input data to account for the actual development of harvest and mortality. This leads to larger changes in mineral soil and litter emissions in the latest 2025 submission. These results are also shown in Figure 90.

Figure 90: Comparison of emissions from mineral soil including litter for the 2025 and 2026 submissions



Source: own illustration, Thünen-Institut

When modelling organic soil carbon in forests, there have been significant changes compared with the previous year (1) in the annual change to organic input resulting from forest management and (2) in the consideration and modelling of dead wood.

1. Instead of applying the harvest factors derived from forest management up to 2013 and then using averages thereafter, the period of annual harvest factors has been extended up to 2024. This results in increased carbon accumulation in the simulation period 2018-2023, which coincides with a period of high forest biomass removal driven by ecological disturbances.
2. In the modelling using Yasso15, dead wood is now taken into account at the initialisation stage and subsequently subtracted from the simulation results. This is also the case for the simulation period 2018-2023 where a far more significant and unrealistic increase would occur without reducing the amount of dead wood. In addition, dead wood is covered separately (Chapter 6.4.2.3).

Table 377: Comparison of the land-use matrix as reported in the 2025 and 2026 submissions

Area [kha]	submission	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Forest land	2025	10,680	10,732	10,785	10,793	10,813	10,824	10,864	10,871	10,877	10,884
	2026	10,631	10,676	10,720	10,763	10,807	10,818	10,857	10,863	10,869	10,875
	Difference	-49	-57	-65	-29	-6	-6	-7	-8	-8	-9
	in %	-0.46%	-0.53%	-0.61%	-0.27%	-0.05%	-0.05%	-0.07%	-0.07%	-0.08%	-0.08%

Table 378: Comparison of emissions as reported in the 2025 and 2026 submissions [kt CO_2-eq.]

CRF No. 4.A Forest Land				
CO_2	**2025 submission**	**2026 submission**	**Difference**	**in %**
1990	-25,836.72	-26,920.55	-1,083.82	4%
1995	-68,584.44	-69,352.90	-768.46	1%
2000	-52,287.25	-53,251.16	-963.91	2%
2005	-33,495.41	-33,804.86	-309.45	1%
2010	-40,591.00	-40,167.48	423.51	-1%
2015	-47,836.64	-45,317.30	2,519.34	-5%
2020	23,796.03	-2,395.67	-26,191.70	-110%
2021	15,572.54	-4,723.27	-20,295.81	-130%
2022	18,319.81	2,207.91	-16,111.91	-88%
2023	20,478.91	7,117.72	-13,361.19	-65%
CH_4	**2025 submission**	**2026 submission**	**Difference**	**in %**
1990	33.15	32.44	-0.71	-2.16%
1995	26.99	26.51	-0.48	-1.78%
2000	27.00	26.83	-0.17	-0.63%
2005	24.75	24.82	0.07	0.27%
2010	27.30	27.36	0.06	0.23%
2015	27.67	27.70	0.03	0.11%
2020	27.11	27.11	0.00	0.01%
2021	25.71	25.71	0.00	0.01%
2022	44.46	44.44	-0.02	-0.04%
2023	32.77	32.73	-0.05	-0.14%
N_2O	**2025 submission**	**2026 submission**	**Difference**	**in %**
1990	440.81	435.49	-5.32	-1.21%
1995	430.81	414.81	-16.00	-3.71%
2000	436.13	426.03	-10.11	-2.32%
2005	430.24	419.82	-10.41	-2.42%
2010	381.16	379.89	-1.27	-0.33%
2015	371.52	391.96	20.45	5.50%
2020	378.51	374.41	-4.10	-1.08%

CRF No. 4.A Forest Land				
2021	346.44	342.31	-4.14	-1.19%
2022	386.79	393.42	6.63	1.71%
2023	414.47	334.17	-80.30	-19.37%

6.4.6 Category-specific planned improvements (4.A)

Beyond the planned measures listed in Chapter 6.1.2.1.9, no specific measures for improvement of methods in the area of Forest Land are currently planned.

6.5 Cropland (4.B)

6.5.1 Category description (4.B)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
L/T	4 B, Cropland	0	CO_2	25,789.59	2.00	16,833.12	2.38	-34.73
-/-	4 B, Cropland	0	CH_4	413.90	0.04	312.23	0.05	-24.57
-/-/2	4 B, Cropland	0	N_2O	543.02	0.05	370.18	0.06	-31.83

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2/Tier 3	RS/NS	CS/D
N_2O	Tier 2	RS/NS	CS/D
CH_4	Tier 2/Tier 3	RS/NS	CS/D

The category *Cropland* (CRF 4.B) consists of the seven subcategories $Cropland_{annual}$, Hops, Vineyards, Orchards, Tree nurseries, Christmas tree plantations and Short-rotation plantations (cf. also Chapter 6.2.2, Chapter 6.3.1.2.1, Table 341). A stratified, itemised list of the emissions-calculations results for these subcategories is provided in the CRFs. The category is a key category for CO_2 emissions in terms of emissions level and trend, and a key category for N_2O emissions pursuant to Approach 2 analysis.

Reporting in the *Cropland* category covers emissions/removals of CO_2 from and to mineral and organic soils, and from and to above-ground and below-ground biomass. It also includes direct and indirect nitrous oxide emissions from humus losses from mineral soils following land-use conversions to Cropland, and it covers methane emissions from organic soils and drainage ditches. In accordance with the IPCC Guidelines (IPCC, 2006a), direct and indirect nitrous oxide emissions from fertiliser application (artificial fertiliser, manure, sewage sludge, etc.), crop residues and drainage of organic soils under cultivation are reported under Agriculture (CRF 3.D). For this reason, in the Cropland chapter, those categories are marked as “IE”. Burning of fields and crop residues is prohibited by law in Germany (Bundesanzeiger Verlag, 2004) and thus not reported (NO).

Emissions from the land-use category Cropland (the sum of $Cropland_{annual}$, Hops, Vineyards, Orchards, Tree nurseries, Christmas tree plantations and Short-rotation plantations) are listed separately by pool in Table 379 and in CRF tables 4, 4.B, 4(II).B and 4(III).B. The total emissions in 2024 in Germany amounted to 17,515.5 kt CO_2 equivalent. The main source of the emissions

from Cropland are the soils; for example, organic soils used as cropland contributed 61.8%, and mineral soils 32.7% to the total emissions, especially due to emissions resulting from management of permanent cropland. In the Cropland sector, the anthropogenically related net emissions of CO_2 from biomass are low (5.5%). No land-use changes from Forest Land to Cropland took place. As a result, no emissions from dead organic matter occurred.

Perennial crops account for a much smaller share (1%) of the total emissions from Cropland than annual crops (99%). In 2024, all of the Cropland subcategories were net sources (Table 379).

The predominating greenhouse gas in the Cropland sector is CO_2, accounting for 16,833.1 kt CO_2 equivalent (96.1%). The reported nitrous oxide emissions from decomposition of soil organic matter as a result of land-use change to Cropland are low by comparison (total of 370.2 kt CO_2-eq. ≙ 2.1%, consisting of direct (257.1 kt CO_2-eq. (CRF 4(III)) and indirect emissions (113.1 kt CO_2-eq. (CRF 4(III)); this also applies to methane emissions (312.2 kt CO_2-eq. ≙ 1.8% (CRF 4(II).B)) from use of organic soils).

Table 379: CO_2, N_2O and CH_4 emissions [kt CO_2-eq.] from Cropland in 2024. The table includes both the relevant sums and the upper and lower bounds of the 95% confidence interval.

Cropland$_{annual}$, emissions, 2024						
Category	**GHG**	**[kt CO_2-eq.]**			**[%]**	
		Emission	**2.5% perc.**	**97.5% perc.**	**2.5% perc.**	**97.5% perc.**
Cropland$_{annual}$ [1]	∑	17,345.9	14,051.9	19,878.4	19.0	14.6
Mineral soils	CO_2 [2]	5,263.5	4,510.3	6,016.7	14.3	14.3
	$N_2O_{indirect}$ [3]	111.5	0.1	345.4	99.9	209.7
	N_2O_{direct} [3]	253.4	46.7	460.1	81.6	81.6
Organic soil	CO_2 [2]	10,363.8	7,171.1	12,524.1	30.8	20.9
	CH_4 [5]	304.6	149.8	1,329.3	50.8	336.4
	N_2O [4]	IE	IE	IE	IE	IE
Biomass	CO_2 [2]	1,049.1	923.7	1,222.2	12.0	16.5
Litter/dead wood	CO_2 [2]	NO	NO	NO	NO	NO
Hops, emissions, 2024						
Category	**GHG**	**[kt CO_2-eq.]**			**[%]**	
		Emission	**2.5% perc.**	**97.5% perc.**	**2.5% perc.**	**97.5% perc.**
Hops [1]	∑	13.1	8.5	17.9	35.7	36.1
Mineral soils	CO_2 [2]	1.8	1.4	2.3	24.0	24.0
	$N_2O_{indirect}$ [3]	0.0	0.0	0.1	99.9	194.3
	N_2O_{direct} [3]	0.1	0.0	0.2	81.9	81.9
Organic soil	CO_2 [2]	8.4	3.7	12.8	56.5	53.2
	CH_4 [5]	0.5	0.2	2.4	55.7	339.6
	N_2O [4]	IE	IE	IE	IE	IE
Biomass	CO_2 [2]	2.3	0.0	4.7	99.9	108.7
Litter/dead wood	CO_2 [2]	NO	NO	NO	NO	NO
Vineyards, emissions, 2024						
Category	**GHG**	**[kt CO_2-eq.]**			**[%]**	

		Emission	2.5% perc.	97.5% perc.	2.5% perc.	97.5% perc.
Vineyards [1]	∑	66.3	56.9	76.6	14.3	15.4
Mineral soils	CO_2 [2]	36.4	32.3	40.5	11.3	11.3
	$N_2O_{indirect}$ [3]	0.3	0.0	0.8	99.9	156.9
	N_2O_{direct} [3]	0.7	0.3	1.2	62.7	62.7
Organic soil	CO_2 [2]	0.3	0.1	0.5	71.7	68.5
	CH_4 [5]	0.0	0.0	0.1	83.6	323.4
	N_2O [4]	IE	IE	IE	IE	IE
Biomass	CO_2 [2]	28.5	20.6	37.2	27.9	30.6
Litter/dead wood	CO_2 [2]	NO	NO	NO	NO	NO

Orchards, emissions, 2024

Category	GHG	[kt CO_2-eq.]			[%]	
		Emission	2.5% perc.	97.5% perc.	2.5% perc.	97.5% perc.
Orchards [1]	∑	21.0	18.8	23.2	10.5	10.7
Mineral soils	CO_2 [2]	-9.7	-8.8	-10.5	8.4	8.4
	$N_2O_{indirect}$ [3]	0.3	0.0	0.9	99.9	199.1
	N_2O_{direct} [3]	0.7	0.2	1.2	77.5	77.5
Organic soil	CO_2 [2]	56.0	36.3	73.6	35.3	31.4
	CH_4 [5]	3.5	1.9	13.6	47.5	286.6
	N_2O [4]	IE	IE	IE	IE	IE
Biomass	CO_2 [2]	-29.9	-26.7	-33.3	10.8	11.2
Litter/dead wood	CO_2 [2]	NO	NO	NO	NO	NO

Tree nurseries, emissions, 2024

Category	GHG	[kt CO_2-eq.]			[%]	
		Emission	2.5% perc.	97.5% perc.	2.5% perc.	97.5% perc.
Tree nurseries [1]	∑	39.3	35.4	43.0	10.0	9.5
Mineral soils	CO_2 [2]	61.4	53.8	68.9	12.3	12.3
	$N_2O_{indirect}$ [3]	0.9	0.0	2.4	99.9	168.1
	N_2O_{direct} [3]	2.0	0.7	3.4	65.5	65.5
Organic soil	CO_2 [2]	61.9	44.2	75.3	28.6	21.6
	CH_4 [5]	2.9	1.6	10.8	43.5	273.1
	N_2O [4]	IE	IE	IE	IE	IE
Biomass	CO_2 [2]	-89.8	-78.0	-101.8	13.2	13.3
Litter/dead wood	CO_2 [2]	NO	NO	NO	NO	NO

Christmas tree plantations, emissions, 2024

Category	GHG	[kt CO_2-eq.]			[%]	
		Emission	2.5% perc.	97.5% perc.	2.5% perc.	97.5% perc.
Christmas tree plantations [1]	∑	6.2	4.0	8.0	34.7	30.0
Mineral soils	CO_2 [2]	0.9	0.8	1.0	11.3	11.3
	$N_2O_{indirect}$ [3]	NO	NO	NO	NO	NO
	N_2O_{direct} [3]	NO	NO	NO	NO	NO
Organic soil	CO_2 [2]	5.3	2.9	7.0	44.1	31.8

	CH_4 [5]	0.3	0.1	1.4	69.3	448.7
	N_2O [4]	IE	IE	IE	IE	IE
Biomass	CO_2 [2]	-0.3	-0.2	-0.4	32.9	32.9
Litter/dead wood	CO_2 [2]	NO	NO	NO	NO	NO

Short-rotation plantations, emissions, 2024						
Category	**GHG**	**[kt CO_2-eq.]**			**[%]**	
		Emission	**2.5% perc.**	**97.5% perc.**	**2.5% perc.**	**97.5% perc.**
SRPs[1]	∑	23.8	19.4	28.1	18.5	18.3
Mineral soils	CO_2 [2]	0.5	0.3	0.6	29.7	30.6
	$N_2O_{indirect}$ [3]	0.1	0.0	0.2	99.9	222.8
	N_2O_{direct} [3]	0.1	0.0	0.2	95.5	95.5
Organic soil	CO_2 [2]	12.2	5.6	18.4	54.4	51.0
	CH_4 [5]	0.4	0.1	1.3	64.7	276.8
	N_2O [4]	IE	IE	IE	IE	IE
Biomass	CO_2 [2]	10.6	8.2	13.1	23.0	23.2
Litter / dead wood	CO_2 [2]	NO	NO	NO	NO	NO

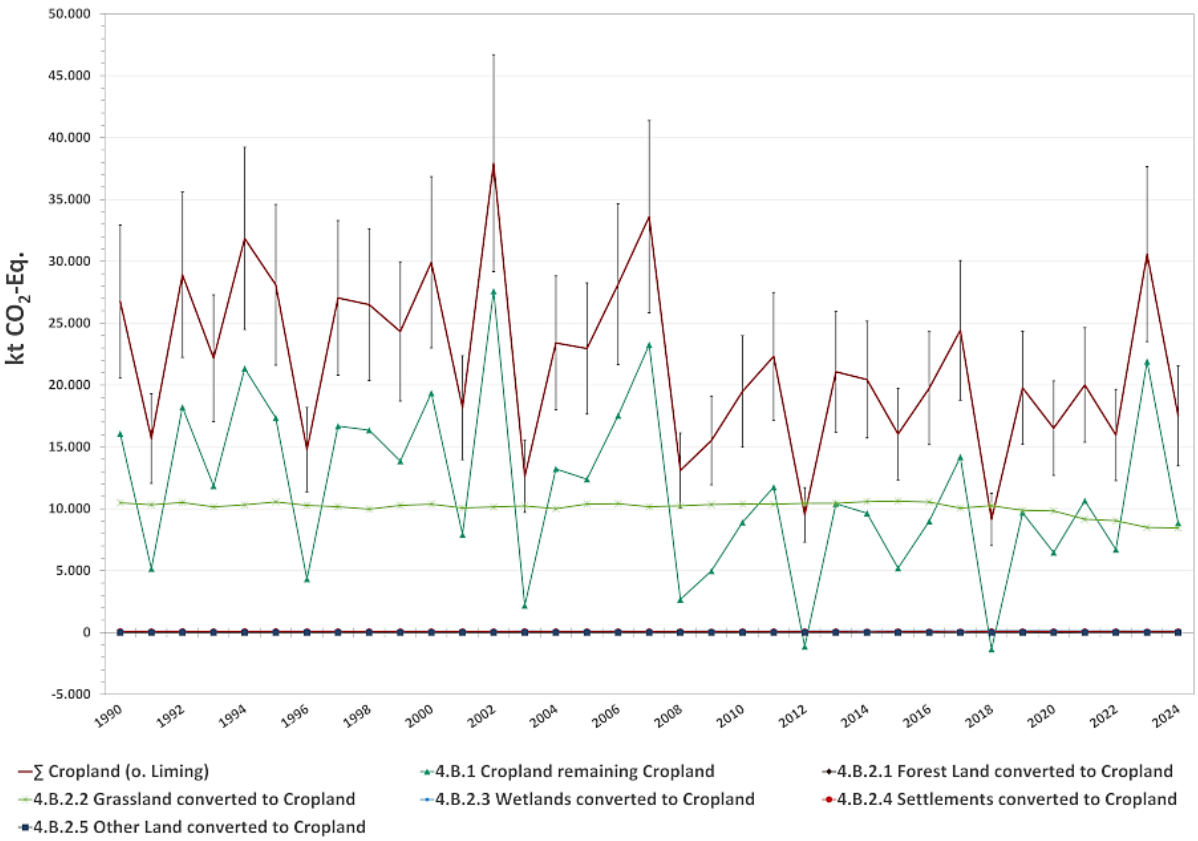
1) Sum of the emissions from CRF tables 4.B, 4.(II).B and 4.(III).B.
2) CRF 4.B
3) CRF 4.(III) B
4) CRF 3.D.1.f
5) CRF 4.(II) B

Figure 91 and Figure 92 show the trends over time in emissions from Cropland. The total emissions in 2024 were -9,231 kt CO_2-eq or ≙ -34.5% lower than in the base year 1990. The shape of the emissions plot broadly follows the plot of emissions from mineral soils, which typically exhibit pronounced annual variations mainly due to weather conditions. Despite the strong annual fluctuations in the emissions curve, the trend for GHG emissions from mineral soils under cropland shows a clear average decline between the base year 1990 and 2024 (approximately 62%) that is attributable to changes in weather conditions (increasing droughts), the reduction in cropland area (> 10,000 km^2-eq ≙ -8%) and a marked decrease in grassland tillage (area change: approx. -26%). Emissions from organic soils show little absolute difference in between 1990 and 2024. However, the increasing drought, particularly in extreme years (e.g. 2018), along with correspondingly low groundwater levels, resulted in extreme emission events in absolute terms. Consequently, the amplitude of the emissions curve for organic soils is opposite to that of mineral soils. Overall, soil-based net emissions account for 94.5% of the greenhouse gas total for the cropland sector (CRF 4.B.; 4.B.1; 4.B.2, including all subcategories). 50.5% (≙ 8,843 kt CO_2-eq.) of the cropland sector's emissions stem from permanent croplands (remaining category), while 48.3% (≙ 8,459 kt CO_2-eq.) arise from land-use changes from Grassland (in the strict sense) to Cropland. The emissions resulting from land-use changes from Wetlands to Cropland are small (133.6 kt CO_2-eq. ≙ 0.8%). In 2024, conversion of Settlement areas led to emissions of 70 kt CO_2-eq. (≙ 0.4%) in 2024. Land-use transitions from Other Land to Cropland were negligible in 2024, yet they functioned as a marginal sink (-1.2 kt CO_2-eq., ≙ 0.01%).

The shapes of the time series plots – especially the noticeable changes they show – are primarily due to the periodicity in surveying of the relevant area data (cf. Chapter 6.3.1.5). Land-use changes were determined on the basis of spatially explicit data sets from the years 1990, 1995, 2000, 2005, 2010, 2015, 2020 and 2024 (cf. Chapter 6.3.1). Land-use changes that occurred

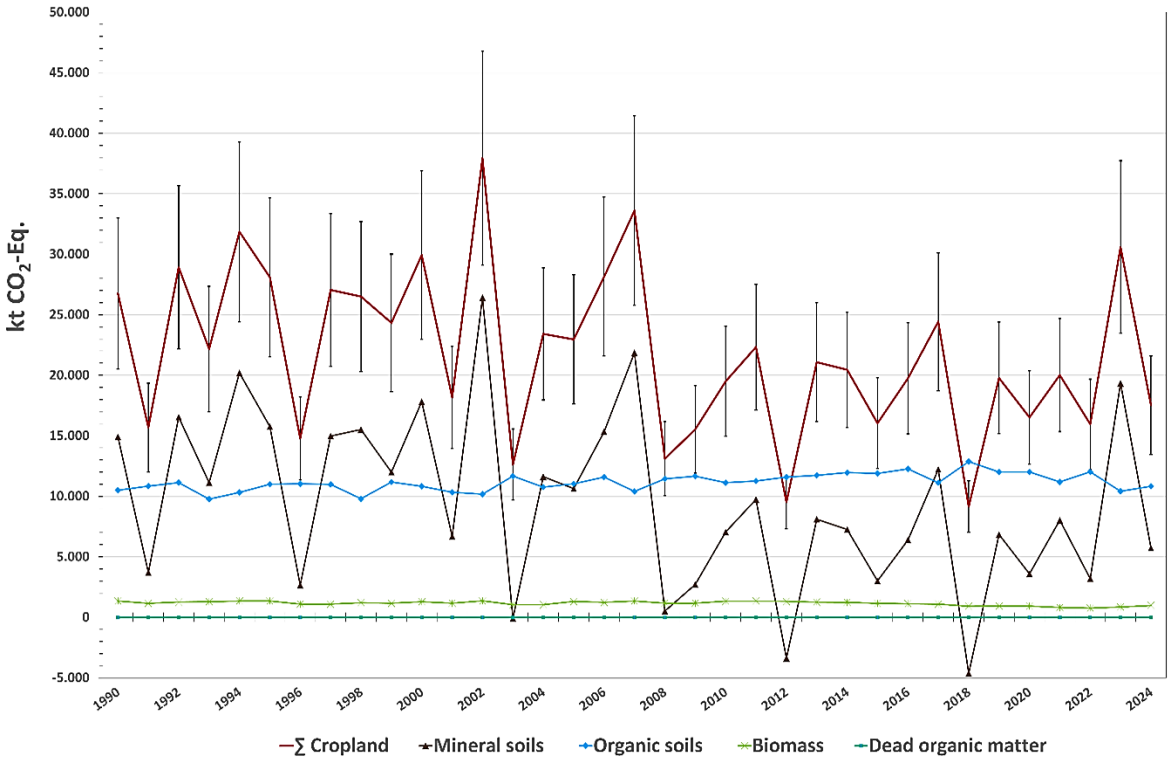
between those years were determined by linear interpolation, and thus the annual conversion areas did not change between the survey time points. Land use before the year 2010 was determined by extrapolation using stochastic methods (cf. Chapter 6.3.1.2.2).

Figure 91: GHG emissions from Cropland (sum of CO_2, CH_4 and N_2O) [kt CO_2-eq.] as a result of land use and land-use change, 1990-2024, by subcategory (with uncertainties shown only for the total sum)



Source: own illustration, Thünen-Institut

Figure 92: GHG emissions from Cropland (sum of CO_2, CH_4 and N_2O) [kt CO_2-eq.] as a result of land use and land-use change, 1990-2024, by pool (with uncertainties shown only for the total sum)



Source: own illustration, Thünen-Institut

6.5.2 Methodological issues (4.B)

6.5.2.1 Sources of data

The following data sources/sets were used:

- Federal Statistical Office, Fachserie 3, Reihe 3, agriculture and forestry, fisheries, agricultural soil use and crop cultivation; (Statistisches Bundesamt, FS 3, R 3),
- Federal Statistical Office, Fachserie 3, Reihe 3, agriculture and forestry, fisheries, growth and harvests – crops; (Statistisches Bundesamt, FS 3, R 3.2.1)
- Federal Statistical Office, Fachserie 3, Reihe 3, agriculture and forestry, fisheries – soil use by sectoral operations; (Statistisches Bundesamt, FS 3, R 3.1.2);
- 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Agriculture, Forestry and Other Land Use (IPCC, 2006a);
- "Ordinance on application of fertilisers, soil additives, culture substrates and plant additives according to the principles of good practice in fertilisation (Fertilisation Ordinance – Düngeverordnung (DüV))" (Ordinance on Fertilisation in the version as promulgated 27 February 2007 (Federal Law Gazette I, p. 221), last amended by Article 5 (36) of the Act of 24 February 2012 (Federal Law Gazette I. p. 212), (Bundesgesetzblatt, 2012);
- Interim report in the research project "Methodenentwicklung zur Erfassung der Biomasse mehrjährig verholzter Pflanzen außerhalb von Wäldern" ("Development of methods for

determining the biomass of plants outside of forests with multiple years of wood growth") (Pöpken, 2011).

- (Jacobs et al., 2018): Landwirtschaftlich genutzte Böden in Deutschland - Ergebnisse der Bodenzustandserhebung (Agricultural soils in Germany – Results of the Soil Inventory); Johann Heinrich von Thünen Institute, 316 pp. Thünen Report 64; Braunschweig. DOI:10.3220/REP1542818391000.

6.5.2.2 Biomass

In the Cropland category, the biomass pool is subdivided in accordance with basic characteristics of the plants concerned (cf. Chapter 6.2.2 and Chapter 6.3.1.2.1):

- herbaceous plants ($Cropland_{annual}$)
- woody perennial crops (Hops, Vineyards, Orchards, Tree nurseries, Christmas tree plantations and Short-rotation plantations).

The methods and assumptions used for calculation of carbon-stock changes in above-ground and below-ground biomass of plants are described in Chapters 6.1.2.3 ff, while the specific methods and emission-factor derivations for the various categories are described in the following chapters:

- herbaceous plants of annual crops ($Cropland_{annual}$) in Chapter 6.1.2.3.3,
- for Hops, in Chapter 6.1.2.3.5.6,
- for Orchards, in Chapter 6.1.2.3.5.1,
- for Vineyards, in Chapter 6.1.2.3.5.2,
- for Christmas tree plantations, in Chapter 6.1.2.3.5.4,
- for Tree nurseries, in Chapter 6.1.2.3.5.3,
- for Short-rotation plantations, in Chapter 6.1.2.3.5.5.

The emission factors for herbaceous plants, regionalised at the level of the German federal states, are used as a basis for emissions calculations.

6.5.2.2.1 Land-use change

Annual and perennial crops are now documented spatially explicitly and comprehensively, and broken down by the subcategories listed in Chapter 6.5.2.2. In the event of land-use changes leading from/to Cropland, and in accordance with the methods described in Chapter 6.1.2.3.1 ff., the carbon stocks listed in Chapter 6.1.2.3.3 and Chapter 6.1.2.3.4 for above-ground and below-ground biomass are used as initial and final values as a basis for calculation of CO_2 removals/emissions in/from the Cropland biomass pool.

6.5.2.2.2 Remaining category

In the remaining categories $Cropland_{annual}$ and Hops, consistent vegetation structures occur with the result that biomass in those categories can be assumed to reach dynamic equilibria (and with the result that no emissions occur; the notation key "NA" is entered in the relevant spaces in the tables) (cf. Chapter 6.1.2.3.1). In the subcategories Vineyards, Orchards, Tree nurseries, Christmas tree plantations and Short-rotation plantations, by contrast, the carbon stocks of plant biomass are calculated for each report year. Area conversions between the individual Cropland

subcategories are treated like land-use changes and explicitly listed as such in CRF 4.B. The area changes between annual crops and listed perennial crops are documented spatially explicitly and comprehensively. Relevant calculations are carried out using the gain-loss method (IPCC, 2006a) described in Chapters 6.1.2.3.1 ff.

6.5.2.3 Mineral soils

6.5.2.3.1 Land-use change

Calculation of CO_2 emissions resulting from area conversions leading to Cropland is described in Chapter 6.1.2.1, while calculation of direct N_2O emissions is described in Chapter 6.1.2.7 and calculation of indirect N_2O emissions is described in Chapter 6.1.2.8. The manner in which the emission factors have been derived is described in Chapter 6.1.2.1, while the pertinent uncertainties are listed in Chapter 6.5.3. The results for emissions from mineral soils are presented as follows:

- CO_2 emissions in CRF 4.B.2.a-4.B.2.e,
- direct and indirect N_2O emissions in CRF 4(III)B.2.

In accordance with the 2006 IPCC Guidelines (IPCC, 2006a), direct and indirect nitrous oxide emissions from decomposition of organic matter in mineral soils of the Cropland remaining category are reported in the tables for the Agricultural sector (CRF 3.D.1.e).

6.5.2.3.2 Remaining category

For sites remaining in Cropland use, this submission reports for the first time emissions for each hectare by using a mathematical process-based model to calculate the carbon stock change in mineral soils. A description of the model and method is provided in Chapter 6.1.2.1.

Transitions of use between the subcategories of Cropland are treated like land-use changes. The emissions resulting from them are combined (summed) within the remaining category, however (Chapter 6.1.2.1). The results for emissions from the remaining categories of mineral soils under Cropland are presented as follows:

- CO_2 emissions in CRF 4.B.1
- direct and indirect N_2O emissions in CRF 4(III)B.2.1 and 4(III)B.2.

6.5.2.4 Organic soils

The way in which CO_2, N_2O and CH_4 emissions from organic soils as a result of land use and land-use changes have been calculated, and the way in which the relevant emission factors have been derived, are described in Chapter 6.1.2.2. The manner in which the relevant areas and area land uses have been determined is described in Chapters 6.3.1 ff. The annual emissions from land-use changes are calculated in the same way as the emissions from Cropland remaining Cropland. The latter emissions are listed in CRF 4.B.1, while emissions from land-use changes are listed in CRF 4.B.2.a - 4.B.2.e.

N_2O emissions from cultivated organic soils are reported as part of the Agriculture sector, under Chapter 3.D.1.f “Cultivation of Histosols”.

The areas reported in the Agriculture sector, under Chapter 3.D.1.f “Cultivation of Histosols”, do not differ from those reported in the LULUCF sector (cf. also Chapter 6.1.2.2.1).

The methane emissions from organic soils and from drainage ditches are listed in CRF 4(II).B.2 Cropland.

6.5.3 Uncertainties and time series consistency (4.B)

The uncertainties for the emission factors and the activity data were determined in accordance with the 2006 IPCC Guidelines (IPCC, 2006a). Additional relevant information is provided in Chapter 6.1.2.1. Table 380 to Table 387 show the uncertainties in the emission factors (EFs) for the Cropland sector, by pool and subcategory.

The tables highlight the fact that the EFs for mineral soils and biomass mainly have standard normal distributions and near-normal distributions. The majority of the uncertainties in connection with soils exhibit a log-normal distribution, while the CO_2 emissions from organic soils exhibit a triangular distribution. The EFs for N_2O emissions from mineral soils show the largest uncertainties. This is due primarily to use of the IPCC default factors.

In the framework of Gaussian calculation of uncertainties propagation, a few uncertainties > 100% were calculated for the lower bound of the 95% confidence interval. While the calculation method used conforms to the rules, it is not effective in the present context in which certain processes cannot lead to removals. This is the case, for example, for direct/indirect N_2O emissions from mineral soils as a result of decomposition of organic soil substance. For this reason, the uncertainty for the lower bound has been set to 99.9%.

The large uncertainty seen in the EFs for methane and nitrous oxide from organic soils is due to extremely large variability in field measurements, as well as to the fact that negative emissions are possible for methane (cf. Chapter 6.1.2.2.2).

The uncertainties for the activity data have a normal distribution and half of the 95% confidence interval for the Cropland category falls within the range 0.045-196%. For system-related reasons, the sampling error with the sample-grid system depends on the sample size, and thus on the relevant subcategory's share of the total area (cf. Chapter 6.3.1). In the Cropland sector, for example, major uncertainties (≥ 100%) are seen only in those subcategories whose absolute area is ≤ 3 ha (0.0002% of the total Cropland area). Area-weighted derivation of a total uncertainty for the area data in the Cropland category yields an uncertainty of 0.045% during the entire reference period [half of the 95% confidence interval].

The total uncertainty for the land-use category Cropland for the year 2024 is 18.3% [2.5% percentile] and 14.1% [97.5% percentile]. The main contribution to this comes from CO_2 emissions from organic soils (94.2%), followed by mineral soils (5.6%). Only the emissions from organic soils (5.2%) make a significant contribution to the uncertainty of the entire LULUCF inventory.

The following tables show the implied emission factors [t C ha^{-1} a^{-1}] for calculation of GHG emissions from Germany's Cropland subcategories, and the uncertainties (2.5% and 97.5% percentile [%]) of the implied emission factors resulting from the pertinent emissions calculations, differentiated by pool and subcategory, for the year 2024.

Table 380: Implied emission factors [t C ha^{-1} a^{-1}] and their uncertainties for GHG emissions from $Cropland_{annual}$, 2024

$Cropland_{annual}$		Implied emission factor	Uncertainty bounds	
Initial land use	Final land use		lower	upper
Mineral soils, CO_2-C [1)]		[t C ha^{-1} a^{-1}]	[%]	[%]
$Cropland_{annual}$	$Cropland_{annual}$	-0.038	23.29	23.28
Forest Land		NO	NO	NO
Hops		-0.163	16.7	16.7

Cropland$_{annual}$		Implied emission factor	Uncertainty bounds	
Initial land use	**Final land use**		**lower**	**upper**
Vineyards		0.321	22.97	22.97
Orchards		-0.632	14.16	14.16
Short-rotation plantations		NO	NO	NO
Tree nurseries		-0.252	13.96	13.96
Christmas tree plantations		NO	NO	NO
Grassland (in the strict sense)		-0.862	18.88	18.88
Woody grassland		-0.987	19.37	19.36
Hedges		-0.96	23.91	23.91
Terr. Wetlands		-1	66.41	66.41
Settlements		-0.262	15.81	15.91
Photovoltaic areas		NO	NO	NO
Other Land		2	73.02	73.02
Mineral soils, N_2O_{direct} [2)]		**[kg N_2O ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Cropland$_{annual}$	NO	NO	NO
Grassland (in the strict sense)		0.804	85.91	85.91
Woody grassland		0.909	86.02	86.02
Hedges		0.796	87.16	87.16
Terr. Wetlands		1.3687	99.9	107.75
Settlements		NO	NO	NO
Photovoltaic areas		0.3654	89.66	88.82
Other Land		NO	NO	NO
Mineral soils, $N_2O_{indirect}$ [2)]		**[kg N_2O ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Cropland$_{annual}$	NO	NO	NO
Grassland (in the strict sense)		0.354	99.9	220.94
Woody grassland		0.4	99.9	220.98
Hedges		0.35	99.9	221.43
Terr. Wetlands		0.602	99.9	230.31
Settlements		0.161	99.9	247.44
Photovoltaic areas		NO	NO	NO
Other Land		NO	NO	NO
Biomass [3)]		**[t C ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Cropland$_{annual}$	NO	NO	NO
Hops		0.008	14.6	14.6
Vineyards		-0.072	21.21	21.21
Orchards		-0.628	13.39	13.39
Short-rotation plantations		NO	NO	NO
Tree nurseries		-0.5	20.8	20.8
Christmas tree plantations		NO	NO	NO
Grassland (in the strict sense)		-0.03	16.73	16.73
Woody grassland		-5.373	16.4	22.91
Hedges		-26.755	21.47	26.77
Terr. Wetlands		-2.405	35.89	38.9
Peat extraction		0.352	19.43	19.43

Cropland$_{annual}$		Implied emission factor	Uncertainty bounds	
Initial land use	**Final land use**		**lower**	**upper**
Settlements		-0.008	45.9	47.36
Photovoltaic area		NO	NO	NO
Other Land		NO	NO	NO
Dead organic matter [3]		**[t C ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Cropland$_{annual}$	NO	NO	NO

1) The calculation covers a 20-year period; stock change: positive ≙ sink; negative ≙ source

2) The calculation covers a 20-year period; emission: positive ≙ source; negative ≙ sink

3) The calculation is only for the first year of the land-use change; stock change: positive ≙ sink; negative ≙ source

Table 381: Implied emission factors [t C ha^{-1} a^{-1}] and their uncertainties for GHG emissions from Hops, 2024

Hops		Implied emission factor	Uncertainty bounds	
Initial land use	**Final land use**		**lower**	**upper**
Mineral soils, CO_2-C [1]		**[t C ha^{-1} a^{-1}]**	**[%]**	**[%]**
Hops	Hops	-0.02	11.22	11.21
Forest Land		NO	NO	NO
Cropland$_{annual}$		0.041	16.7	16.7
Vineyards		0.589	99.99	196.23
Orchards		-0.428	74.56	74.56
Short-rotation plantations		NO	NO	NO
Tree nurseries		-0.096	99.9	196.16
Christmas tree plantations		NO	NO	NO
Grassland (in the strict sense)		-0.655	38.48	38.48
Woody grassland		-0.741	99.9	196.71
Hedges		-1.073	99.9	196.71
Terr. Wetlands		NO	NO	NO
Settlements		-0.141	99.99	139.1
Photovoltaic area		NO	NO	NO
Other Land		NO	NO	NO
Mineral soils, N_2O_{direct} [2]		**[kg N_2O ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Hops	NO	NO	NO
Grassland (in the strict sense)		0.472	92.23	92.23
Woody grassland		0.647	99.9	213.83
Hedges		0.751	99.9	213.83
Terr. Wetlands		NO	NO	NO
Settlements		0.219	99.9	164.27
Photovoltaic area		NO	NO	NO
Other Land		NO	NO	NO
Mineral soils, $N_2O_{indirect}$ [2]		**[kg N_2O ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Hops	NO	NO	NO
Grassland (in the strict sense)		0.208	99.9	223.47
Woody grassland		0.285	99.9	295.22
Hedges		0.331	99.9	295.22

Hops		Implied emission factor	Uncertainty bounds	
Initial land use	**Final land use**		**lower**	**upper**
Terr. Wetlands		NO	NO	NO
Settlements		0.096	99.9	221.83
Photovoltaic area		NO	NO	NO
Other Land		NO	NO	NO
Biomass [3)]		**[t C ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land		NO	NO	NO
Cropland$_{annual}$		-0.018	14.61	14.61
Vineyards		-0.364	99.9	196.45
Orchards		-1.338	75.08	75.08
Short-rotation plantations		NO	NO	NO
Tree nurseries		NO	NO	NO
Christmas tree plantations		NO	NO	NO
Grassland (in the strict sense)	Hops	-0.067	37.82	37.82
Woody grassland		-3.221	99.9	197.3
Hedges		NO	NO	NO
Terr. Wetlands		NO	NO	NO
Peat extraction		NO	NO	NO
Settlements		NO	NO	NO
Photovoltaic area		NO	NO	NO
Other Land		NO	NO	NO
Dead organic matter [3)]		**[t C ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Hops	NO	NO	NO

1) The calculation covers a 20-year period; stock change: positive ≙ sink; negative ≙ source

2) The calculation covers a 20-year period; emission: positive ≙ source; negative ≙ sink

3) The calculation is only for the first year of the land-use change; stock change: positive ≙ sink; negative ≙ source

Table 382: Implied emission factors [t C ha^{-1} a^{-1}] and their uncertainties for GHG emissions from Vineyards, 2024

Vineyards		Implied emission factor	Uncertainty bounds	
Initial land use	**Final land use**		**lower**	**upper**
Mineral soils, CO_2-C [1)]		**[t C ha^{-1} a^{-1}]**	**[%]**	**[%]**
Vineyards		-0.02	16.13	16.12
Forest Land		NO	NO	NO
Cropland$_{annual}$		-0.397	19.72	19.71
Hops		-1.159	99.9	196.23
Orchards		-1.105	30.86	30.86
Short-rotation plantations		NO	NO	NO
Tree nurseries	Vineyards	-0.712	99.9	138.91
Christmas tree plantations		NO	NO	NO
Grassland (in the strict sense)		-1.245	26.88	26.88
Woody grassland		-1.199	36.15	36.15
		-1.528	99.9	139.84
Terr. Wetlands		-0.869	99.9	196.28

Vineyards		Implied emission factor	Uncertainty bounds	
Initial land use	**Final land use**		**lower**	**upper**
Settlements		-0.579	50.81	50.85
Photovoltaic area		NO	NO	NO
Other Land		1.974	99.9	168.56
Mineral soils, N_2O_{direct} 2)		**[kg N_2O ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Vineyards	NO	NO	NO
Grassland (in the strict sense)		0.823	88.02	88.02
Woody grassland		0.803	91.28	91.28
Hedges		1.104	99.9	163.03
Terr. Wetlands		0.705	99.9	213.83
Settlements		0.439	99.9	101.1
Photovoltaic area		NO	NO	NO
Other Land		NO	NO	NO
Mineral soils, $N_2O_{indirect}$ 2)		**[kg N_2O ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Vineyards	NO	NO	NO
Grassland (in the strict sense)		0.362	99.9	221.77
Woody grassland		0.353	99.9	223.08
Hedges		0.486	99.9	260.79
Terr. Wetlands		0.31	99.9	295.23
Settlements		0.193	99.9	227.28
Photovoltaic area		NO	NO	NO
Other Land		NO	NO	NO
Biomass 3)		**[t C ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Vineyards	NO	NO	NO
$Cropland_{annual}$		0.085	17.77	17.77
Hops		0.163	99.9	196.45
Orchards		-0.821	31.54	31.54
Short-rotation plantations		NO	NO	NO
Tree nurseries		0.111	99.9	139.95
Christmas tree plantations		NO	NO	NO
Grassland (in the strict sense)		0.037	25.95	25.95
Woody grassland		-7.055	34.71	38.13
Hedges		0.132	99.9	140.36
Terr. Wetlands		0.132	99.9	197.09
Peat extraction		NO	NO	NO
Settlements		0.08	51.25	51.25
Photovoltaic areas		NO	NO	NO
Other Land		0.142	99.9	168.39
Dead organic matter 3)		**[t C ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Vineyards	NO	NO	NO

1) The calculation covers a 20-year period; stock change: positive ≙ sink; negative ≙ source
2) The calculation covers a 20-year period; emission: positive ≙ source; negative ≙ sink
3) The calculation is only for the first year of the land-use change; stock change: positive ≙ sink; negative ≙ source

Table 383: Implied emission factors [t C ha^{-1} a^{-1}] and their uncertainties for GHG emissions from Orchards, 2024

Orchards		Implied emission factor	Uncertainty bounds	
Initial land use	Final land use		lower	upper
Mineral soils, CO_2-C [1)]		**[t C ha^{-1} a^{-1}]**	**[%]**	**[%]**
Orchards	Orchards	-0.02	12.57	12.57
Forest Land		NO	NO	NO
Cropland$_{annual}$		0.456	13.97	13.97
Hops		0.346	99.9	113.48
Vineyards		0.962	44.94	44.94
Short-rotation plantations		NO	NO	NO
Tree nurseries		0.334	19.17	19.16
Christmas tree plantations		NO	NO	NO
Grassland (in the strict sense)		-0.579	18.89	18.88
Woody grassland		-0.455	29.71	29.71
Hedges		-0.58	99.9	114.32
Terr. Wetlands		-1.641	99.9	196.23
Settlements		0.222	23.74	23.8
Photovoltaic areas		NO	NO	NO
Other Land		NO	NO	NO
Mineral soils, N_2O_{direct} [2)]		**[kg N_2O ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Orchards	NO	NO	NO
Grassland (in the strict sense)		0.412	85.92	85.92
Woody grassland		0.237	88.92	88.92
Hedges		0.306	99.9	141.75
Terr. Wetlands		1.121	99.9	213.79
Settlements		0.045	91.39	90.57
Photovoltaic areas		NO	NO	NO
Other Land		NO	NO	NO
Mineral soils, $N_2O_{indirect}$ [2)]		**[kg N_2O ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Orchards	NO	NO	NO
Grassland (in the strict sense)		0.181	99.9	220.94
Woody grassland		0.104	99.9	222.13
Hedges		0.135	99.9	248.05
Terr. Wetlands		0.493	99.9	295.19
Settlements		0.02	99.9	222.79
Photovoltaic areas		NO	NO	NO
Other Land		NO	NO	NO
Biomass [3)]		**[t C ha-1 a-1]**	**[%]**	**[%]**
Forest Land	Orchards	NO	NO	NO
Cropland$_{annual}$		0.047	13.19	13.19
Hops		0.662	99.9	113.82
Vineyards		-0.185	14.41	14.41
Short-rotation plantations		NO	NO	NO
Tree nurseries		-0.759	22.5	22.5

Orchards		Implied emission factor	Uncertainty bounds	
Initial land use	Final land use		lower	upper
Christmas tree plantations		NO	NO	NO
Grassland (in the strict sense)		-0.168	16.17	16.17
Woody grassland		-6.516	28.45	31.76
Hedges		0.159	99.9	114.91
Terr. Wetlands		1.04	99.9	168.19
Peat extraction		0.902	99.9	196.53
Settlements		-1.063	24.01	24.01
Photovoltaic area		NO	NO	NO
Other Land		NO	NO	NO
Dead organic matter [3]		**[t C ha^{-1} a^{-1}]**	**[t C ha^{-1} a^{-1}]**	**[%]**
Forest Land	Orchards	NO	NO	NO

1) The calculation covers a 20-year period; stock change: positive ≙ sink; negative ≙ source
2) The calculation covers a 20-year period; emission: positive ≙ source; negative ≙ sink
3) The calculation is only for the first year of the land-use change; stock change: positive ≙ sink; negative ≙ source

Table 384: Implied emission factors [t C ha^{-1} a^{-1}] and their uncertainties for GHG emissions from Tree nurseries, 2024

Tree nurseries		Implied emission factor	Uncertainty bounds	
Initial land use	Final land use		lower	upper
Mineral soils, CO_2-C [1]		**[t C ha^{-1} a^{-1}]**	**[%]**	**[%]**
Tree nurseries		-0.02	11.17	11.16
Forest Land		NO	NO	NO
Cropland$_{annual}$		-0.221	14.53	14.53
Hops		-0.021	99.9	196.16
Vineyards		0.613	99.9	138.91
Orchards		-0.352	28.23	28.22
Short-rotation plantations		NO	NO	NO
Christmas tree plantations	Tree nurseries	NO	NO	NO
Grassland (in the strict sense)		-1.084	21.48	21.48
Woody grassland		-0.978	19.32	19.32
Hedges		-1.366	67.74	67.74
Terr. Wetlands		-0.638	99.9	196.22
Settlements		1.000	38.85	38.88
Photovoltaic area		NO	NO	NO
Other Land		NO	NO	NO
Mineral soils, N_2O_{direct} [2]		**[kg N_2O ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land		NO	NO	NO
Grassland (in the strict sense)		0.554	86.52	86.52
Woody grassland		0.57	86.01	86.01
Hedges	Tree nurseries	0.486	99.9	107.77
Terr. Wetlands		0.971	99.9	213.78
Settlements		0.114	96.43	95.64
Photovoltaic area		NO	NO	NO

Tree nurseries		Implied emission factor	Uncertainty bounds	
Initial land use	**Final land use**		**lower**	**upper**
Other Land		NO	NO	NO
Mineral soils, $N_2O_{indirect}$ 2)		**[kg N_2O ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Tree nurseries	NO	NO	NO
Grassland (in the strict sense)		0.244	99.9	221.18
Woody grassland		0.251	99.9	220.98
Hedges		0.214	99.9	230.32
Terr. Wetlands		0.427	99.9	295.19
Settlements		0.05	99.9	224.9
Photovoltaic area		NO	NO	NO
Other Land		NO	NO	NO
Biomass 3)		**[t C ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Tree nurseries	NO	NO	NO
$Cropland_{annual}$		1.753	21.2	21.2
Hops		2.372	99.9	197.06
Vineyards		3.081	99.9	139.95
Orchards		1.157	30.58	30.58
Short-rotation plantations		NO	NO	NO
Christmas tree plantations		NO	NO	NO
Grassland (in the strict sense)		1.844	23.72	23.72
Woody grassland		-0.516	16.96	21.53
Hedges		-9.12	65.7	67.02
Terr. Wetlands		2.577	99.9	139.65
Peat extraction		NO	NO	NO
Settlements		2.197	40.73	40.73
Photovoltaic area		NO	NO	NO
Other Land		NO	NO	NO
Dead organic matter 3)		**[t C ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Tree nurseries	NO	NO	NO

1) The calculation covers a 20-year period; stock change: positive ≙ sink; negative ≙ source
2) The calculation covers a 20-year period; emission: positive ≙ source; negative ≙ sink
3) The calculation is only for the first year of the land-use change; stock change: positive ≙ sink; negative ≙ source

Table 385: Implied emission factors [t C ha^{-1} a^{-1}] and their uncertainties for GHG emissions from Christmas tree plantations, 2024

Christmas tree plantations		Implied emission factor	Uncertainty bounds	
Initial land use	**Final land use**		**lower**	**upper**
Mineral soils, CO_2-C 1)		**[t C ha^{-1} a^{-1}]**	**[%]**	**[%]**
Christmas tree plantations	Christmas tree plantations	-0.0200	11.26	11.25
Forest Land		NO	NO	NO
$Cropland_{annual}$		NO	NO	NO
Hops		NO	NO	NO
Vineyards		NO	NO	NO
Orchards		NO	NO	NO

Christmas tree plantations		Implied emission factor	Uncertainty bounds	
Initial land use	**Final land use**		**lower**	**upper**
Tree nurseries		NO	NO	NO
Christmas tree plantations		NO	NO	NO
Grassland (in the strict sense)		NO	NO	NO
Woody grassland		NO	NO	NO
Hedges		NO	NO	NO
Terr. Wetlands		NO	NO	NO
Settlements		NO	NO	NO
Photovoltaic area		NO	NO	NO
Other Land		NO	NO	NO
Mineral soils, N_2O_{direct} 2)		**[kg N_2O ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Christmas tree plantations	NO	NO	NO
Grassland (in the strict sense)		NO	NO	NO
Woody grassland		NO	NO	NO
Hedges		NO	NO	NO
Terr. Wetlands		NO	NO	NO
Settlements		NO	NO	NO
Photovoltaic area		NO	NO	NO
Other Land		NO	NO	NO
Mineral soils, $N_2O_{indirect}$ 2)		**[kg N_2O ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Christmas tree plantations	NO	NO	NO
Grassland (in the strict sense)		NO	NO	NO
Woody grassland		NO	NO	NO
Hedges		NO	NO	NO
Terr. Wetlands		NO	NO	NO
Settlements		NO	NO	NO
Photovoltaic area		NO	NO	NO
Other Land		NO	NO	NO
Biomass 3)		**[t C ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Christmas tree plantations	NO	NO	NO
$Cropland_{annual}$		NO	NO	NO
Hops		NO	NO	NO
Vineyards		NO	NO	NO
Orchards		NO	NO	NO
Tree nurseries		NO	NO	NO
Christmas tree plantations		NO	NO	NO
Grassland (in the strict sense)		NO	NO	NO
Woody grassland		NO	NO	NO
Hedges		NO	NO	NO
Terr. Wetlands		NO	NO	NO
Peat extraction		NO	NO	NO
Settlements		NO	NO	NO
Photovoltaic area		NO	NO	NO
Other Land		NO	NO	NO

Christmas tree plantations		Implied emission factor	Uncertainty bounds	
Initial land use	Final land use		lower	upper
Dead organic matter [3]		[t C ha^{-1} a^{-1}]	[%]	[%]
Forest Land	Christmas tree plantations	NO	NO	NO

1) The calculation covers a 20-year period; stock change: positive ≙ sink; negative ≙ source
2) The calculation covers a 20-year period; emission: positive ≙ source; negative ≙ sink
3) The calculation is only for the first year of the land-use change; stock change: positive ≙ sink; negative ≙ source

Table 386: Implied emission factors [t C ha^{-1} a^{-1}] and their uncertainties for GHG emissions from Short-rotation plantations, 2022024

Short-rotation plantations		Implied emission factor	Uncertainty bounds	
Initial land use	Final land use		lower	upper
Mineral soils, CO_2-C [1]		[t C ha^{-1} a^{-1}]	[%]	[%]
Short-rotation plantations	Short-rotation plantations	-0.02	13.91	13.9
Forest Land		-1.238	83.44	87.94
Cropland$_{annual}$		0.37	31.33	31.32
Hops		NO	NO	NO
Vineyards		NO	NO	NO
Orchards		-0.152	8.48	8.47
Tree nurseries		NO	NO	NO
Christmas tree plantations		NO	NO	NO
Grassland (in the strict sense)		-0.759	48.06	48.06
Woody grassland		-0.648	99.9	196.71
Hedges		-0.838	99.9	196.71
Terr. Wetlands		NO	NO	NO
Settlements		-0.507	99.9	196.36
Photovoltaic area		NO	NO	NO
Other Land		NO	NO	NO
Mineral soils, N_2O_{direct} [2]		[kg N_2O ha^{-1} a^{-1}]	[%]	[%]
Forest Land	Short-rotation plantations	NO	99.9	158.84
Grassland (in the strict sense)		0.449	96.62	96.62
Woody grassland		0.463	99.9	213.83
Hedges		0.602	99.9	213.83
Terr. Wetlands		NO	NO	NO
Settlements		0.528	99.9	214.92
Photovoltaic area		NO	NO	NO
Other Land		NO	NO	NO
Settlements		Settlements	[%]	[%]
Forest Land	Short-rotation plantations	NO	99.9	258.19
Grassland (in the strict sense)		0.197	99.9	225.32
Woody grassland		0.204	99.9	295.22
Hedges		0.265	99.9	295.22
Terr. Wetlands		NO	NO	NO
Settlements		0.233	99.9	296.02
Photovoltaic area		NO	NO	NO

Short-rotation plantations		Implied emission factor	Uncertainty bounds	
Initial land use	**Final land use**		**lower**	**upper**
Other Land		NO	NO	NO
Biomass [3)]		**[t C ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Short-rotation plantations	NO	NO	NO
Cropland$_{annual}$		-2.395	27.65	28.29
Hops		-0.951	7.77	9.83
Vineyards		NO	80.38	80.6
Orchards		NO	35.92	36.28
Tree nurseries		-0.87	99.9	138.93
Christmas tree plantations		NO	9.36	10.62
Grassland (in the strict sense)		NO	23.95	24.68
Woody grassland		2.997	99.9	196.5
Hedges		-1.577	99.9	196.5
Terr. Wetlands		4.075	8.08	11.05
Peat extraction		NO	NO	NO
Settlements		4.075	99.9	196.24
Photovoltaic area		NO	NO	NO
Other Land		NO	NO	NO
Dead organic matter [3)]		**[t C ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Short-rotation plantations	NO	NO	NO

1) The calculation covers a 20-year period; stock change: positive ≙ sink; negative ≙ source

2) The calculation covers a 20-year period; emission: positive ≙ source; negative ≙ sink

3) The calculation is only for the first year of the land-use change; stock change: positive ≙ sink; negative ≙ source

Table 387: Implied emission factors for organic soils under Cropland [t CO_2-eq. IPCC AR5 ha^{-1} a^{-1}] and their uncertainties (2.5% and 97.5% percentile [%]), for the year 2024

Land use	Greenhouse gas	Emission factor	Uncertainty bounds	
			lower	**upper**
Organic soils [1)]		**[kt CO_2-eq. [ha^{-1} a^{-1}]**	**[%]**	**[%]**
Cropland$_{annual}$	CO_2	31.59	30.81	20.85
	N_2O [2)]	IE	IE	IE
	CH_4	1.14	50.81	336.35
Organic soils [1)]		**[kt CO_2-eq. [ha^{-1} a^{-1}]**	**[%]**	**[%]**
Hops	CO_2	27.58	56.49	53.19
	N_2O [2)]	IE	IE	IE
	CH_4	1.67	55.72	339.6
Organic soils [1)]		**[kt CO_2-eq. [ha^{-1} a^{-1}]**	**[%]**	**[%]**
Vineyards	CO_2	13.93	71.72	68.51
	N_2O [2)]	IE	IE	IE
	CH_4	1.24	83.57	323.38
Organic soils [1)]		**[kt CO_2-eq. [ha^{-1} a^{-1}]**	**[%]**	**[%]**
Orchards	CO_2	25.27	35.31	31.37

Land use	Greenhouse gas	Emission factor	Uncertainty bounds	
			lower	upper
	N_2O 2)	IE	IE	IE
	CH_4	1.51	47.48	286.63
Organic soils 1)		**[kt CO_2-eq. [ha^{-1} a^{-1}]**	**[%]**	**[%]**
Tree nurseries	CO_2	28.35	28.59	21.63
	N_2O 2)	IE	IE	IE
	CH_4	1.23	43.51	273.07
Organic soils 1)		**[kt CO_2-eq. [ha^{-1} a^{-1}]**	**[%]**	**[%]**
Christmas tree plantations	CO_2	29.95	44.14	31.78
	N_2O 2)	IE	IE	IE
	CH_4	0.87	69.34	448.74
Organic soils 1)		**[kt CO_2-eq. [ha^{-1} a^{-1}]**	**[%]**	**[%]**
Short-rotation plantations	CO_2	31.06	54.41	51
	N_2O 2)	IE	IE	IE
	CH_4	0.65	64.71	276.83

1) Annual calculation; emission: positive ≙ source; negative ≙ sink

2) Is reported under 3.D.1.f (Agricultural sector)

The calculations are spatially consistent over time and complete for the entire reporting period, 1990-2024.

6.5.4 Category-specific QA/QC and verification (4.B)

Details regarding this year's reviews are provided in Chapter 6.1.3.

The data sources used in preparation of this inventory fulfil the review criteria of the QSE manual for data sources (QSE-Handbuch für Datenquellen). Quality assurance for input data (ATKIS®, BÜK, official statistics; cf. Chapter 6.3) is the responsibility of the relevant data administrators (cf. the documentation in the inventory description).

The emissions-calculation results as presented in the present report cannot be compared with other relevant data sources for Germany since no such other data sources exist that meet applicable requirements, i.e. provide nationwide coverage, are comprehensive and are independent of the methods and data sources described in the present report.

The following tables present an intra-European comparison of implied emission factors (IEFs) for various pools. Values of neighbouring countries obtained from the 2025 submission to the Climate Secretariat (UNFCCC NID submission 2025 – Inventory year 2023, (UNFCCC, 2021)) were used for this comparison. The values for Germany in 2024 were obtained from the current 2026 submission.

The comparison is problematic from the outset because the values to be compared were not all obtained with the same methods (in some cases, the methods differ widely), and especially because the demarcations of the systems differ – in some cases, markedly. In view of this fact, and taking account of the major uncertainties and the scattering seen in the reported values (cf. Chapter 6.5.3), in none of the compared pools does the comparison show implied emission

factors (IEFs) that must clearly be considered outliers. Most of the EFs are similar, in terms of both absolute size and trends, to those of various central European neighbouring countries.

Table 388: Carbon-stock changes in living biomass in Cropland of various countries (Germany, for 2023 & 2024; other countries, for 2023), in [t C ha^{-1} a^{-1}]

	4.B.1. - Cropland Remaining Cropland	4.B.2 - Land Converted To Cropland	4.B.2.1 - Forest Land Converted To Cropland	4.B.2.2 - Grassland Converted To Cropland	4.B.2.3 - Wetlands Converted To Cropland	4.B.2.4 - Settlements Converted To Cropland	4.B.2.5 - Other Land Converted To Cropland
Belgium	-0.006	-0.142	-3.671	-0.094	NO	NO	NO
Denmark	0.007	-0.094	-1.906	0.162	-0.883	0	NA
France	-0.009	-0.666	-4.916	-0.064	0.012	0.011	NA
United Kingdom	0	0.074	IE, NO	0.072	NO	0.376	NO
Netherlands	NA	-0.21	-4.968	-0.183	0.428	0.373	0.307
Austria	0.004	0.073	-2.051	0.153	NO	NO	NO
Poland	0.132	NO	NO	NO	NO	NO	NO
Switzerland	-0.37	-0.246	-0.382	-0.248	-0.393	-0.194	-0.131
Czech Republic	0.001	-0.229	-5.299	-0.211	0.299	0.402	NO
Germany, 2024	0.0006	-0.345	NO	-0.308	-0.46	-1.265	0.049
Germany, 2025	0.0006	-0.203	-2.395	-0.208	-0.25	0.01	0.003

Positive: carbon removal by sink; negative: carbon emission by source; Source: (UNFCCC, 2023c)

Table 389: Carbon-stock changes in dead organic matter in Cropland of various countries (Germany, for 2023 & 2024; other countries, for 2023), in [t C ha^{-1} a^{-1}]

	4.B.1. - Cropland Remaining Cropland	4.B.2 - Land Converted To Cropland	4.B.2.1 - Forest Land Converted To Cropland	4.B.2.2 - Grassland Converted To Cropland	4.B.2.3 - Wetlands Converted To Cropland	4.B.2.4 - Settlements Converted To Cropland	4.B.2.5 - Other Land Converted To Cropland
Belgium	NO	-0.001	-0.08	NO	NO	NO	NO
Denmark	NA	-0.16	-1.292	IE, NA	IE, NA	0	NA
France	0	-0.088	-0.709	0	NA	NA	NA
United Kingdom	NO	IE, NO	NO	IE	NO	IE, NO	NO
Netherlands	NA	-0.015	-1.828	NA	NA	NA	NA
Austria	NO	-0.032	-0.892	NO	NO	NO	NO
Poland	0.001	NO	NO	NO	NO	NO	NO
Switzerland	NA, NO	NA, NO	NA	NO	NO	NO	NO
Czech Republic	NO	-0.018	-0.355	NO	NO	NO	NO
Germany, 2023	IE	NO	NO	IE	IE	IE	IE
Germany, 2024	IE	NO	NO	IE	IE	IE	IE

Positive: carbon removal by sink; negative: carbon emission by source; Source: (UNFCCC, 2023c)

Table 390: Carbon-stock changes in mineral soils in Cropland of various countries (Germany, for 2023 & 2024; other countries, for 2023), in [t C ha^{-1} a^{-1}]

	4.B.1. - Cropland Remaining Cropland	4.B.2 - Land Converted To Cropland	4.B.2.1 - Forest Land Converted To Cropland	4.B.2.2 - Grassland Converted To Cropland	4.B.2.3 - Wetlands Converted To Cropland	4.B.2.4 - Settlements Converted To Cropland	4.B.2.5 - Other Land Converted To Cropland
Belgium	-0.092	-1.435					
Denmark	-0.023	0	0	IE	-1.77	0	NA
France	0.003	-0.543	-0.726	-0.523	-0.093	0.457	0.583
United Kingdom	-0.326	-1.207	-2.952	-1.228	NO	2.731	NO
Netherlands	-0.194	-0.882	0	-0.893	0	0	0
Austria	-0.011	-0.714	-0.738	-0.716	NO	NO	NO
Poland	-0.007	-0.173					
Switzerland	0.242	0.012					
Czech Republic	0.001	-0.26	-0.26	-0.47		0.04	
Germany, 2023	-0.139	-0.826	NO	-0.897	-1.364	0.791	2.267
Germany, 2024	-0.038	-0.846	-1.238	-0.867	-1.269	-0.255	2.095

Positive: carbon removal by sink; negative: carbon emission by source; Source: (UNFCCC, 2025)

Table 391: Carbon-stock changes in organic soils in Cropland of various countries (Germany, for 2023 & 2024; other countries, for 2023), in [t C ha^{-1} a^{-1}]

	4.B.1. - Cropland Remaining Cropland	4.B.2 - Land Converted To Cropland	4.B.2.1 - Forest Land Converted To Cropland	4.B.2.2 - Grassland Converted To Cropland	4.B.2.3 - Wetlands Converted To Cropland	4.B.2.4 - Settlements Converted To Cropland	4.B.2.5 - Other Land Converted To Cropland
Belgium	-10.00	NO					
Denmark	-7.247	IE, NA					
France	IE	NO	NO	NO	NO	NO	NO
United Kingdom	-5.692	-5.058	-7.829	IE	NO	IE	NO
Netherlands	-3.758	-3.779		-3.779			
Austria	IE, NO	NO	NO	NO	NO	NO	NO
Poland	-5.00	-5.00					
Switzerland	-9.52	-9.52					
Czech Republic	NO	NO					
Germany, 2023	-7.194	-6.543	NO	-7.249	-6.482	-6.142	-6.441
Germany, 2024	-8.51	-8.787	-8.364	-8.767	-9.37	-8.55	-10.349

Positive: carbon removal by sink; negative: carbon emission by source; Source: (UNFCCC, 2023c)

6.5.5 Category-specific recalculations (4.B)

This year's submission includes category-specific recalculations for the entire period 1990-2024. The emissions were recalculated in order to take account of new and improved data sources, the introduction of new methods, changes in methods, and error corrections made as part of ongoing inventory improvements. The corresponding measures are listed in Chapter 6.1.3.4.2 and all affected the results of the emissions calculations for the Cropland land-use category:

In Table 391 (areas) and Table 393 (emissions), the results of the current recalculations for the Cropland category are compared with the corresponding results in the previous year's submission.

The slight differences between the area data of the current and previous year's submissions (contribution of < 1.3% throughout the entire time series) are mainly due to correction algorithms. They became necessary in connection with introducing the new land-use subcategories and updating the map data to determine activity data as a result of integrating the newly added data of the last time series year. It is assumed that the most recent data is the highest quality and therefore the previous time series is adjusted if necessary (cf. also Chapters 6.3.1 ff).

The differences between the GHG emissions of this and the preceding year's submission in terms of CO_2 are mainly due to

- the first inclusion of emissions at hectare level from the remaining category of mineral soils,
- the modifications of the calculation of carbon stocks in soils and biomass of the Buildings and open areas subcategory, and
- the implementation of the modified hydrological model to determine groundwater levels in organic soils.

The latter is particularly true for the methane emissions, some of which are a factor of 3 greater in this submission than in the previous one. The differences regarding nitrous oxide emissions are mainly due to documenting emissions from mineral soils at hectare level for the first time.

The much lower N_2O emissions in the current submission are due to area-related effects, particularly resulting from the introduction of the new area maps for organic soils and hedges.

Table 392: Comparison of area data [kha] for the Cropland category as reported in the current and previous year's submissions

Area [kha]	Submission	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Cropland	2025	13,339.06	13,355.77	13,372.48	13,018.22	12,762.78	12,554.47	12,408.23	12,375.45	12,342.71	12,309.97
	2026	13,437.54	13,330.18	13,211.01	13,075.25	12,915.39	12,717.15	12,568.81	12,528.87	12,488.92	12,448.99
	Difference (absolute)	98	-26	-161	57	153	163	161	153	146	139
	in %	0.73%	-0.19%	-1.22%	0.44%	1.18%	1.28%	1.28%	1.22%	1.17%	1.12%

Table 393: Comparison of greenhouse gas emissions [kt CO_2-eq.] for the Cropland category as reported in the current and previous year's submissions

GHG	Submission	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
CO_2	2025	20,381.76	20,320.77	19,965.46	22,007.12	19,708.91	20,736.35	21,938.82	20,791.45	21,581.02	19,195.91
	2026	25,789.59	27,291.70	29,090.34	22,155.00	18,688.38	15,189.25	15,922.47	19,302.68	15,449.12	29,580.56
	Difference	5,407.83	6,970.93	9,124.88	147.88	-1,020.53	-5,547.10	-6,016.35	-1,488.77	-6,131.90	10,384.65
	in %	26.53%	34.30%	45.70%	0.67%	-5.18%	-26.75%	-27.42%	-7.16%	-28.41%	54.10%
CH_4	2025	338.95	253.47	272.6	254.57	361.51	455.42	173.61	289.14	140.27	535.51
	2026	413.9	281.81	321.26	308.78	316.97	374.94	165.74	296.08	114.08	620.83
	Difference	74.95	28.34	48.65	54.2	-44.55	-80.49	-7.87	6.94	-26.2	85.33
	in %	22.11%	11.18%	17.85%	21.29%	-12.32%	-17.67%	-4.54%	2.40%	-18.68%	15.93%
N_2O	2025	135.82	136.08	137.49	204.18	219.09	315.61	348.14	339.13	331.02	323.64
	2026	543.02	521.14	505.7	491.17	480.1	469.3	425.9	412.01	398.05	384.27
	Difference	407.2	385.06	368.21	286.99	261.01	153.69	77.76	72.88	67.03	60.63
	in %	2.998	282.98%	267.82%	140.56%	119.13%	48.70%	22.33%	21.49%	20.25%	18.73%

6.5.6 Category-specific planned improvements (4.B)

Apart from the planned medium-term measures set out in Chapter 6.1.2.1.9 and Chapter 6.1.4, there are no further specific measures currently planned to improve the methods used for Cropland.

6.6 Grassland (4.C)

6.6.1 Category description (4.C)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
L/T	4 C, Grassland	0	CO_2	22,519.9	2.38	21469.1	2.98	-28.2
L/T	4 C, Grassland	0	CH_4	2,582.3	0.01	2,657.3	0.02	-35.1
-/-	4 C, Grassland	0	N_2O	80.60	0.12	52.0	0.23	7.2

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2/Tier 3	RS/NS	CS/D
N_2O	Tier 2	RS/NS	CS/D
CH_4	Tier 2	RS/NS	CS/D

The category Grassland (4.C) is a key category for CO_2 and CH_4 emissions in terms of emissions level and trend.

In 2024, the net anthropogenic GHG emissions from Grassland amounted to 24,178.4 kt CO_2-eq. (95% confidence interval: 19,189.6 kt CO_2-eq. (≙ -20.6)% - 29,063.9 kt CO_2-eq. (≙ 20.2%)). Drainage of organic grassland soils resulted in emissions of 26,282.8 kt of CO_2, 2,657.3 kt CO_2-eq. of methane and 46.5 kt CO_2-eq. of nitrous oxide. Mineral soils (-4,468.6 kt CO_2) served as a carbon sink in the Grassland sector.

These emissions consist of the sum of the emissions from the subcategories Grassland (in the strict sense), Woody Grassland, and Hedges. GHG emissions in each of these three subcategories differ considerably from those in the other subcategories, both quantitatively and qualitatively. As Table 394 and Figure 93 and Figure 94 show, Grassland (in the strict sense) is clearly a CO_2 source. Its absolute emissions, amounting to 28,995.1 kt CO_2-eq., are dominated by emissions from organic soils (27,662.7 kt CO_2-eq.) and the percentage share of the CO_2 emissions therein (90.9%) greatly exceeds that of methane (9.1%). Whereas biomass, at 5,509.5 kt CO_2-eq., also functions as a source, contributing a share of 16.6% to the gross emissions (33,172.2 kt CO_2-eq.) in the subcategory Grassland (in the strict sense), mineral soils continue to function as a carbon sink. They reduce the gross emissions in the subcategory Grassland (in the strict sense) by 12.6%.

Table 394: CO_2, N_2O and CH_4 emissions [kt CO_2-eq.] from Grassland in 2024, broken down by pool and subcategory. The table includes both the relevant sums and the upper and lower bounds of the 95% confidence interval.

Grassland (in the strict sense) Emissions, 2024						
Pool	**GHG**	**[kt CO_2-eq.]**			**[%]**	
		Emission	**2.5% perc.**	**97.5% perc.**	**2.5% perc.**	**97.5% perc.**
Grassland (in the strict sense).$_{total}$ [1]		28,995.1	19,788.7	37,990.1	31.8	30.93
Mineral soils	CO_2 [2]	-4,179.25	-3,516.5	-4,842	15.86	15.86
	$N_2O_{indirect}$ [3]	0.6	0.2	1.3	68.3	108.2
	N_2O_{direct} [3]	1.5	0.8	2.1	42.3	44.4
Organic soil	CO_2 [2]	25,135	13,035.5	34,787.8	48.1	38.4
	CH_4 [5]	2,527.7	1,260.27	3,050.4	50.14	268.17
	N_2O [4]	IE	IE	IE	IE	IE
Biomass	CO_2 [2]	5,509.5	4,702	6,648.7	14.66	20.68
Dead organic matter	CO_2 [2]	NO	NO	NO	NO	NO
Woody Grassland, emissions, 2024						
Pool	**GHG**	**[kt CO_2-eq.]**			**[%]**	
		Emission	**2.5% perc.**	**97.5% perc.**	**2.5% perc.**	**97.5% perc.**
Woody Grassland$_{total}$ [6]		-5,379.30	-4,885.90	-6,064.90	9.17	12.75
Mineral soils	CO_2 [2]	-304.41	-274.69	-334.15	9.76	9.77
	$N_2O_{indirect}$ [3]	0.68	0.05	1.66	92.63	145.51
	N_2O_{direct} [3]	1.54	0.65	2.43	57.66	58.17
Organic soil	CO_2 [2]	615.17	382.4	801.1	37.83	30.23
	CH_4 [5]	100	60.76	114.15	39.23	209.17
	N_2O [4]	26.37	9.8	94.3	62.98	257.51
Biomass	CO_2 [2]	-5,818.58	-5,234.10	-6,643.70	10.05	14.18
Dead organic matter	CO_2 [2]	NO	NO	NO	NO	NO
Hedges, emissions, 2024						
Pool	**GHG**	**[kt CO_2-eq.]**			**[%]**	
		Emission	**2.5% perc.**	**97.5% perc.**	**2.5% perc.**	**97.5% perc.**
Hedges$_{total}$ [6]		562.60	301.20	795.80	46.46	41.45
Mineral soils	CO_2 [2]	9.56	8.09	11.03	15.4	15.4
	$N_2O_{indirect}$ [3]	0.36	0	1.16	99.9	220.64
	N_2O_{direct} [3]	0.83	0.1	1.55	87.75	87.75
Organic soil	CO_2 [2]	532.67	238.06	767.75	55.31	44.13
	CH_4 [5]	29.61	12.38	121.73	58.19	311.15
	N_2O [4]	20.09	1.43	96.46	92.87	380.06
Biomass	CO_2 [2]	-30.68	-24.40	-37.20	20.36	21.32
Dead organic matter	CO_2 [2]	0.14	0.03	0.25	81.28	81.28

1) Subtotals of emissions from CRF 4.C, 4.(II).C, 4.(III).C

2) Subtotal of emissions from CRF 4.C

3) CRF 4.(III).C

4) CRF 3.D.1.f

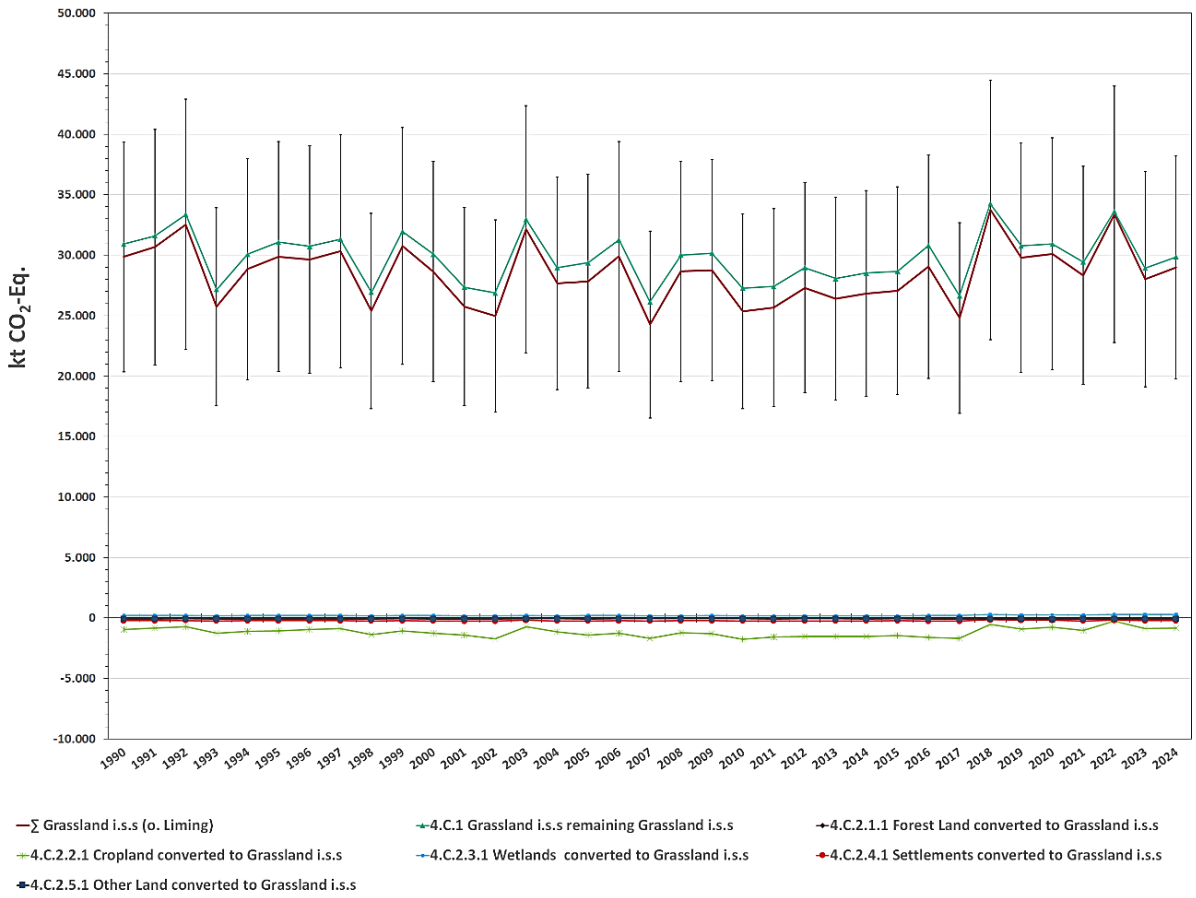
5) CRF 4.(II).C

6) Subtotals of emissions from CRF 4.C, 4.(II).C and sum from 4.(III).C

In 2024, the time series for total emissions from Grassland (in the strict sense) includes emissions that are -866.5 kt CO_2-eq. or ≙ -2.9% lower than in the base year 1990. In terms of absolute levels, emissions from organic soils predominate in the time series for total emissions. Over the entire reporting period, mineral soils function as an almost unchanged sink (4.1% increase in the sink function relative to 1990). The biomass emissions are positive and have been continuously increasing since 2010 (+130.9% compared with 1990), particularly due to intensified land-use changes from Woody Grassland to Grassland (in the strict sense).

The shapes of the time series plots – especially the noticeable changes they show – are due primarily to periodicity in surveying of the relevant area data. Land-use changes were determined on the basis of spatially explicit data sets from the years 1990, 1995, 2000, 2005, 2010, 2015, 2020 and 2023 (cf. Chapter 6.3.1). Land-use changes that occurred between those years were determined by linear interpolation, and thus the annual conversion areas did not change between the survey time points. Land use before the year 2010 was determined by extrapolation using stochastic methods (cf. Chapter 6.3.1.2.2).

Figure 93: GHG emissions (sum of CO_2, CH_4 and N_2O) [kt CO_2-eq.] as a result of land use and land-use change from Grassland (in the strict sense), 1990-2024, by subcategory



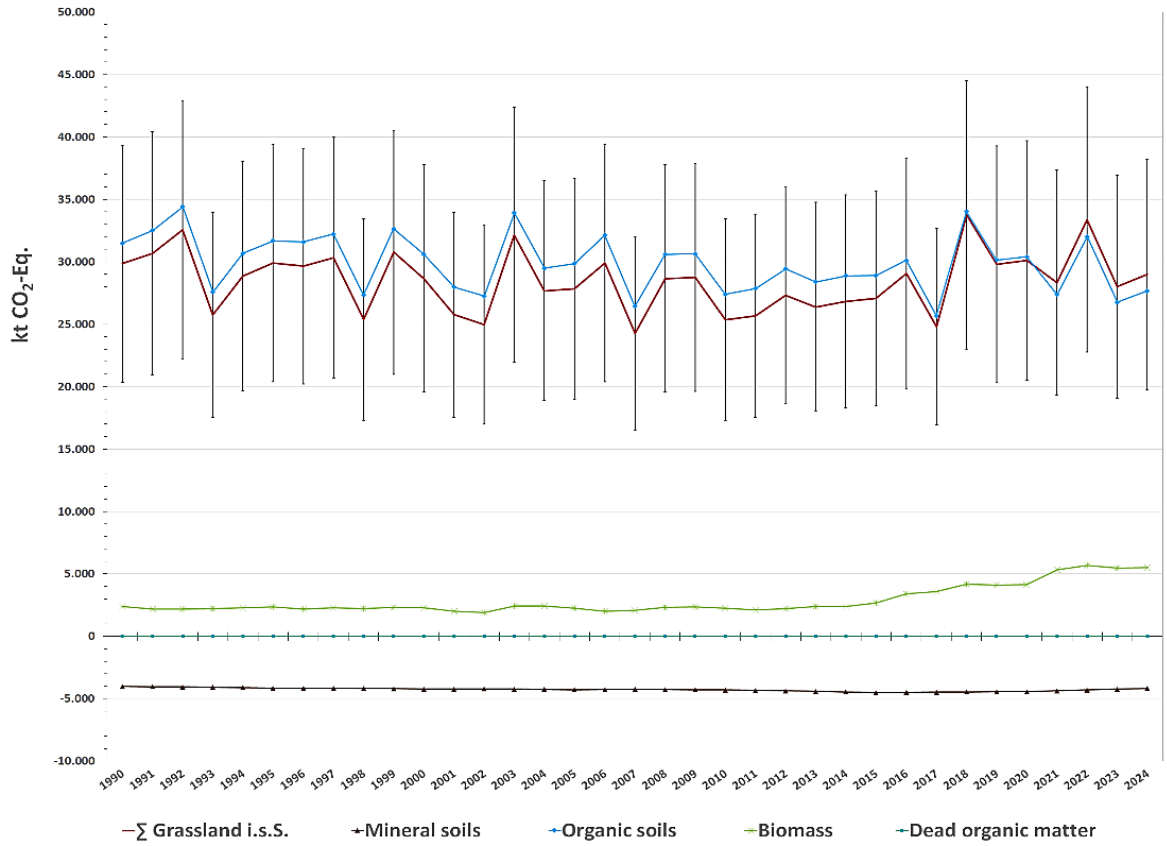
Source: own illustration, Thünen-Institut

The net emissions in the subcategory Woody Grassland are shaped primarily by emissions from the biomass pool. In 2024, this pool functioned as a sink, with emissions of -5,818.6 kt CO_2-eq., as did the mineral soils pool (-302.2 kt CO_2-eq.) The pools' sink effects more than offset the positive emissions from organic soils (741.5 kt CO2-eq.), with the result that the subcategory Woody

Grassland was a net carbon sink in 2024 (-5,379.3 kt CO2-eq.; Table 394 and Figure 94 and Figure 96).

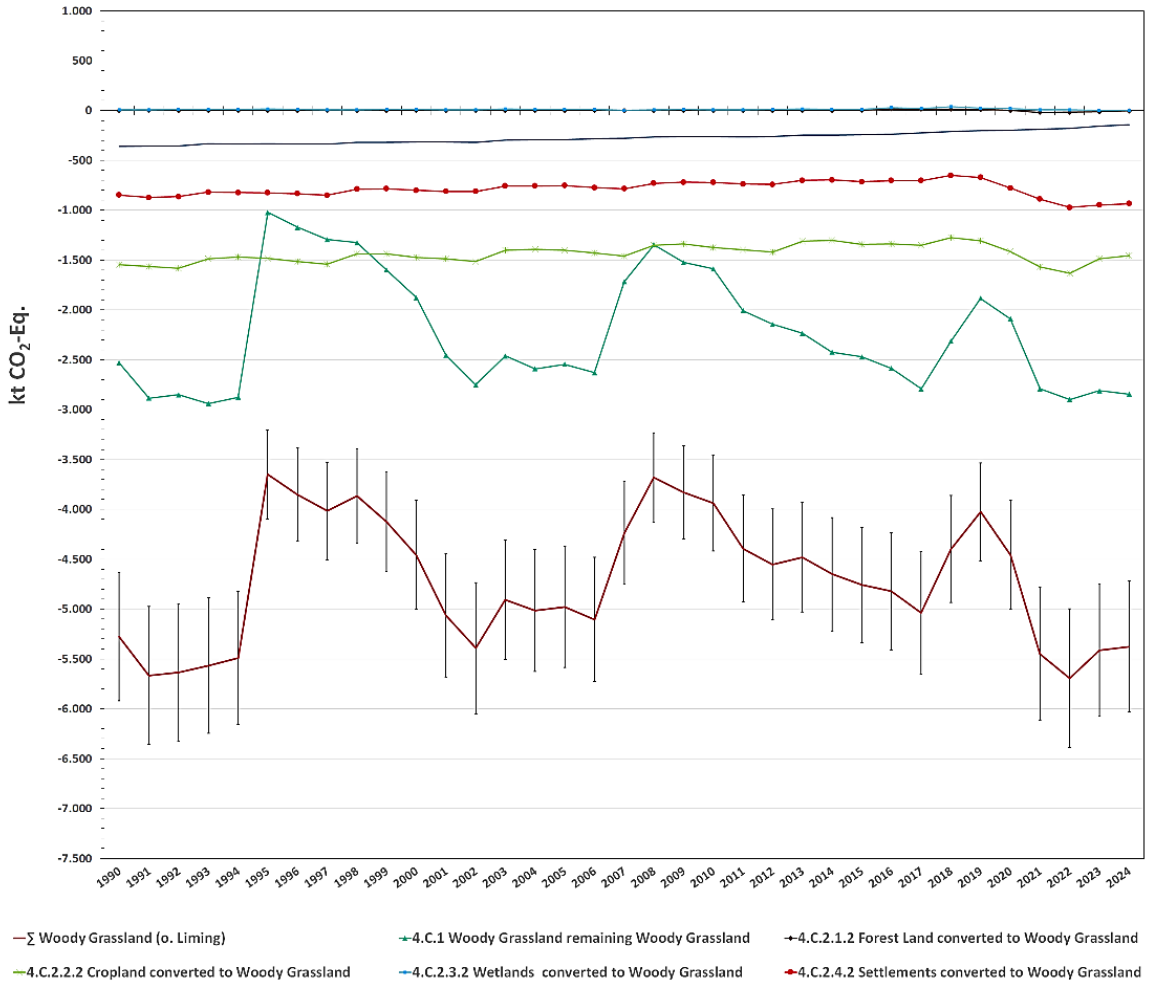
The curve progressions of the time series in Figure 94 and Figure 96 show that, as a result of ongoing use of biomass and of land-use changes from and to the subcategory Woody Grassland, this subcategory a) is highly dynamic due to the considerable carbon stocks found in its biomass, and b) is shaped by the 12-year rotation period for hedges and field copses on which the model is based (cf. Chapter 6.1.2.3.6).

Figure 94: GHG emissions (sum of CO_2, CH_4 and N_2O) [kt CO_2-eq.] as a result of land use and land-use change from Grassland (in the strict sense), 1990-2024, by pool



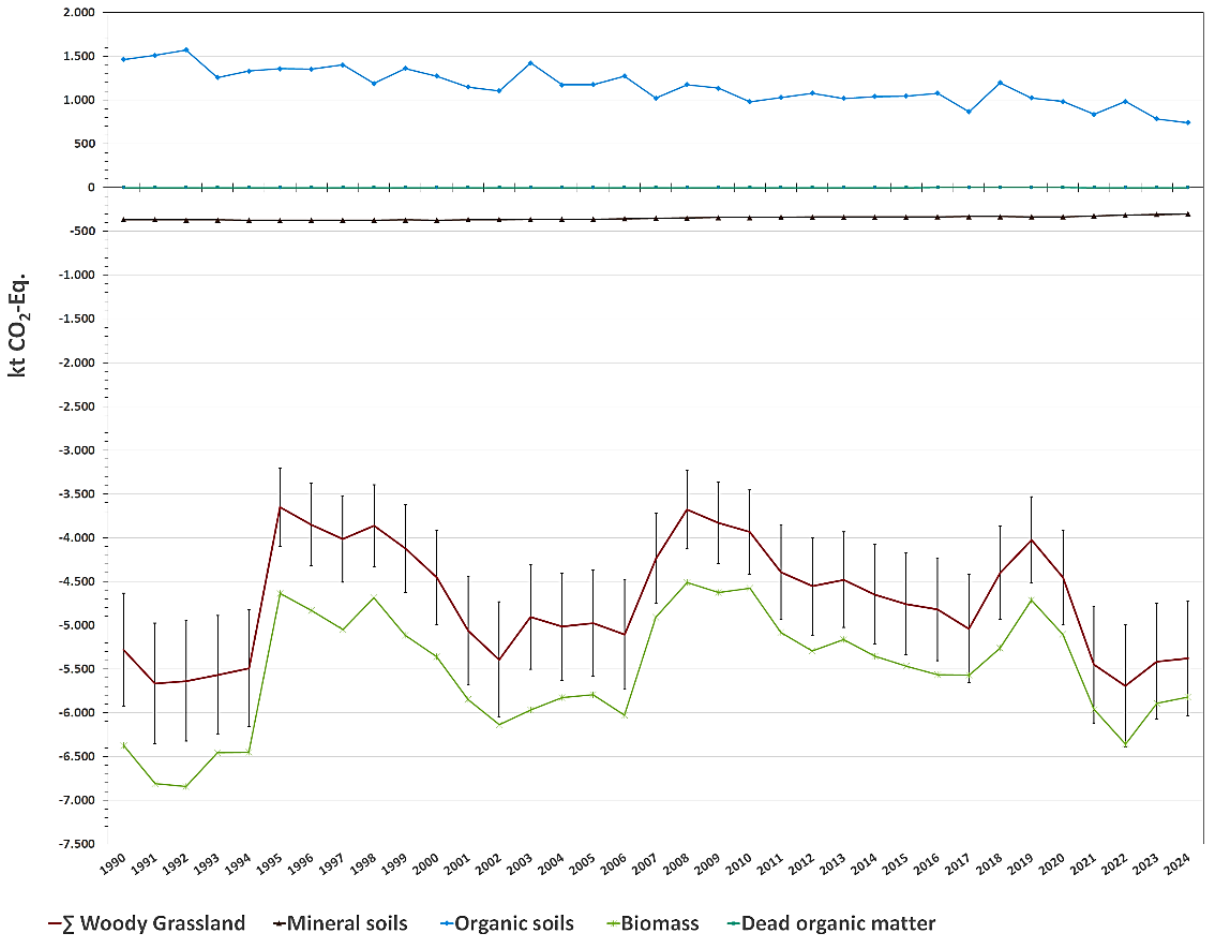
Source: own illustration, Thünen-Institut

Figure 95: GHG emissions (sum of CO_2, CH_4 and N_2O) [kt CO_2-eq.] as a result of land use and land-use change from Woody Grassland and Hedges, 1990-2024, by subcategory



Source: own illustration, Thünen-Institut

Figure 96: GHG emissions (sum of CO_2, CH_4 and N_2O) [kt CO_2-eq.] as a result of land use and land-use change from Woody Grassland and Hedges, 1990-2024, by pool



Source: own illustration, Thünen-Institut

In 2024, the subcategory Hedges, with net emissions of 562.6 kt CO_2-eq., contributed only slightly to the net emissions in the land-use category Grassland (1.9%). Emissions in the Hedges category are shaped by the continuing high emissions of organic soils (2024: 582.4 kt CO_2-eq.); the net-emissions curve in the time series continues to be shaped by the extremely variable emissions from biomass, which depend strongly on age distribution and rotation periods.

6.6.2 Methodological issues (4.C)

6.6.2.1 Sources of data

The following data sources / sets have been used:

- Federal Statistical Office, Fachserie 3, Reihe 3.1.2, agriculture and forestry, fisheries – soil use by sectoral operations; (various years) (Statistisches Bundesamt, FS 3, R 3);
- 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Agriculture, Forestry and Other Land Use (IPCC, 2006a);
- 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use (IPCC, 2019)

- "Ordinance on application of fertilisers, soil additives, culture substrates and plant additives according to the principles of good practice in fertilisation (Fertilisation Ordinance – Düngeverordnung (DüV))" (Ordinance on Fertilisation in the version as promulgated 27 February 2007 (Federal Law Gazette I, p. 221), last amended by Article 5 (36) of the Act of 24 February 2012 (Federal Law Gazette I. p. 212), (Bundesgesetzblatt, 2012);
- Interim report in the research project "Methodenentwicklung zur Erfassung der Biomasse mehrjährig verholzter Pflanzen außerhalb von Wäldern" ("Development of methods for determining the biomass of plants outside of forests with multiple years of wood growth") (Pöpken, 2011).
- (Drexler et al., 2021): Carbon sequestration in hedgerow biomass and soil in the temperate climate zone. Regional Environmental Change (2021) 21:74; https://doi.org/10.1007/s10113-021-01798-8; Springer
- (Jacobs et al., 2018): Landwirtschaftlich genutzte Böden in Deutschland - Ergebnisse der Bodenzustandserhebung (Agricultural soils in Germany – Results of the Soil Inventory); Johann Heinrich von Thünen Institute, 316 pp. Thünen Report 64; Braunschweig. DOI:10.3220/REP1542818391000

6.6.2.2 Biomass

In the Grassland category, the biomass pool is further subdivided in accordance with basic characteristics of the plants concerned (cf. Chapter 6.2.3 and Table 341 in Chapter 6.3.1.2.1):

- herbaceous plants (subcategory Grassland (in the strict sense))
- perennial woody plants in hedges and field copses (subcategories Woody Grassland and Hedges)

The GHG emissions from plant biomass of perennial hedge and field copse plants in the subcategories Woody Grassland and Hedges are determined as follows: the growth stages of plants are modelled chronologically accurately as a function of crop age and type of management (rotation periods) so that emissions can be reported – in accordance with the requirements of the 2006 IPCC Guidelines (IPCC, 2006a) – in the year in which they occur. The methods and assumptions used for calculation of carbon-stock changes in above-ground and below-ground biomass of woody plants are described in Chapters 6.1.2.4 ff., while the specific methods and emission factor derivations for Woody Grassland and Hedges are described in Chapter 6.1.2.3.6.

For the subcategory Grassland (in the strict sense), regionalised carbon stocks are determined for herbaceous biomass (Chapter 6.1.2.3.3). They are available for all relevant emissions calculations on a yearly basis. In the Grassland remaining Grassland in the strict sense category, the phytomass is assumed to be in dynamic equilibrium; consequently, no emissions occur. The notation key "NA" is entered in the relevant spaces in the tables (cf. Chapter 6.1.2.3.1). The plant biomass of the subcategories Woody Grassland and Hedges is calculated for each report year (Chapters 6.1.2.4 ff.). Area conversions between the individual Grassland subcategories are treated like land-use changes, and explicitly listed as such in CRF 4.C. The area changes between annual and perennial plants can be documented spatially explicitly and completely. Relevant calculations are carried out using the gain-loss method (IPCC, 2006a) described in Chapters 6.1.2.3.1 and 6.1.2.3.2.

In the tables, "IE" is entered in the spaces for dead organic matter in the Grassland category, since the complete biomass is taken into account in the model.

6.6.2.3 Mineral soils

For "remaining as..." areas in the Grassland category with the same name, the changes in the carbon stocks in mineral soils were calculated using a mathematical process-based model and the CO_2 and N_2O emissions derived from this; the methodology, maps used and model description are sketched out in Chapters 6.1.2.1 ff. Areas undergoing conversions between the subcategories of the Grassland category are treated like land-use changes.

Calculation of CO_2 emissions resulting from conversions to Grassland (in the strict sense), and to Woody Grassland and Hedges, is described in Chapter 6.1.2.1, while the emission factors and their uncertainties are also described in Table 395 to Table 400 in Chapter 6.6.3

The emissions in the categories remaining in a land use are listed in CRF 4.C.1, while the emissions resulting from land-use changes are listed in CRFs 4.C.2.a-4.C.2.e. The nitrous oxide emissions from mineral soils are included in the values in CRF 4(III).C.

6.6.2.4 Organic soils

In the land-use category Grassland, CO_2, CH_4 and N_2O emissions from organic soils are reported; nitrous oxide emissions are reported only for the subcategories Woody Grassland and Hedges. N_2O emissions from organic soils under Grassland (in the strict sense) are reported as part of the Agriculture sector in CRF 3.D.a.6 "Cultivation of Histosols" (cf. Chapter 6.5.2). A discussion of the area differences with regard to Grassland as reported in the LULUCF sector and the relevant values listed in CRF 3.D.1.f "Cultivation of Histosols" for the agricultural sector is provided in Chapter 6.1.2.2.1. The methods used to calculate emissions from organic soils and to derive the relevant emission factors are described in Chapter 6.1.2.2.

The annual emissions following land-use changes to Grassland (in the strict sense) are calculated with the same methodology used for emissions from organic soils in the subcategory Grassland (in the strict sense) remaining Grassland (in the strict sense). The same holds for emissions from organic soils following land-use changes leading to Woody Grassland and Hedges. The emissions in the categories remaining in a land use are listed in CRF 4.C.1, while the emissions resulting from land-use changes are listed in CRFs 4.C.2.a-4.C.2.e. Methane emissions from organic soils and from drainage ditches, and nitrous oxide emissions from the subcategories Woody Grassland and Hedges, are listed in CRF 4(II).C.

6.6.3 Uncertainties and time series consistency (4.C)

The uncertainties for the activity data of the land-use category Grassland have a normal distribution, with values of 0.07-196.0% for half of the 95% confidence interval. Here as well, the uncertainty depends on the sample size; the smaller the area, the larger the uncertainty. Weighted by area, the total uncertainty for activity data in the category Grassland is 0.07%.

The total uncertainty for the land-use category Grassland is 20.6% [2.5% percentile] and 20.2% [97.5% percentile], while that for the subcategory Grassland (in the strict sense) is 31.8% [2.5% percentile] and 30.9% [97.5% percentile]; that for the subcategory Woody Grassland is 9.2% [2.5% percentile] and 12.8% [97.5% percentile]; and that for the subcategory Hedges is 46.5% [2.5% percentile] and 41.5% [97.5% percentile]. In the subcategory Grassland (in the strict sense), CO_2 emissions from organic soils make the largest contribution to the subcategory's total uncertainty. In addition, they make the largest contribution to the variance of the overall inventory (cf. Chapter 6.1.2.10). The contributions of the subcategories Woody Grassland and Hedges to the uncertainty of the total inventory are marginal.

Table 395 to Table 400 show the uncertainties regarding the implied emission factors for the subcategories Grassland (in the strict sense), Woody Grassland and Hedges.

Table 395: Emission factors [t C ha^{-1} a^{-1}] with uncertainties [% of central tendency] as used for calculation of 2024 GHG emissions from Grassland (in the strict sense)

Grassland$_{(in\ the\ strict\ sense)}$		**Implied EF**	**Uncertainty bounds**	
Land use$_{initial}$	**Land use$_{final}$**		**upper**	**lower**
Mineral soils, CO_2-C [1)]		**[t C ha^{-1} a^{-1}]**	**[%]**	**[%]**
Grassland$_{(in\ the\ strict\ sense)}$	Grassland$_{(in\ the\ strict\ sense)}$	-0.02	19.50	19.50
Forest Land		NO	NO	NO
Cropland$_{annual}$		0.801	18.88	18.88
Hops		0.901	50.4	50.4
Vineyards		1.375	23.68	23.68
Orchards		0.549	17.5	17.5
Short-rotation plantations		NO	NO	NO
Tree nurseries		0.91	21.15	21.15
Christmas tree plantations		NO	NO	NO
Woody Grassland		0.057	19.66	19.66
Hedges		-0.02	26.22	26.22
Terr. Wetlands		-0.684	26.54	26.54
Peat extraction		NO	NO	NO
Settlements		0.825	18.06	18.12
Photovoltaic areas		NO	NO	NO
Other Land		3.407	27.24	27.24
Mineral soils, $N_2O_{indirect}$		**[kg N_2O ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Grassland$_{(in\ the\ strict\ sense)}$	NO	NO	NO
Cropland$_{annual}$		0.0003	99.9	223.34
Hops		NO	NO	NO
Vineyards		0.00004	99.9	225.18
Orchards		0.013	99.9	223.4
Short-rotation plantations		NO	NO	NO
Tree nurseries		0.001	99.9	224.45
Christmas tree plantations		NO	NO	NO
Woody Grassland		0.006	99.9	222.75
Hedges		0.006	99.9	223.42
Terr. Wetlands		0.335	99.9	223.5
Peat extraction		NO	NO	NO
Settlements		0.003	99.9	224.47
Photovoltaic areas		NO	NO	NO
Other Land		NO	NO	NO
Mineral soils, N_2O_{direct}		**[kg N_2O ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Grassland$_{(in\ the\ strict\ sense)}$	NO	NO	NO
Cropland$_{annual}$		0.001	85.86	91.9
Hops		NO	NO	NO
Vineyards		0.0001	89.47	96.3
Orchards		0.03	86.81	92.04
Short-rotation plantations		NO	NO	NO
Tree nurseries		0.003	87.22	94.56
Christmas tree plantations		NO	NO	NO

Grassland(in the strict sense)		**Implied EF**	**Uncertainty bounds**	
Woody Grassland		0.013	86.09	90.46
Hedges		0.015	87.82	92.11
Terr. Wetlands		0.762	88.91	92.29
Peat extraction		NO	NO	NO
Settlements		0.008	90.08	94.62
Photovoltaic areas		NO	NO	NO
Other Land		NO	NO	NO
Biomass [2)]		**[t C ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Grassland(in the strict sense)	NO	NO	NO
Cropland$_{annual}$		0.048	16.73	16.73
Hops		0.126	50.92	50.92
Vineyards		-0.036	22.61	22.61
Orchards		-0.55	14.56	14.56
Short-rotation plantations		NO	NO	NO
Tree nurseries		-0.699	23.81	23.81
Christmas tree plantations		NO	NO	NO
Woody Grassland		-9.694	16	22.58
Hedges		-25.717	22.86	27.87
Terr. Wetlands		-5.784	19.21	24.31
Peat extraction		0.5	37.66	37.66
Settlements		0.04	18.67	18.67
Photovoltaic areas		NO	NO	NO
Other Land		0.26	31.86	31.86
Dead organic matter [2)]		**[t C ha^{-1} a^{-1}]**	**[t C ha^{-1} a^{-1}]**	**[%]**
Forest Land	Grassland(in the strict sense)	NO	NO	NO

All factors are annually variable

1) The calculation covers a 20-year period; stock change: positive ≙ sink; negative ≙ source

2) The calculation is only for the first year of the land-use change; stock change: positive ≙ sink; negative ≙ source

Table 396: Uncertainties for emission factors [2.5% and 97.5% percentile, in % of central tendency] for emissions from organic soils under Grassland (in the strict sense), 2024

Land use	**Greenhouse gas**	**Emission factor**	**Uncertainty bounds**	
			lower	**upper**
Organic soils [1)]		[kt CO_2-eq. [ha^{-1} a^{-1}]	[%]	[%]
Grassland in the strict sense	CO_2	28.69	48.14	38.40
Grassland in the strict sense	CH_4	2.35	50.14	268.17
Grassland in the strict sense	N_2O	IE	IE	IE

1) Annual calculation; emission: positive ≙ source; negative ≙ sink

Table 397: Emission factors [t C ha^{-1} a^{-1}], with uncertainties [% of central tendency], as used for calculation of 2024 GHG emissions from Woody Grassland areas

Woody Grassland Land use$_{initial}$ Mineral soils, CO_2-C [1]	Land use$_{final}$	Emission factor [t C ha^{-1} a^{-1}]	Uncertainty bounds upper [%]	 lower [%]
Woody Grassland	Woody Grassland	-0.02	19.50	19.50
Forest Land		0.158	32.22	40.04
Cropland$_{annual}$		0.933	19.23	19.23
Hops		NO	NO	NO
Vineyards		1.287	26.95	26.95
Orchards		0.535	21.06	21.05
Short-rotation plantations		NO	NO	NO
Tree nurseries		0.86	28.28	28.27
Christmas tree plantations		NO	NO	NO
Grassland in the strict sense		0.105	19.61	19.61
Hedges		-0.02	42.19	42.19
Terr. Wetlands		-0.707	51.05	51.05
Peat extraction		NO	NO	NO
Settlements		0.749	18.48	18.54
Photovoltaic areas		NO	NO	NO
Other Land		3.814	27.14	27.14
Mineral soils, N_2O_{direct} [3]		**[kg N_2O ha^{-1} a^{-1}]**	**[kg N_2O ha^{-1} a^{-1}]**	**[%]**
Forest Land	Woody Grassland	NO	NO	NO
Cropland$_{annual}$		0.001	85.93	91.98
Hops		NO	NO	NO
Vineyards		NO	NO	NO
Orchards		0.026	87.59	92.79
Short-rotation plantations		NO	NO	NO
Tree nurseries		0.004	89.22	96.41
Christmas tree plantations		NO	NO	NO
Grassland in the strict sense		0.013	86.08	90.45
Hedges		0.016	93.84	97.86
Terr. Wetlands		0.73	99.03	102.08
Peat extraction		NO	NO	NO
Settlements		0.01	90.17	94.71
Photovoltaic areas		NO	NO	NO
Other Land		NO	NO	NO
Mineral soils, $N_2O_{indirect}$ [3]		**[kg N_2O ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Woody Grassland	NO	NO	NO
Cropland$_{annual}$		0.001	99.9	223.37
Hops		NO	NO	NO
Vineyards		NO	NO	NO
Orchards		0.011	99.9	223.7
Short-rotation plantations		NO	NO	NO
Tree nurseries		0.002	99.9	225.23

Woody Grassland		Emission factor	Uncertainty bounds	
Christmas tree plantations		NO	NO	NO
Grassland in the strict sense		0.006	99.9	222.74
Hedges		0.007	NO	NO
Terr. Wetlands		0.321	99.9	225.85
Peat extraction		NO	NO	NO
Settlements		0.004	99.9	224.51
Photovoltaic areas		NO	NO	NO
Other Land		NO	NO	NO
Biomass [2)]		**[t C ha^{-1} 1 a^{-1}]**	**[%]**	**[%]**
Forest Land		23.42	25.55	28.61
$Cropland_{annual}$		7.488	16.24	22.8
Hops		10.697	196.64	197.3
Vineyards		9.149	24.99	29.56
Orchards		9.768	19.41	24
Short-rotation plantations		NO	NO	NO
Tree nurseries		8.851	26.22	29.38
Christmas tree plantations	Woody Grassland	NO	NO	NO
Grassland in the strict sense		7.986	15.94	22.55
Hedges		-17.042	38.63	40.39
Terr. Wetlands		3.539	25.58	28.41
Peat extraction		12.182	71.24	73.17
Settlements		8.636	16.29	22.66
Photovoltaic areas		NO	NO	NO
Other Land		6.843	19.26	25.5
Dead organic matter [2)]		**[t C ha^{-1} 1 a^{-1}]**	**[t C ha^{-1} 1 a^{-1}]**	**[%]**
Forest Land	Woody Grassland	NO	NO	NO

All factors are annually variable

1) The calculation covers a 20-year period; stock change: positive ≙ sink; negative ≙ source

2) The calculation is only for the first year of the land-use change; stock change: positive ≙ sink; negative ≙ source

3) The calculation covers a 20-year period; emission: positive ≙ source; negative ≙ sink

Table 398: Uncertainties for emission factors [2.5% and 97.5% percentile, in % of central tendency] for emissions from organic soils for Hedges, in 2024

Land use	Greenhouse gas	Emission factor	Uncertainty bounds	
			lower	upper
Organic soils [1)]		[kt CO_2-eq. [ha^{-1} a^{-1}]	[%]	[%]
Woody Grassland	CO_2	21.49	37.83	30.23
Woody Grassland	CH_4	3.425	39.23	209.17
Woody Grassland	N_2O	0.999	62.98	257.51

Annual calculation; emission: positive ≙ source; negative ≙ sink

Table 399: Emission factors [t C ha^{-1} a^{-1}], with uncertainties [% of central tendency], as used for calculation of 2024 GHG emissions from Hedges

Woody Grassland Land use$_{initial}$ Mineral soils, CO_2-C [1]	Land use$_{final}$	Emission factor [t C ha^{-1} a^{-1}]	Uncertainty bounds upper [%]	 lower [%]
Hedges	Hedges	-0.0200	15.55	16.13
Forest Land		-0.2271	74.62	74.65
Cropland$_{annual}$		0.9638	100.08	100.69
Hops		0.5594	138.96	138.98
Vineyards		1.0080	80.83	80.88
Orchards		0.3929	37.80	37.87
Short-rotation plantations		0.9250	32.23	32.32
Tree nurseries		0.1958	62.80	62.84
Christmas tree plantations		0.5217	88.23	88.27
Grassland in the strict sense		0.2114	99.99	113.73
Woody Grassland		NO	NO	NO
Terr. Wetlands		NO	NO	NO
Peat extraction		NO	NO	NO
Settlements		NO	NO	NO
Photovoltaic areas		1.7816	99.99	196.20
Other Land		NO	NO	NO
Mineral soils, N_2O_{direct} [3]		**[kg N_2O ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Hedges	NO	NO	NO
Cropland$_{annual}$		0.0025	99.99	132.55
Hops		NO	NO	NO
Vineyards		NO	NO	NO
Orchards		0.0239	93.08	93.08
Short-rotation plantations		0.0036	92.66	93.50
Tree nurseries		0.0033	99.99	107.92
Christmas tree plantations		0.0001	99.99	124.45
Grassland in the strict sense		0.0113	99.99	142.58
Woody Grassland		NO	NO	NO
Terr. Wetlands		NO	NO	NO
Peat extraction		NO	NO	NO
Settlements		NO	NO	NO
Photovoltaic areas		NO	NO	NO
Other Land		NO	NO	NO
Mineral soils, $N_2O_{indirect}$ [3]		**[kg N_2O ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Hedges	NO	NO	NO
Cropland$_{annual}$		0.0011	99.99	292.18
Hops		NO	NO	NO
Vineyards		NO	NO	NO
Orchards		0.0105	99.99	276.52
Short-rotation plantations		0.0016	99.99	276.66
Tree nurseries		0.0015	99.99	281.86
Christmas tree plantations		NO	99.99	288.59

Woody Grassland		Emission factor	Uncertainty bounds	
Grassland in the strict sense		0.0050	99.99	296.86
Woody Grassland		NO	NO	NO
Terr. Wetlands		NO	NO	NO
Peat extraction		NO	NO	NO
Settlements		NO	NO	NO
Photovoltaic areas		NO	NO	NO
Other Land		NO	NO	NO
Biomass [2)]		**[t C ha^{-1} 1 a^{-1}]**	**[t C ha^{-1} 1 a^{-1}]**	**[%]**
Forest Land	Hedges	-12.1656	75.42	76.52
$Cropland_{annual}$		-0.4399	89.07	90.50
Hops		0.9875	99.99	140.43
Vineyards		0.0051	81.53	83.04
Orchards		-3.0187	38.47	40.98
Short-rotation plantations		-7.9020	30.87	32.40
Tree nurseries		-0.5853	63.53	64.90
Christmas tree plantations		-0.6868	88.90	89.98
Grassland in the strict sense		0.2847	99.99	127.86
Woody Grassland		NO	NO	NO
Terr. Wetlands		2.5230	99.99	196.77
Peat extraction		NO	NO	NO
Settlements		NO	NO	NO
Photovoltaic areas		-8.2559	99.99	196.94
Other Land		NO	NO	NO
Dead organic matter [2)]		**[t C ha^{-1} 1 a^{-1}]**	**[t C ha^{-1} 1 a^{-1}]**	**[%]**
Forest Land	Hedges	-0.7190	90.68	90.68

All factors are annually variable

1) The calculation covers a 20-year period; stock change: positive ≙ sink; negative ≙ source

2) The calculation is only for the first year of the land-use change; stock change: positive ≙ sink; negative ≙ source

3) The calculation covers a 20-year period; emission: positive ≙ source; negative ≙ sink

Table 400: Uncertainties for emission factors [2.5% and 97.5% percentile, in % of central tendency] for emissions from organic soils for Hedges, in 2024

Land use	Greenhouse gas	Emission factor	Uncertainty bounds	
			lower	upper
Organic soil		[kt CO_2-eq. [ha^{-1} a^{-1}]	[%]	[%]
Hedges	CO_2	28.11	55.31	44.13
Hedges	CH_4	1.276	58.19	311.15
Hedges	N_2O	1.123	92.87	380.06

1) Annual calculation; emission: positive ≙ source; negative ≙ sink

For Grassland (in the strict sense), Woody Grassland and Hedges, the calculations are spatially and chronologically consistent and complete for the entire reporting period, 1990-2024.

6.6.4 Category-specific QA/QC and verification (4.C)

Details regarding this year's reviews are provided in Chapter 6.1.3.

The data sources used in preparation of this inventory fulfil the review criteria of the QSE manual for data sources (QSE-Handbuch für Datenquellen). Quality assurance for input data (ATKIS®, BÜK, official statistics) is the responsibility of the relevant data administrators (cf. the documentation in the inventory description).

The emissions calculation results as presented in the present report cannot be compared with other relevant data sources for Germany since no such other data sources exist that meet applicable requirements, i.e. provide nationwide coverage, are comprehensive and are independent of the methods and data sources described in the present report.

The following tables 410 to 413 present an intra-European comparison of implied emission factors (IEFs) for various pools. For this comparison, values of neighbouring countries, obtained from the 2025 submission to the Climate Secretariat (UNFCCC NID submission 2025, Inventory year 2023, (UNFCCC, 2025)) are used. The values for Germany in 2024 were obtained from the current 2026 submission.

The comparison is generally problematic because the values to be compared were not all obtained with the same methods (in some cases, the methods differ widely), and especially because the demarcations of the systems differ – in some cases, markedly. In this comparison, Grassland in Germany always refers to the sum of the subcategories Grassland (in the strict sense), Woody Grassland and Hedges. These system demarcations are defined very differently from country to country, and thus the relevant mean emission factors of different countries often cannot be directly compared. In view of this fact, and taking account of the major uncertainties and the scattering seen in the reported values (cf. Chapter 6.6.3), in none of the compared pools does the comparison show implied emission factors (IEFs) that must clearly be considered outliers. Most of the EFs are similar, in terms of both absolute size and trends, to those of various central European neighbouring countries.

Table 401: Carbon-stock changes in living biomass in Grassland of various countries (Germany, for 2023 & 2024; other countries, for 2023), in [t C ha^{-1} a^{-1}]

	4.C.1. - Grassland Remaining Grassland	4.C.2 - Land Converted To Grassland	4.C.2.1 - Forest Land Converted To Grassland	4.C.2.2 - Cropland Converted To Grassland	4.C.2.3 - Wetlands Converted To Grassland	4.C.2.4 - Settlements Converted To Grassland	4.C.2.5 - Other Land Converted To Grassland
Belgium	NO	-0.73	-5.92	0.079	0.03	0.016	NO
Denmark	NA	-0.111	-0.969	-0.096	-2.66	NA	NA, NO
France	0.01	0.035	-0.221	0.11	0.136	0.417	0.001
United Kingdom	-0.001	-0.118	-2.003	-0.073	NO	0.043	NO
Netherlands	0.002	0.034	-3.572	0.145	0.371	0.534	0.86
Austria	NA	-0.855	-2.548	-0.097	NO	NO	NO
Poland	0.002	0.107	NO	0.134	IE, NO	IE, NO	NO
Switzerland	0.02	-0.58	-2.92	-0.105	0.532	0.099	0.406
Czech Republic	NO	0.125	-5.212	0.125	0.416	0.591	NO
Germany, 2023	-0.027	0.243	-12.166	0.283	-3.467	-0.232	0.937
Germany, 2024	-0.116	0.395	8.974	0.281	-3.432	1.679	2.557

Positive: carbon removal by sink; negative: carbon emission by source; Source: (UNFCCC, 2023c)

Table 402: Carbon-stock changes in dead organic mass in Grassland of various countries (Germany, for 2023 & 2024; other countries, for 2023), in [t C ha^{-1} a^{-1}]

	4.C.1. - Grassland Remaining Grassland	4.C.2 - Land Converted To Grassland	4.C.2.1 - Forest Land Converted To Grassland	4.C.2.2 - Cropland Converted To Grassland	4.C.2.3 - Wetlands Converted To Grassland	4.C.2.4 - Settlements Converted To Grassland	4.C.2.5 - Other Land Converted To Grassland
Belgium	NO	-0.10	-0.78	NO	NO	NO	NO
Denmark	NA	-0.019	-1.137	NA	NA	NA	NA
France	0	-0.067	-0.293	0	0.001	0.019	NA
United Kingdom	NO	-0.014	-0.582	IE	NO	IE, NO	NO
Netherlands	NA	-0.083	-1.764	NA	NA	NA	NA
Austria	NO	-0.368	-1.189	NO	NO	NO	NO
Poland	0.001	-0.004	NO	NO	-0.07	NO	NO
Switzerland	NA, NE, NO	-0.18	-0.82	NA	NA	NA	NA
Czech Republic	NO	-0.005	-0.35	NO	NO	NO	NO
Germany, 2023	IE	-0.00001	-0.719	IE	IE	IE	IE
Germany, 2024	IE	0.08	-0.399	IE	IE	IE	IE

Positive: carbon removal by sink; negative: carbon emission by source; Source: (UNFCCC, 2023c)

Table 403: Carbon-stock changes in mineral soils in Grassland of various countries (Germany, for 2023 & 2024; other countries, for 2023), in [t C ha^{-1} a^{-1}]

	4.C.1. - Grassland Remaining Grassland	4.C.2 - Land Converted To Grassland	4.C.2.1 - Forest Land Converted To Grassland	4.C.2.2 - Cropland Converted To Grassland	4.C.2.3 - Wetlands Converted To Grassland	4.C.2.4 - Settlements Converted To Grassland	4.C.2.5 - Other Land Converted To Grassland
Belgium	-0.05	1.04	0.00	0	0	0	0
Denmark	IE	0.047	2.738	IE	-1.624	NA	NA
France	0.024	0.584	-0.014	0.766	0.174	0.535	0.336
United Kingdom	0.135	0.705	-1.165	0.689	NO	2.757	NO
Netherlands	0.239	0.936	0.27	0.983	0.48	0.76	3.984
Austria	NA	0.679	0.763	0.646	NO	NO	NO
Poland	0.005	0.965					
Switzerland	-0.05	-0.09					
Czech Republic	0.118	0.443	-0.108	0.474	NO	0.347	0
Germany, 2023	-0.012	0.868	-0.227	0.828	-0.008	1.929	3.526
Germany, 2024	-0.014	0.177	-0.015	0.803	-0.689	0.811	3.55

Positive: carbon removal by sink; negative: carbon emission by source; Source: (UNFCCC, 2023c)

Table 404: Carbon-stock changes in organic soils in Grassland of various countries (Germany, for 2023 & 2024; other countries, for 2023)

Country	4.C.1. - Grassland Remaining Grassland [t C ha^{-1} a^{-1}]	4.C.2 - Land Converted To Grassland [t C ha^{-1} a^{-1}]	4.C.2.1 - Forest Land Converted To Grassland [t C ha^{-1} a^{-1}]	4.C.2.2 - Cropland Converted To Grassland [t C ha^{-1} a^{-1}]	4.C.2.3 - Wetlands Converted To Grassland [t C ha^{-1} a^{-1}]	4.C.2.4 - Settlements Converted To Grassland [t C ha^{-1} a^{-1}]	4.C.2.5 - Other Land Converted To Grassland [t C ha^{-1} a^{-1}]
Belgium	NO	22.46	3.03	19.178	0.126	0.126	NO
Denmark	-4.508	IE, NA	IE	IE	NA	NA	NA
France	IE	NO	NO	NO	NO	NO	NO
United Kingdom	-0.512	-3.662	-3.662	NO	NO	NO	NO
Netherlands	-3.58	-3.561	-2.736	-3.631	-3.554	-3.646	-3.384
Austria	IE	NO	NO	NO	NO	NO	NO

Country	4.C.1. - Grassland Remaining Grassland [t C ha^{-1} a^{-1}]	4.C.2 - Land Converted To Grassland [t C ha^{-1} a^{-1}]	4.C.2.1 - Forest Land Converted To Grassland [t C ha^{-1} a^{-1}]	4.C.2.2 - Cropland Converted To Grassland [t C ha^{-1} a^{-1}]	4.C.2.3 - Wetlands Converted To Grassland [t C ha^{-1} a^{-1}]	4.C.2.4 - Settlements Converted To Grassland [t C ha^{-1} a^{-1}]	4.C.2.5 - Other Land Converted To Grassland [t C ha^{-1} a^{-1}]
Poland	-0.25	-0.25					
Switzerland	-9.08	-9.07					
Czech Republic	NO	NO	NO	NO	NO	NO	
Germany, 2023	-6.964	-7.136	NO	-7.136	-6.657	-7.555	-7.003
Germany, 2024	-6.799	-6.436	NO	-6.409	-6.376	-7.16	-5.559

Positive: carbon removal by sink; negative: carbon emission by source; Source: (UNFCCC, 2023c)

6.6.5 Category-specific recalculations (4.C)

This year's submission includes category-specific recalculations for the entire period 1990-2024. The emissions were recalculated in order to take account of new and improved data sources, the introduction of new methods, changes in methods, and error corrections made as part of ongoing inventory improvements. The corresponding measures are listed in Chapter 6.1.3.4.2 and all affected the results of the emissions calculations for the *Grassland* land-use category:

In Table 405 (areas) and Table 406 (emissions), the results of the current recalculations for the *Grassland* category are compared with the corresponding results in the previous year's submission.

The slight differences between the area data of the current and previous year's submissions (< 2.5% throughout the entire time series; Table 406) are due mainly to correction algorithms. They became necessary in connection with introducing the new land-use subcategories and updating the map data to determine activity data as a result of integrating the newly added data of the last time series year. It is assumed that the most recent data is the highest quality and therefore the previous time series is adjusted if necessary (cf. also Chapters 6.3.1 ff).

The differences between the GHG emissions of this and the preceding year's submission(Table 406) in terms of CO_2 are mainly due to

- modifying the RothC process model; the first inclusion of emissions at hectare level from the remaining category of mineral soils,
- the modifications of the calculation of carbon stocks in soils and biomass of the Buildings and open areas subcategory, and
- the implementation of the modified hydrological model to determine groundwater levels in organic soils.

The differences in methane emissions, which are much greater in this submission than in the preceding one (Table 406), are caused by the improvement of the hydrological model to record the groundwater level in organic soils.

The effects of these method changes on nitrous oxide emissions after recalculation are negligible.

Table 405: Comparison of area data [kha] for the Grassland category as reported in the current submission and in the previous year's submission

Area [kha]	Submission	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Grassland	2025	6,847.1	6,768.5	6,690.0	6,804.9	6,873.9	6,855.4	6,838.2	6,837.7	6,837.1	6,836.5
	2026	6,999.8	6,929.5	6,857.2	6,785.9	6,720.5	6,694.1	6,681.2	6,686.4	6,691.7	6,696.9
	Difference	152.7	161.0	167.2	-19.1	-153.5	-161.3	-157.0	-151.3	-145.4	-139.6
	in %	2.2	2.4	2.5	-0.3	-2.2	-2.4	-2.3	-2.2	-2.1	-2

Table 406: Comparison of greenhouse gas emissions [kt CO_2-eq.] for the Grassland category as reported in the current and previous year's submissions

	GHG	Submission	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Grassland	CO_2	2025	30,634.0	32,146.5	31,741.0	33,572.8	21,692.5	24,279.1	27,216.0	22,983.4	28,004.1	21,998.5
		2026	22,519.1	24,395.6	22,406.7	21,217.2	19,312.2	20,997.2	24,819.5	20,862.8	27,132.0	19,503.1
		Difference	-8,115.0	-7,750.9	-9,334.3	-12,355.5	-2,380.4	-3,281.9	-2,396.6	-2,120.6	-872.1	-2,495.5
		in %	-26.5	-24.1	-29.4	-36.8	-11.0	-13.5	-8.8	-9.2	-3.1	-11.3
	CH_4	2025	1,521.6	1,245.2	1,276.9	1,262.3	1,510.2	1,217.1	815.6	1,391.0	728.1	1,631.1
		2026	2,582.3	2,390.5	2,324.9	2,173.2	2,643.0	1,834.2	1,425.0	2,468.7	1,061.8	3,508.2
		Difference	1,060.8	1,145.3	1,048.0	910.9	1,132.7	617.1	609.4	1,077.6	333.7	1,877.2
		in %	69.7	92.0	82.1	72.2	75.0	50.7	74.7	77.5	45.8	115.1
	N_2O	2025	81.5	78.4	76.4	64.4	59.8	60.1	58.8	54.1	56.3	48.3
		2026	80.6	75.2	71.9	68.5	59.9	64.0	62.2	56.5	61.4	51.5
		Difference	-0.9	-3.2	-4.5	4.1	0.0	3.9	3.4	2.4	5.1	3.2
		in %	-1.1	-4.1	-5.9	6.3	0.0	6.4	5.8	4.4	9.0	6.6

6.6.6 Category-specific planned improvements (4.C)

In addition to the planned, soil-relevant measures listed in Chapter 6.1.2.1.9, most of which are medium-term measures, there are no further specific measures currently planned to improve the methods used for Grassland.

6.7 Wetlands (4.D)

6.7.1 Category description (4.D)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
L/T	4 D, Wetlands	0	CO_2	3,586.67	0.28	3,478.53	0.50	-3.01
L/T	4 D, Wetlands	0	CH_4	5,368.71	0.42	5,447.38	0.77	1.47
-/-	4 D, Wetlands	0	N_2O	26.27	0.01	26.76	0.01	1.86

Gas		Method used	Source for the activity data	Emission factors used
CO_2	Mineral soils	Tier 2	NS/M	CS
N_2O	Mineral soils	Tier 2	NS/M	CS/D
CH_4	Water bodies	Tier 2	NS/M	CS/D
CO_2	Organic soil	Tier 3/M	NS/M	CS/M
N_2O	Organic soil	Tier 2	NS/M	CS
CH_4	Organic soil	Tier 3/M	NS/M	CS/M
CO_2	Biomass	Tier 2/M	NS/M	CS/M
CO_2	Dead wood	Tier 2/M	NS/M	CS/M

The category Wetlands is a key category for CO_2 and CH_4 emissions in terms of emissions level and trend.

The Wetlands category primarily includes Germany's peatlands and other wetlands that cannot be allocated to any of the other land-use categories. In the present report, these lands are combined under the umbrella term Terrestrial wetlands (other wetlands), Natural water bodies, Standing artificial water bodies (such as fish breeding ponds, and reservoirs), Flowing artificial water bodies (such as drainage ditches and canals for water resources management), Artificial water bodies used for navigation (such as harbour basins and canals), and areas for Peat extraction to produce horticultural peat.

Quantified area allocations to the individual subcategories, as well as remarks regarding the pools and GHG from the remaining and conversion categories that, pursuant to the 2006 IPCC Guidelines (IPCC, 2006a), the 2013 IPCC Wetland Supplements (IPCC et al., 2014) and the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2019), are to be reported on, are presented in Chapter 6.2.4.

The results of the emissions calculations for the year 2024 are shown in Table 407, while the emissions trends by pool and subcategory are presented in Figure 97 and Figure 98.

Table 407: CO_2, N_2O and CH_4 emissions [kt CO_2-eq.] from Wetlands in 2024. The table includes both the relevant sums and the upper and lower bounds of the 95% confidence intervals.

Terrestrial Wetlands						
Pool	GHG	[kt CO_2-eq.]			[%]	
		Emission	2.5% perc.	97.5% perc.	2.5% perc.	97.5% perc.
Terrestrial wetlands$_{total}$		1,902.6	1,371.7	2,708.7	27.9	42.4
Mineral soils	CO_2	-15.2	-12.3	-18.1	19.0	19.3
	$N_2O_{indirect}$	0.0	0.0	0.0	99.9	205.6
	N_2O_{direct}	0.0	0.0	0.0	80.4	85.2
Organic soil	CO_2	1,811.4	995.9	3,016.4	45.0	66.5
	CH_4	273.8	134.5	634.5	50.9	131.7
	N_2O	23.2	5.4	70.8	76.7	205.6
Biomass	CO_2	-198.6	-178.4	-224.0	10.2	12.8
Litter/dead wood	CO_2	8.0	3.6	12.4	54.7	54.7
Peat extraction						
Pool	GHG	[kt CO_2-eq.]			[%]	
		Emission	2.5% perc.	97.5% perc.	2.5% perc.	97.5% perc.
Total, peat extraction		1,878.3	1,177.5	2,579.2	37.3	37.3
Mineral soils	CO_2	NO	NO	NO	NO	NO
	N_2O	NO	NO	NO	NO	NO
Organic soil	CO_2	1,845.7	1,144.9	2,546.5	38.0	38.0
	N_2O	1.8	0.9	2.7	51.8	50.9
	CH_4	3.6	2.0	5.2	44.4	44.4
Biomass	CO_2	27.2	21.0	34.2	22.7	25.9
Litter/dead wood	CO_2	0.1	0.0	0.1	86.8	86.8
artificial standing water bodies						
Pool	GHG	[kt CO_2-eq.]			[%]	

Terrestrial Wetlands						
		Emission	2.5% perc.	97.5% perc.	2.5% perc.	97.5% perc.
artificial standing water bodies, total		4,739.0	3,016.3	6,039.0	36.4	27.4
Mineral soils	CO_2	NA	NA	NA	NA	NA
	N_2O	NA	NA	NA	NA	NA
	CH_4	4,738.4	3,328.2	6,242.8	29.8	31.8
Organic soil	CO_2	NA	NA	NA	NA	NA
	N_2O	NA	NA	NA	NA	NA
	CH_4	0.6	0.4	0.9	41.1	42.5
Biomass	CO_2	NA	NA	NA	NA	NA
Litter/dead wood	CO_2	NA	NA	NA	NA	NA
artificial flowing water bodies						
Pool	**GHG**	**[kt CO_2-eq.]**			**[%]**	
		Emission	**2.5% perc.**	**97.5% perc.**	**2.5% perc.**	**97.5% perc.**
artificial flowing water bodies, total		240.1	149.4	386.1	37.8	60.8
Mineral soils	CO_2	NA	NA	NA	NA	NA
	N_2O	NA	NA	NA	NA	NA
	CH_4	240.1	149.4	386.1	37.8	60.8
Organic soil	CO_2	NA	NA	NA	NA	NA
	N_2O	NA	NA	NA	NA	NA
	CH_4	NA	NA	NA	NA	NA
Biomass	CO_2	NA	NA	NA	NA	NA
Litter/dead wood	CO_2	NA	NA	NA	NA	NA
artificial water bodies used for navigation						
Pool	**GHG**	**[kt CO_2-eq.]**			**[%]**	
		Emission	**2.5% perc.**	**97.5% perc.**	**2.5% perc.**	**97.5% perc.**
Bodies of water used for navigation, total		192.80	119.98	310.09	37.77	60.84
Mineral soils	CO_2	NO	NO	NO	NO	NO
	CH_4	192.80	119.98	310.09	37.77	60.84
	N_2O	NO	NO	NO	NO	NO
Organic soil	CO_2	NO	NO	NO	NO	NO
	CH_4	NO	NO	NO	NO	NO
	N_2O	NO	NO	NO	NO	NO
Biomass	CO_2	NO	NO	NO	NO	NO
DOM	CO_2	NO	NO	NO	NO	NO

1) Only drainage ditches

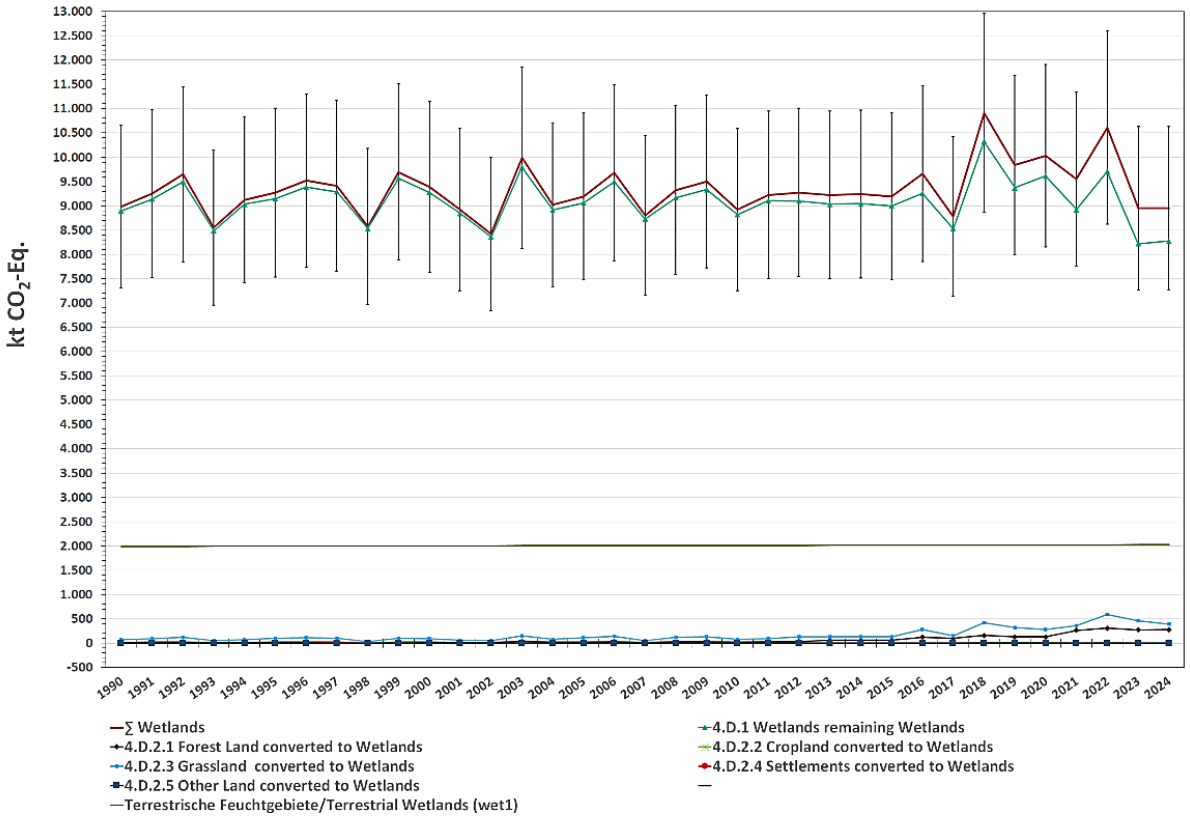
In 2024, a total of 8,952.7 kt CO_2-eq. was emitted from Wetlands (95% confidence interval: 7,278.5-10,555.2 kt CO_2-eq.). As Table 407 shows, the emissions in the land-use category Wetlands consist mainly of CO_2 releases from organic soils (40.8%) and methane emissions from flowing and standing artificial water bodies (57.8%). The gross carbon dioxide releases consist of two major components of about equal size: CO_2 emissions from peat extraction (50.4%) and CO_2 emissions from drainage of terrestrial organic soils (49.4%). Releases of nitrous oxide are very low (26.8 kt CO_2-eq.) with respect to the total emissions. The emissions from mineral soils

(-11.4 kt CO_2-eq.) and biomass (-171.4 kt CO_2-eq.) are negative. Consequently, they function as a very minor sink (Figure 98, Figure 99 and Figure 100).

Emissions from industrial peat extraction are divided into emissions that occur in extraction areas during peat extraction (on-site emissions) and emissions that are emitted during application of peat products (off-site emissions). In 2024, the latter amounted to 1,786.7 ± 700.4 kt CO_2-eq. and were thus the main factor responsible for the magnitude of total emissions from peat extraction (95.1 %). The on-site emissions, at 41.2 kt CO_2-eq., are low by comparison. They are dominated by CO_2 (91.7%), followed by nitrous oxide (5.8%) and methane (2.5%).

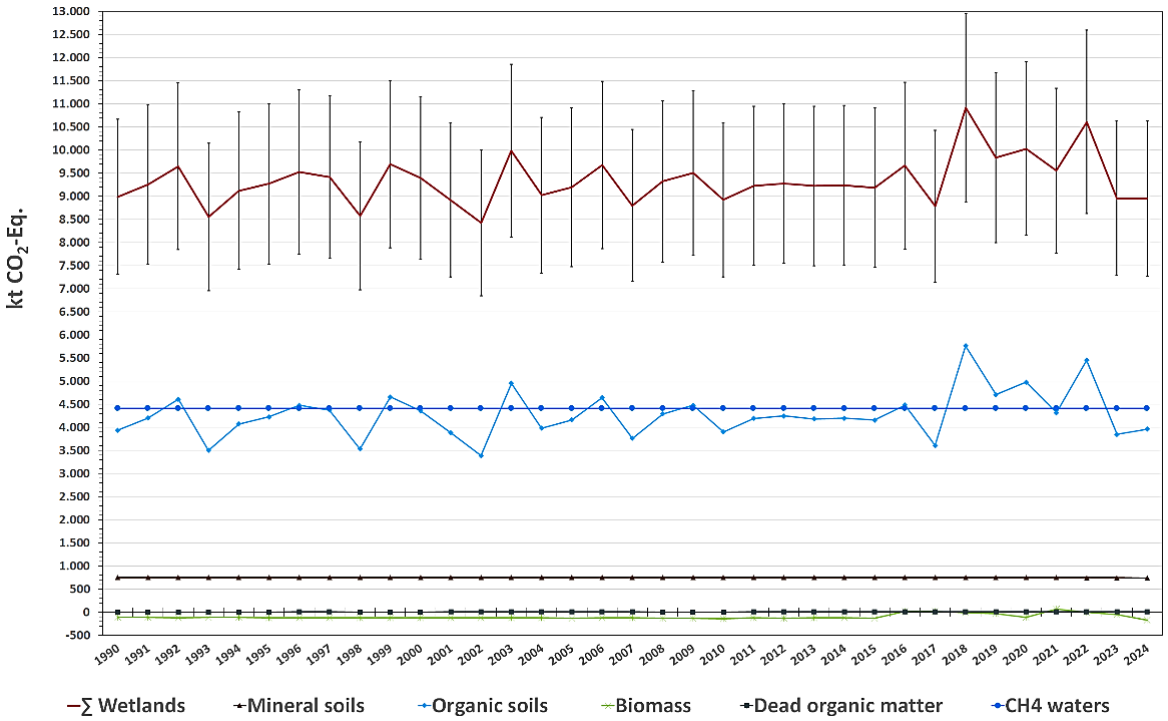
The time series trends in Figure 98, Figure 99 and Figure 100 show that the total emissions from the Wetlands category remain virtually unchanged throughout the reference period. Methane emissions are virtually constant. The small changes are mainly caused by changes in the water level in organic soils. However, only 5.1% of methane emissions derive from organic soils, meaning that the CH_4 emissions from water bodies dominate and smooth the curve (Figure 99). The trend curve is largely determined by CO_2 emissions from peat extraction and especially by off-site emissions which, over time, display clear amplitudes, but on average only deviate slightly from the average (standard error: 2.2%).

Figure 97: GHG emissions (sum of CO_2, CH_4 and N_2O) [kt CO_2-eq.] as a result of land use and land-use change from Wetlands, 1990-2024, by subcategory



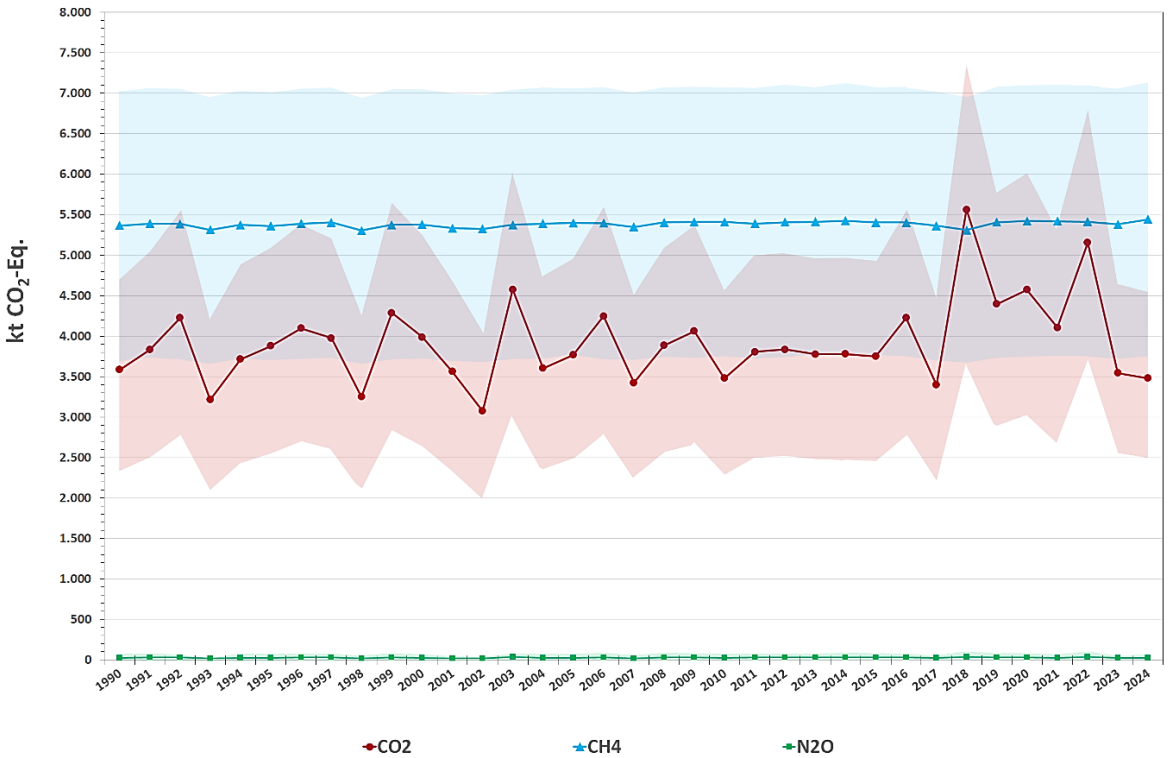
Source: own illustration, Thünen-Institut

Figure 98: GHG emissions (sum of CO_2, CH_4 and N_2O) [kt CO_2-eq.] as a result of land use and land-use change from Wetlands, 1990-2024, by pool



Source: own illustration, Thünen-Institut

Figure 99: GHG emissions (∑ CO_2, ∑ CH_4 and ∑ N_2O) [kt CO_2-eq.] as a result of land use and land-use change from Wetlands, 1990-2024



Source: own illustration, Thünen-Institut

6.7.2 Methodological issues (4.D)

0.1.1.1 Sources of data

The production-quantity data for industrial peat extraction were taken from official German statistics (Statistisches Bundesamt, FS 4, R 3.1).

For further sources, cf. Chapters 6.1.2 ff., Chapter 6.2.4 and Chapter 6.3.1.2.

6.7.2.1 Biomass

Water areas are free of vegetation cover and thus the biomass carbon stocks are zero and always reported in the CRFs as NO (not occurring); the same applies to peat extraction areas.

The method for calculation of biomass on areas within the subcategory Terrestrial Wetlands is described in detail in Chapters 6.1.2.4 ff. and, specifically for Terrestrial Wetlands, in Chapter 6.1.2.3.7. Changes in biomass carbon stocks as a result of land-use changes are calculated with the procedures and methods described in Chapters 6.1.2.4 ff.

The implied emission factors and corresponding uncertainties are presented in Chapter 6.7.3.

6.7.2.2 Mineral soils

It was assumed that no changes in the carbon stocks of mineral soils occurred in connection with land-use conversions to water bodies (NO in CRF 4.D.1). The mineral soils in the remaining categories of Terrestrial Wetlands and Water bodies are assumed to be in equilibrium. For this reason, “NA” is entered in the relevant spaces of the CRFs.

For the subcategory Terrestrial Wetlands, changes in mineral soil organic carbon stocks as a result of land-use changes are calculated with the procedures and methods described in Chapter 6.1.2.1.

The implied emission factors and corresponding uncertainties are presented in Chapter 6.7.3.

6.7.2.3 Organic soils

The emissions have been calculated in accordance with the methods described in Chapter 6.1.2.2.

6.7.2.4 Peat extraction

Greenhouse gas emissions from peat extraction were calculated in line with the Tier 2 method in the 2006 IPCC Guidelines. The total emissions, comprising both on-site and off-site emissions, were calculated using Equations 7.2 to 7.5 of the 2006 IPCC Guidelines (IPCC, 2006a). In the subcategory peat extraction, CO_2 emissions (on-site: emissions and DOC, off-site: extracted and spread peat), CH_4 emissions (emissions, and emissions from drainage ditches) and N_2O emissions (on-site) are reported. The manner in which the relevant emission factors are derived is described in Chapter 6.1.2.2. The estimates are based on the following activity data:

- Calculation of on-site emissions: The areas on which industrial peat extraction takes place, and the amounts of shifting of areas to and from those areas, were determined with the Basis-DLM (cf. Chapter 6.3.1). The relevant data sets were not completely added to the Basis-DLM until 2008. As a result, the peat extraction areas determined for 2008 are used to calculate the on-site emissions for all years prior to 2008. As of 2008, the current values determined for the relevant survey reference year in each case are used.
- Calculation of off-site emissions from annual production quantities, the figures for which come from official German statistics (Statistisches Bundesamt, FS 4, R 3.1).

Calculation pursuant to Equation 7.3 (IPCC, 2006a):

Equation 91:

$$CO_2\text{-eq.}_{peatextraction} = CO_2\text{-eq.}_{on\text{-}site} + CO_2\text{-eq.}_{off\text{-}site}$$

- $CO_2\text{-eq.}_{peatextraction}$ = GHG emissions from peat extraction [t C-eq. a^{-1}]
- $CO_2\text{-eq.}_{on\text{-}site}$ = GHG emissions that occur on-site during production [t C-eq. a^{-1}]
- $CO_2\text{-eq.}_{off\text{-}site}$ = GHG emissions from extracted peat that is spread for horticultural purposes [t C-eq. a^{-1}]

In Germany, only peat from raised bogs is extracted. For this reason, Equation 7.4 (IPCC, 2006a) was modified in the following manner:

Equation 92:

$$CO_2\text{-eq.}_{on\text{-}site} = A_{peat,\ oligotrophic} \times (EF_{peat,\ oligotrophic_CO2} + EF_{peat,\ oligotrophic_N2O} + EF_{peat,\ oligotrophic_CH4})$$

- $CO_2\text{-eq.}_{on\text{-}site}$ = On-site emissions that occur on site during peat production [t CO_2-eq. a^{-1}]
- $A_{peat,\ oligotrophic}$ = Peat extraction area on raised bogs [ha]
- $EF_{peat,\ oligotrophic_(CO2,\ N2O,\ CH4)}$ = Country-specific emission factors for raised bogs on which peat extraction is taking place [t CO_2-eq. ha^{-1} a^{-1}] (cf. Chapter 6.1.2.2)

Off-site emissions were calculated with Equation 7.5 (IPCC, 2006a):

Equation 93:

$$CO_2\text{-Eq.}_{off\text{-}site} = Vol_{peat_dry} \times Cfraction_{vol_peat}$$

- $CO_{2off\text{-}site}$ = CO_2-eq. emissions from extracted peat that is spread for horticultural purposes [t CO_2-eq. a^{-1}]
- Vol_{peat_dry} = Volume of air-dried peat [m^3]
- $C_{fraction\ vol_peat}$ = Carbon fraction with respect to the volume of air-dried peat [0.2567 t CO_2-eq. m^3 air-dried peat (IPCC (2006a), Table 7.5)]

The emission factors for the on-site emissions are listed in Table 410 (Chapter 6.7.3). The off-site emissions, calculated from the quantities of peat produced, and the IEFs for the off-site emissions, are shown in Table 408.

Table 408: Peat extraction: $IEF_{off\text{-}site}$ [t CO_2-eq. ha^{-1} a^{-1}] and off-site emissions [kt CO_2-eq.]

Peat extraction Year	IEF [t CO_2-eq. [ha^{-1} a^{-1}]	Off-site emissions [kt CO_2-eq.]
1990	97.47	2,029.5 ± 795.6
1995	105.84	2,203.9 ± 863.9
2000	116.04	2,416.2 ± 947.2
2005	104.67	2,179.6 ± 854.4

Peat extraction	IEF	Off-site emissions
2010	99.75	1,991.5 ± 780.7
2015	106.36	2,066.4 ± 810.0
2020	125.25	2,212.9 ± 867.5
2021	145.57	2,226.1 ± 896.6
2022	154.60	1,997.1 ± 782.9
2023	170.93	1,802.3 ± 706.5
2024	177.32	1,786.7 ± 700.4

6.7.2.5 Water bodies

Chapter 6.1.2.6 and Chapter 6.2.4 outline the manner in which the land-use category Water bodies is subdivided and provide descriptions of the relevant subcategories and methods used to obtain activity data and derive emission factors.

In accordance with the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2019), only methane emissions are reported. They are determined only for the subcategories Standing artificial water bodies, Flowing artificial water bodies and Artificial water bodies used for navigation. The results are recorded in CRF 4.(II).D. Emissions from Natural water bodies do not have to be reported. For this reason, the notation key NO is entered into the relevant fields in CRT 4.(II).D.

Pursuant to the reporting rules, methane emissions from drainage ditches on organic soils do not fall within the land-use category Flowing artificial water bodies. In accordance with the current use of drained peatlands, they are listed in CRT 4.(II). A/B/C/D/E.

6.7.3 Uncertainties and time series consistency (4.D)

The time series for activity data provided by the Federal Statistical Office for peat extraction are consistent and available for the entire reporting period. Pursuant to the Federal Statistical Office, the uncertainties for these activity data are equal to zero since the data have been obtained by way of a comprehensive survey entailing an obligation to provide information. Nonetheless, an uncertainty of 20% is assumed in accordance with the 2006 IPCC Guidelines. This uncertainty is due primarily to the uncertainty in conversion, for peat, of volume units to mass units. The uncertainties of up to 40% for Peat extraction listed in Table 409 to Table 412 are the result of uncertainties propagation. They are due in particular to the large uncertainties in the IPCC default values used. The statements made in Chapter 6.5.3 and Chapter 6.6.3 also apply to the uncertainties for the emission factors for methane and nitrous oxide.

The activity data and area data have a normal distribution. Their uncertainties, depending on the area and sampling sizes involved, range from 0.5 to 196%. The total uncertainty for the area data in the category Wetlands is 0.22%.

The total uncertainty for emissions in the land-use category Wetlands is 18.7% / +17.9% [95% percentile], while that for the subcategory Terrestrial Wetlands is -27.9% / +42.37%; that for Water bodies is -56.1% / +56.1%; that for Peat extraction is -37.3% / +37.3%, for Standing artificial water bodies it is -36.4% / +27.4%; and for Flowing artificial water bodies and Artificial water bodies used for navigation it is -37.8% / +60.8%. The Wetlands category's contribution to the total uncertainty in the LULUCF sector is small, namely 2.3%. Nonetheless, the relevant values in the subcategory Terrestrial Wetlands in connection with methane emissions from water bodies and emissions from Peat extraction and organic soils are discernible.

Table 409: Implied emission factors and uncertainties [in % of central tendency] used for calculation of GHG emissions from Terrestrial Wetlands for 2024, by pool and subcategory

$Wetlands_{terrestrial}$		Implied emission factors	Uncertainty bounds	
$Land\ use_{initial}$	$Land\ use_{final}$		lower	upper
Mineral soils, CO_2-C[1]		[t C ha^{-1} a^{-1}]	[%]	[%]
Forest Land	$Wetlands_{terrestrial}$	0.516	48.89	53.29
$Cropland_{annual}$		1.456	57.82	57.82
Hops		NO	NO	NO
Vineyards		0	NO	NO
Orchards		1.608	99.9	167.56
Short-rotation plantations		NO	NO	NO
Tree nurseries		2.207	99.9	196.22
Christmas tree plantations		NO	NO	NO
$Grassland_{(in\ the\ strict\ sense)}$		0.868	24.52	24.52
Woody Grassland		0.888	49.65	49.65
Hedges		NO	NO	NO
Peat extraction		NO	NO	NO
Settlements		1.567	98.64	98.65
Photovoltaic areas		NO	NO	NO
Other Land		3.622	99.9	196.53
Mineral soils, N_2O_{direct}[2]		[kg N_2O ha^{-1} a^{-1}]	[%]	[%]
$Grassland_{(in\ the\ strict\ sense)}$	$Wetlands_{terrestrial}$	0.02	87.33	92.59
Woody Grassland		0.009	97.42	102.16
Mineral soils, $N_2O_{indirect}$[2]		[kg N_2O ha^{-1} a^{-1}]	[%]	[%]
$Grassland_{(in\ the\ strict\ sense)}$	$Wetlands_{terrestrial}$	0.009	99.9	223.62
Woody Grassland		0.004	99.9	227.75
Biomass[3]		[t C ha^{-1} a^{-1}]	[%]	[%]
Forest Land	$Wetlands_{terrestrial}$	-3.613	21.56	23.91
$Cropland_{annual}$		3.29	45.28	47.7
Hops		NO	NO	NO
Vineyards		NO	NO	NO
Orchards		0.399	99.9	168.19
Short-rotation plantations		NO	NO	NO
Tree nurseries		-0.358	99.9	168.17
Christmas tree plantations		NO	NO	NO
Grassland (in the strict sense)		3.661	17.2	22.76
Woody Grassland		-8.777	20.63	24.04
Hedges		-16.558	99.9	114.49
$Wetlands_{terrestrial}$		NO	NO	NO
Peat extraction		3.945	21.87	27.28

$Wetlands_{terrestrial}$		**Implied emission factors**	**Uncertainty bounds**	
Settlements		3.621	66.95	68.51
Photovoltaic areas		NO	NO	NO
Other Land		5.57	99.9	197.34
Dead organic matter		**[t C ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	$Wetlands_{terrestrial}$	-0.266	54.74	54.74

Positive: sink; negative: Source

1) The calculation covers a 20-year period; stock change: positive ≙ sink; negative ≙ source

2) The calculation covers a 20-year period; emission: positive ≙ source; negative ≙ sink

3) Calculation only for the first year following the pertinent land-use change

Table 410: Implied emission factors and uncertainties [in % of central tendency] used for calculation of GHG emissions from Peat extraction in 2023, for the biomass

Peat extraction		**Implied emission factors**	**Uncertainty bounds**	
$Land\ use_{initial}$	**$Land\ use_{final}$**		**upper**	**lower**
Biomass*		**[t C ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Peat extraction	-6.146	74.44	74.44
$Cropland_{annual}$		-0.409	30.9	30.9
Hops		NO	NO	NO
Vineyards		NO	NO	NO
Orchards		NO	NO	NO
Short-rotation plantations		NO	NO	NO
Tree nurseries		NO	NO	NO
Christmas tree plantations		NO	NO	NO
Grassland (in the strict sense)		-0.32	33.33	33.33
Woody Grassland		-6.299	99.9	197.4
Hedges		NO	NO	NO
$Wetlands_{terrestrial}$		-6.504	27.32	31.81
Water bodies		NO	NO	NO
Settlements		-0.35	77.56	77.56
Other Land		NO	NO	NO
Dead organic matter		**[t C ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Peat extraction	-0.117	86.82	86.82

Positive: sink; negative: Source

* Calculation only for the first year following the pertinent land-use change

Table 411: Uncertainties for emission factors [2.5% and 97.5% percentile, in % of central tendency] for water bodies, in 2023

Land use	**Greenhouse gas**	**Implied emission factor**	**Uncertainty bounds**	
			upper	**lower**
		[t CO_2-eq. [ha^{-1} a^{-1}]	**[%]**	**[%]**
Artificial standing water bodies	CH_4	2,565	36.35	27.43
Artificial flowing water bodies/Ports	CH_4	379	37.77	60.83

Table 412: Uncertainties for emission factors [2.5% and 97.5% percentile, in % of central tendency] for emissions from organic soils, for Wetlands and Peat extraction, in 2023

Land use	Greenhouse gas	Emission factor	Uncertainty bounds	
			lower	upper
Organic soils*		[t CO_2-eq. [ha^{-1} a^{-1}]	%	%
$Wetlands_{terrestrial}$	CO_2	13.073	45.02	66.53
$Wetlands_{terrestrial}$	N_2O	0.167	76.67	205.61
$Wetlands_{terrestrial}$	CH_4	1.953	50.88	131.73
Peat extraction	CO_2	6.911	37.97	37.97
Peat extraction	N_2O	0.355	44.44	44.44
Peat extraction	CH_4	0.117	51.76	50.91

* Annual calculation; emission: positive ≙ source; negative ≙ sink

The calculations are spatially and chronologically consistent and complete for the entire reporting period, 1990-2024.

6.7.4 Category-specific QA/QC and verification (4.D)

Details regarding this year's reviews are provided in Chapter 6.1.3.

The data sources used in preparation of this inventory fulfil the review criteria of the QSE manual for data sources (QSE-Handbuch für Datenquellen). Quality assurance for input data (ATKIS®, BÜK, official statistics) is the responsibility of the relevant data administrators (cf. the documentation in the inventory description).

The emissions calculation results as presented in the present report cannot be compared with other relevant data sources for Germany since no such other data sources exist that meet applicable requirements, i.e. provide nationwide coverage, are comprehensive and are independent of the methods and data sources described in the present report.

Table 413 presents an intra-European comparison of implied emission factors (IEFs) for various pools of the category *Wetlands*. Values of neighbouring countries obtained from the 2025 submission to the Climate Secretariat (UNFCCC NID submission 2025 – Inventory year 2023, (UNFCCC, 2025)) were used for this comparison. The values for Germany in 2024 were obtained from the current 2026 submission.

The comparison is problematic from the outset because the values to be compared were not all obtained with the same methods (in some cases, the methods differ widely), and especially because the demarcations of the systems differ – in some cases, markedly. In Germany, and in the context of this comparison, *Wetlands* refers to the sum of the subcategories *Terrestrial wetlands, Natural water bodies, Standing artificial water bodies, Flowing artificial water bodies, Artificial water bodies used for navigation*, and *Peat extraction*. This category composition is not found consistently in all of the countries concerned, and thus comparisons of average emission factors are problematic. Nonetheless: Most of the EFs are similar, in terms of both absolute size and trends, to those of various central European neighbouring countries.

Table 413: Carbon-stock changes in organic soils in Grassland of various countries (Germany, for 2023 & 2024; other countries, for 2023)

Country	4.D.1. - Wetlands Remaining Wetlands			4.D.2 - Land Converted To Wetland			
	Biomass	Dead organic matter	Organic soils	Biomass	Dead organic matter	Mineral soils	Organic soils
	[t C ha^{-1} a^{-1}]	[t C ha^{-1} a^{-1}]	[t C ha^{-1} a^{-1}]	[t C ha^{-} a^{-1}]	[t C ha^{-1} a^{-1}]	[t C ha^{-1} a^{-1}]	[t C ha^{-1} a^{-1}]
Belgium	NO	NO	NO	-1.197	-0.124	0.447	NO
Denmark	NA, NE	NA, NE	-13.739	NE	NE	NE	NE
France	NA	NA	-42.896	NA	NA	NO	NA
United Kingdom	0	NA, NE, NO	-0.042	NO	NO	NO	-2.92
Netherlands	NA, NO	NA, NO	NO	NA	NA	NO	NO
Austria	NA, NO	NA, NO	IE, NO	NO	NO	NO	NO
Poland	NO	NO	-0.29	-0.002	-8.616	NA, NO	-0.007
Switzerland	0	NA	-5.052	-0.807	-0.143	-0.586	-4.748
Czech Republic	NA	NA	NA	NA	NA	NA	NA
Germany, 2023	0.038	IE	-2.267	0.203	-0.061	0.77	-4.234
Germany, 2024	0.039	IE	-2.347	-0.335	-0.05	0.113	-4.218

Positive: carbon removal by sink; negative: carbon emission by source; Source: (UNFCCC, 2023c)

6.7.5 Category-specific recalculations (4.D)

This year's submission includes category-specific recalculations for the entire period 1990-2024. The emissions were recalculated in order to take account of new and improved data sources, the introduction of new methods, changes in methods, and error corrections made as part of ongoing inventory improvements. The corresponding measures are listed in Chapter 6.1.3.4.2 and all affected the results of the emissions calculations for the *Wetlands* land-use category:

In Table 414 (areas) and Table 415 (emissions), the results of the current recalculations for the Wetlands category are compared with the corresponding results in the previous year's submission.

The differences between the area data of the current and previous year's submissions are very minor, in both absolute and relative terms (Table 414). They are due mainly to correction algorithms. They largely became necessary in connection with introducing the new land-use subcategories and updating the map data to determine activity data as a result of integrating the newly added data of the last time series year. It is assumed that the most recent data is the highest quality and therefore the previous time series is adjusted if necessary (cf. also Chapters 6.3.1 ff).

The generally small discrepancies between the CO_2, CH_4 and N_2O emissions in this and the previous year's submission (Table 415) are mainly caused by the introduction of the modified hydrological model for the calculation of the groundwater levels in organic soils.

Table 414: Comparison of area data [kha] for the Wetlands category as reported in the current submission and in the previous year's submission

Area [kha]	Submission	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Wetlands	2025	796.8	796.8	796.8	796.9	797.5	800.0	806.0	809.7	813.5	817.2
	2026	792.8	793.3	794.1	795.1	796.5	799.3	805.5	809.8	814.2	818.6
	Difference	-4.0	-3.5	-2.7	-1.8	-1.0	-0.7	-0.5	0.1	0.7	1.4
	in %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 415: Comparison of greenhouse gas emissions [kt CO_2-eq.] for the Wetlands category as reported in the current and previous year's submissions

	GHG	Submission	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Wetlands	CO_2	2025	3,696.4	4,075.5	4,199.9	3,924.0	3,776.3	3,785.2	4,725.0	4,119.1	5,014.8	3,298.4
		2026	3,586.7	3,879.4	3,988.1	3,766.4	3,480.1	3,750.5	4,572.6	4,104.5	5,153.8	3,544.3
		Difference	-109.7	-196.0	-211.8	-157.5	-296.2	-34.7	-152.4	-14.7	139.0	245.9
		in %	-3.0	-4.8	-5.0	-4.0	-7.8	-0.9	-3.2	-0.4	2.8	7.5
	CH_4	2025	5,423.6	5,445.0	5,430.5	5,438.7	5,470.6	5,432.1	5,479.1	5,470.3	5,476.9	5,446.2
		2026	5,368.7	5,364.5	5,380.1	5,400.0	5,414.3	5,408.6	5,424.0	5,421.6	5,418.1	5,385.4
		Difference	-54.9	-80.5	-50.4	-38.7	-56.3	-23.6	-55.1	-48.7	-58.8	-60.8
		in %	-1.0	-1.5	-0.9	-0.7	-1.0	-0.4	-1.0	-0.9	-1.1	-1.1
	N_2O	2025	26.3	29.1	27.5	27.6	29.0	26.9	35.5	26.9	37.7	22.7
		2026	26.3	27.0	26.6	27.6	27.5	28.3	33.9	26.4	38.2	24.1
		Difference	-0.0	-2.0	-0.9	0.0	-1.5	1.5	-1.6	-0.6	0.5	1.4
		in %	-0.1	-7.0	-3.1	0.1	-5.1	5.5	-4.5	-2.1	1.3	6.3

6.7.6 Category-specific planned improvements (4.D)

Other than the planned medium-term measures set out in Chapter 6.1.2.1.9 and Chapter 6.1.4, there are no specific measures currently planned to improve the methods used for the land-use category *Wetlands*.

6.8 Settlements (4.E)

6.8.1 Category description (4.E)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
L/T	4 E, Settlements	0	CO_2	3,141.45	0.25	4,370.55	0.62	39.13
-/-	4 E, Settlements	0	CH_4	53.82	0.01	96.43	0.02	79.18
-/-/2	4 E, Settlements	0	N_2O	136.11	0.02	177.18	0.03	30.17

Gas	Pool	Method used	Source for the activity data	Emission factors used
CO_2	Mineral soils	Tier 2	NS/M	CS/M
N_2O	Mineral soils	Tier 2	NS/M	CS/D
CO_2	Organic soil	Tier 3/M	NS/M	CS/M
N_2O	Organic soil	Tier 2	NS/M	CS
CH_4	Organic soil	Tier 3/M	NS/M	CS/M
CO_2	Biomass	Tier 2/M	NS/M	CS/M
CO_2	Dead wood	Tier 2/M	NS/M	CS/M

The category Settlements is a key category for CO_2 emissions in terms of emissions level and trend, and pursuant to method 2 for nitrous oxide.

It is subdivided into the subcategories Buildings and open areas, Roads and Railway track beds, and Photovoltaic plants (Chapter 6.2.5). Emissions are reported only from Buildings and open areas as well as Areas with photovoltaic plants since the subcategories Roads and Railway track beds only include fully sealed areas.

Reporting for the land-use category Buildings and open areas covers CO_2 emissions/removals in the pools soil, biomass and dead organic matter on land designated for settlement and transport uses. Precise definitions and category allocations are presented in Chapter 6.2. The results of the estimation of relevant GHG emissions are presented in Table 416 and in Figure 100 and Figure 101.

Table 416: CO_2, N_2O and CH_4 emissions [kt CO_2-eq. pursuant to IPCC AR5] from Settlement areas in 2024. The table includes both the relevant sums and the upper and lower bounds of the 95% confidence interval

Emissions, Settlements, 2024						
Category	GHG	[kt CO_2-eq.]			[%]	
		Emission	2.5% perc.	97.5% perc.	2.5% perc.	97.5% perc.
Settlements$_{total}$ 1)		4,699.4	3,693.6	5,988.4	10.4	11.0
Mineral soils	CO_2 2)	1,020.9	846.3	1,213.3	17.1	18.9
	$N_2O_{indirect}$ 3)	24.1	4.1	55.3	82.8	130.0
	N_2O_{direct} 3)	54.7	26.2	84.1	52.1	53.9
Organic soil	CO_2 2)	1,720.1	1,252.2	2,068.9	27.2	20.3
	CH_4 4)	95.6	49.5	295.0	48.2	208.8
	N_2O 4)	96.7	36.3	343.7	62.5	255.5
Biomass	CO_2 2)	1,643.4	1,458.2	1,860.8	11.3	13.2
Dead wood	CO_2 2)	44.1	21.0	67.3	52.4	52.4
Emissions, photovoltaic areas, 2024						
Category	GHG	[kt CO_2-eq.]			[%]	
		Emission	2.5% perc.	97.5% perc.	2.5% perc.	97.5% perc.
Photovoltaic areas$_{total}$ 1)		-55.0	-56.8	-51.9	14.6	15.4
Mineral soils	CO_2 2)	-100.8	-82.8	-120.8	17.9	19.8
	$N_2O_{indirect}$ 3)	0.1	0.0	0.3	99.9	168.2
	N_2O_{direct} 3)	0.3	0.1	0.5	68.4	70.1
Organic soil	CO_2 2)	29.6	14.4	43.5	51.3	47.1
	CH_4 4)	0.9	0.4	2.6	53.0	195.4
	N_2O 4)	1.7	0.6	5.8	67.6	231.8
Biomass	CO_2 2)	13.3	10.6	16.3	20.1	22.8
Dead wood	CO_2 2)	NO	NO	NO	NO	NO

1) Sum of the emissions from CRF 4.E, 4.(II).E, 4.(III).E

2) CRF 4.E

3) CRF 4.(III).E

4) CRF 4.(II).E

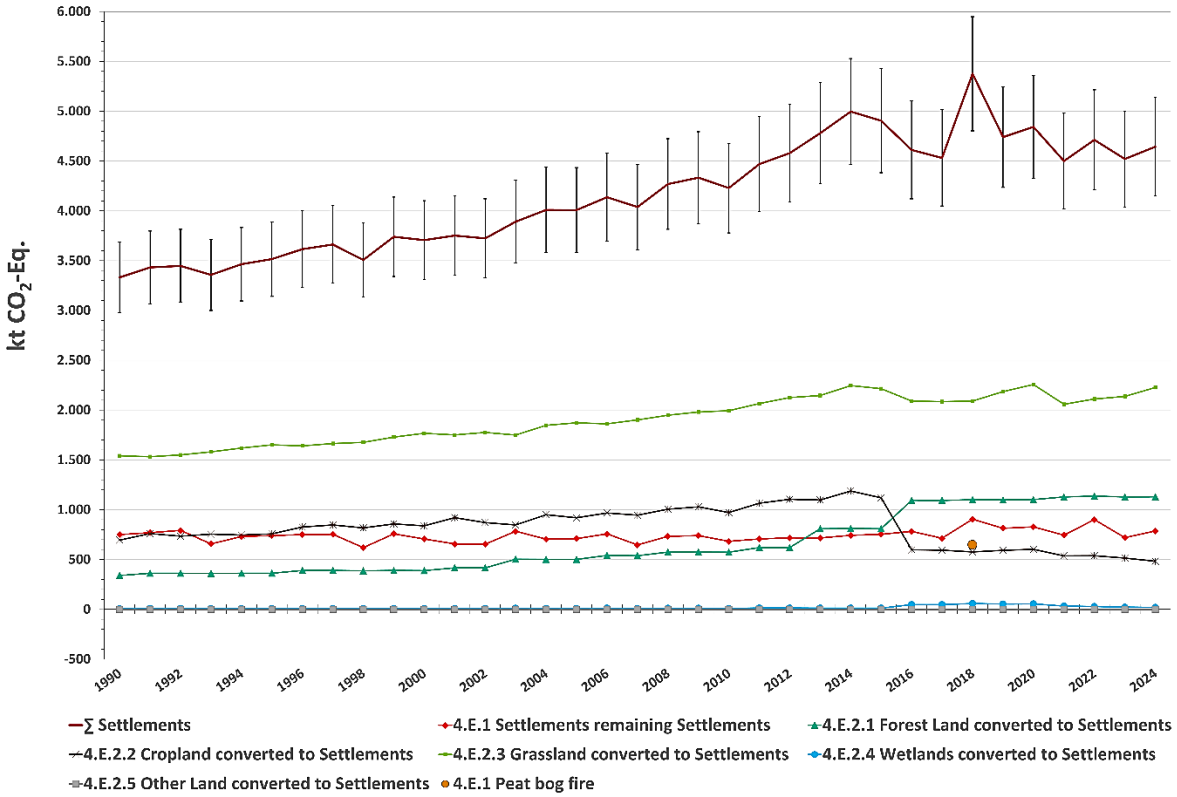
In 2024, the net greenhouse-gas emissions from Germany's settlement and transport areas, resulting from land use and land-use changes, amounted to 4,644,2 kt CO_2-eq. (95% confidence interval: 3,670.2 kt CO_2-eq. ≙ -10.1% - 5,898.7 kt CO_2-eq. ≙ 10.7%). This quantity is the sum of the subcategories Buildings and open areas (with emissions of 4,699.4 kt CO_2-eq. making it a major source) and Photovoltaic plants (with emissions of -54.9 kt CO_2-eq. making it a minor sink) (Table 416). Measured against emissions from the subcategory Buildings and open areas, emissions from areas with Photovoltaic plants are very low due to the small area they cover (35 ha). Across the entire land-use category, all of the pools act as sources of greenhouse gases throughout the entire reporting period. Only the mineral soil in the subcategory Photovoltaic areas acts as a sink, which is far outweighed by emissions from the mineral soils of the other subcategory.

Compared with the base year, emissions for the whole settlement category increased markedly in 2024 (+1,312.8 kt CO_2-eq. ≙ +39.4 %) to (Figure 100, Figure 101). The 28.3 % increase in settlement area during this period was a major contributing factor to the increase in emissions. This emissions trend is reflected consistently across all pools, except for emissions from mineral soils which followed the trend until 2015; after that, emissions declined, particularly due to a reduced frequency of land-use changes from cropland to settlements.

The shapes of the time series plots – especially the noticeable changes they show – are due primarily to the periodicity in surveying of the relevant area data (cf. Chapter 6.3.1.5). Land-use changes were determined on the basis of spatially explicit data sets from the years 1990, 1995, 2000, 2005, 2010, 2015, 2020 and 2024 (cf. Chapter 6.3.1). Land-use changes that occurred between those years were determined by linear interpolation, and thus the annual conversion areas did not change between the survey time points. Land use before the year 2010 was determined by extrapolation using stochastic methods (cf. Chapter 6.3.1.2.2).

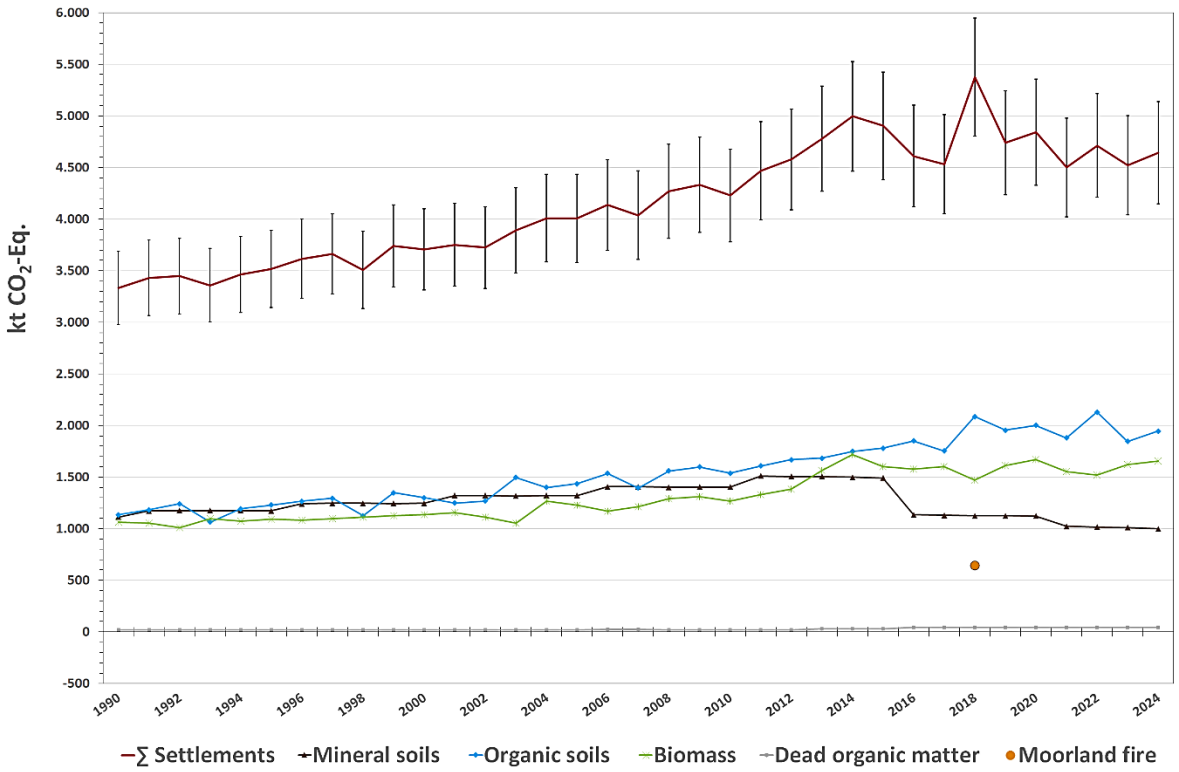
Furthermore, the effects of changing the method used with respect to biomass, sealing factor and the hydrological model for the land-use category are readily apparent.

Figure 100: GHG emissions [kt CO_2-eq. pursuant to IPCC AR5] resulting from land use and land-use changes from Settlements, 1990-2024, by subcategory



Source: own illustration, Thünen-Institut

Figure 101: GHG emissions [kt CO_2-eq. pursuant to IPCC AR5] resulting from land use and land-use changes from Settlements, 1990-2024, by pool



Source: own illustration, Thünen-Institut

6.8.2 Methodological issues (4.E)

6.8.2.1 Sources of data

Further information about the data sources is provided in Chapter 6.3.1.2.

6.8.2.2 Biomass

The method for calculation of biomass is described in detail in Chapters 6.3.1.2 ff. and, specifically for Settlement areas, in Chapter 6.1.2.3.7.

The carbon stocks of dead wood and litter are taken into account in connection with the living biomass. “IE” has been entered in the corresponding spaces in the CRF table.

Emissions for Roads and Railway track beds are not listed since the relevant areas of these subcategories are free of vegetation and static. Consequently, “NO” has been entered in the relevant spaces in CRF 4.E.

6.8.2.3 Mineral soils

In the case of Settlements remaining Settlements, it is assumed that no carbon-stock changes in mineral soils occur. For this reason, “NA” is entered in the relevant spaces in the tables. Carbon-stock changes are reported for land-use conversions to Buildings and open areas, however. Further information about the methods used is provided in Chapter 6.1.2.1. The manner in which the emission factors have been derived and verified, with the sealed area being taken into account, is described in Chapter 6.1.2.1.6.

6.8.2.4 Organic soils

It has also been assumed that organic soils in Settlements have been drained. Since no data have been collected specifically with regard to drainage of organic soils in Settlements, it is assumed that these soils are drained in the same manner that Grassland is drained, and that the relevant emission factors and response functions can therefore be used (Chapter 6.6.2.4). A detailed analysis of organic soils areas in Settlements found that these areas are sealed to a degree of only 15% on average. For this reason, the CO_2 and CH_4 emissions from organic soils that have been calculated for Buildings and open areas have been reduced only by 15%, and the emission factor for nitrous oxide, with the new area factor, has been corrected to 3.91 kg N_2O-N ha^{-1}.

In the case of land-use conversions to Buildings and open areas, the value for remaining Buildings and open areas is immediately applied.

6.8.2.5 Wildfires

No human-caused wildfires occurred in 2024 that would be comparable to the peat fire of 2018 (NIR (UBA et al., 2020), Chapter 6.8.2.5) (NO).

6.8.3 Uncertainties and time series consistency (4.E)

The consistency of the time series is assured with regard to the activity data and emission factors.

The emission factors and uncertainties for the land-use category Buildings and open areas as well as Areas with photovoltaic plants are shown in Table 417 to Table 419.

The uncertainties for the activity data for the year 2024 range from 0.1% to 196%, depending on the size of the area concerned. The total uncertainty for the activity data in the Settlements category is 0.09%.

The total uncertainty for the land-use category Settlements is -10.1% / +10.7% (95% percentile). Emissions from organic soils make the largest contribution to the total uncertainty (68.2%), followed by biomass (23.4%).

Table 417: Implied emission factors and uncertainties [in % of central tendency] used for calculation of GHG emissions from Buildings and open areas for 2024, by pool and subcategory

Settlements	Area	Emission factor	Uncertainty bounds	
Land use$_{initial}$	Land use$_{final}$		lower	upper
Mineral soils, CO_2-C_1		[t C ha^{-1} a^{-1}]	[%]	[%]
Forest Land	Buildings and open areas	-0.60	41.99	63.57
Cropland$_{annual}$		-0.22	26.56	26.55
Hops		-0.25	64.24	64.24
Vineyards		-0.30	30.44	30.44
Orchards		-0.37	20.05	20.05
Short-rotation plantations		NO	NO	NO
Tree nurseries		-0.29	23.82	19.23
Christmas tree plantations		NO	NO	NO
Grassland in the strict sense		-0.41	30.40	30.40

Settlements	Area	Emission factor	Uncertainty bounds	
Woody Grassland		-0.49	30.62	30.62
Hedges		-2.17	42.74	42.74
Terr. Wetlands		-0.66	67.86	67.86
Photovoltaic areas		NO	NO	NO
Other Land		NO	NO	NO
Mineral soils, N_2O_{direct} [1]		**[kg N_2O ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Buildings and open areas	0.12	99.90	244.71
$Cropland_{annual}$		0.07	99.90	223.34
Hops		0.10	99.90	231.87
Vineyards		0.12	99.90	225.83
Orchards		0.14	99.90	223.48
Short-rotation plantations		NO	NO	NO
Tree nurseries		0.11	99.90	224.70
Christmas tree plantations		NO	NO	NO
Grassland (in the strict sense)		0.15	99.90	222.74
Woody Grassland		0.17	99.90	222.77
Hedges		0.69	99.90	224.76
Terr. Wetlands		0.22	99.90	231.78
Photovoltaic areas		NO	NO	NO
Other Land		0.00	99.90	242.55
Mineral soils, $N_2O_{indirect}$ [1]		**[kg N_2O ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Buildings and open areas	0.28	99.90	135.83
$Cropland_{annual}$		0.17	87.86	91.91
Hops		0.22	99.90	111.05
Vineyards		0.27	91.49	97.80
Orchards		0.32	87.36	92.26
Short-rotation plantations		NO	NO	NO
Tree nurseries		0.25	87.91	95.17
Christmas tree plantations		NO	NO	NO
Grassland (in the strict sense)		0.33	89.16	90.44
Woody Grassland		0.39	89.23	90.51
Hedges		1.57	94.08	95.29
Terr. Wetlands		0.50	99.90	110.85
Photovoltaic areas		NO	NO	NO
Other Land		0.01	99.90	131.90
Biomass [2]		**[kt C ha^{-1} a^{-1}]**		**[%]**
Forest Land	Buildings and open areas	-3.00	23.14	23.14
$Cropland_{annual}$		0.03	14.25	14.25

Settlements	Area	Emission factor	Uncertainty bounds	
Hops		0.04	63.87	63.87
Vineyards		-0.10	27.04	27.04
Orchards		-0.40	15.23	15.23
Short-rotation plantations		NO	NO	NO
Tree nurseries		-0.38	25.47	25.47
Christmas tree plantations		NO	NO	NO
Grassland in the strict sense		-0.06	18.57	18.57
Woody Grassland		-5.90	16.11	22.53
Hedges		-26.71	33.58	37.09
Terr. Wetlands		-3.60	48.45	50.60
Photovoltaic areas		0.39	90.61	90.61
Peat extraction		NO	NO	NO
Other Land		0.149	26.44	26.44
Dead organic matter [2]		**[kt C ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Buildings and open areas	-0.15	52.41	52.41

1) The calculation covers a 20-year period; emission: positive ≙ source; negative ≙ sink

2) The calculation is only for the first year of the land-use change; stock change: positive ≙ sink; negative ≙ source

Table 418: Implied emission factors and uncertainties [in % of central tendency] used for calculation of GHG emissions from Photovoltaic areas for 2024, by pool and subcategory

Photovoltaic areas	Area	Emission factor	Uncertainty bounds	
Land use$_{initial}$	**Land use$_{final}$**		**lower**	**upper**
Mineral soils, CO_2-C [3]		**[t C ha$_{-1}$ a$_{-1}$]**	**[%]**	**[%]**
Forest Land	Photovoltaic areas	-0.6	42.0	63.6
Cropland$_{annual}$		-0.2	26.6	26.6
Hops		-0.3	64.2	64.2
Vineyards		-0.3	30.4	30.4
Orchards		-0.4	20.1	20.1
Short-rotation plantations		NO	NO	NO
Tree nurseries		-0.3	23.8	19.2
Christmas tree plantations		NO	NO	NO
Grassland in the strict sense		-0.4	30.4	30.4
Woody Grassland		-0.5	30.6	30.6
Hedges		-2.2	42.7	42.7
Terr. Wetlands		-0.7	67.9	67.9
Buildings and open areas		NO	NO	NO
Other Land		NO	NO	NO
Mineral soils, N_2O_{direct} [1]		**[kg N_2O ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Photovoltaic areas	0.1	99.9	244.7

Photovoltaic areas	Area	Emission factor	Uncertainty bounds	
$Cropland_{annual}$		0.1	99.9	223.3
Hops		0.1	99.9	231.9
Vineyards		0.1	99.9	225.8
Orchards		0.1	99.9	223.5
Short-rotation plantations		NO	NO	NO
Tree nurseries		0.1	99.9	224.7
Christmas tree plantations		NO	NO	NO
Grassland (in the strict sense)		0.1	99.9	222.7
Woody Grassland		0.2	99.9	222.8
Hedges		0.7	99.9	224.8
Terr. Wetlands		0.2	99.9	231.8
Buildings and open areas		NO	NO	NO
Other Land		0.004	99.9	242.55
Mineral soils, $N_2O_{indirect}$ [1]		**[kg N_2O ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Photovoltaic areas	0.3	99.9	135.8
$Cropland_{annual}$		0.2	87.9	91.9
Hops		0.2	99.9	111.1
Vineyards		0.3	91.5	97.8
Orchards		0.3	87.4	92.3
Short-rotation plantations		NO	NO	NO
Tree nurseries		0.2	87.9	95.2
Christmas tree plantations		NO	NO	NO
Grassland (in the strict sense)		0.3	89.2	90.4
Woody Grassland		0.4	89.2	90.5
Hedges		1.6	94.1	95.3
Terr. Wetlands		0.5	99.9	110.9
Buildings and open areas		NO	NO	NO
Other Land		0.009	99.9	131.9
Biomass [2]		**[kt C ha^{-1} a^{-1}]**		**[%]**
Forest Land	Photovoltaic areas	-3.0	23.1	23.1
$Cropland_{annual}$		0.0	14.3	14.3
Hops		0.0	63.9	63.9
Vineyards		-0.1	27.0	27.0
Orchards		-0.4	15.2	15.2
Short-rotation plantations		NO	NO	NO
Tree nurseries		-0.4	25.5	25.5
Christmas tree plantations		NO	NO	NO
Grassland in the strict sense		-0.1	18.6	18.6
Woody Grassland		-5.9	16.1	22.5
Hedges		-26.7	33.6	37.1
Terr. Wetlands		-3.6	48.5	50.6

Photovoltaic areas	Area	Emission factor	Uncertainty bounds	
Buildings and open areas		0.39	90.61	90.61
Peat extraction		NO	NO	NO
Other Land		0.149	26.44	26.44
Dead organic matter [2]		**[kt C ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest Land	Photovoltaic areas	-0.2	52.4	52.4

1) The calculation covers a 20-year period; emission: positive ≙ source; negative ≙ sink

2) The calculation is only for the first year of the land-use change; stock change: positive ≙ sink; negative ≙ source

3) The calculation covers a 20-year period; stock change: positive ≙ sink; negative ≙ source

Table 419: Uncertainties for emission factors [2.5% and 97.5% percentile, in % of central tendency] for emissions from organic soils for Settlements, in 2024

Land use	Greenhouse gas	Emission factor	Uncertainty bounds	
			lower	upper
Organic soils[1]		**[t CO_2-eq. ha^{-1} a^{-1}]**	**[%]**	**[%]**
Buildings and open areas	CO_2	26.78	27.20	20.28
Buildings and open areas	CH_4	1.30	48.21	208.76
Buildings and open areas	N_2O	1.51	62.47	255.52
Photovoltaic areas	CO_2	31.01	51.34	47.14
Photovoltaic areas	CH_4	0.92	52.97	195.41
Photovoltaic areas	N_2O	1.82	67.59	231.77

1) Annual calculation; emission: positive ≙ source; negative ≙ sink

6.8.4 Category-specific QA/QC and verification (4.E)

Details regarding this year's reviews are provided in Chapter 6.1.3.

The data sources used in preparation of this inventory fulfil the review criteria of the QSE manual for data sources (QSE-Handbuch für Datenquellen). Quality assurance for input data (ATKIS®, BÜK, official statistics) is the responsibility of the relevant data administrators (cf. the documentation in the inventory description).

The emissions calculation results as presented in the present report cannot be compared with other relevant data sources for Germany since no such other data sources exist that meet applicable requirements, i.e. provide nationwide coverage, are comprehensive and are independent of the methods and data sources described in the present report.

The following tables compare Germany's implied emission factors for the category Settlements with those of neighbouring European countries. The values of neighbouring countries that were used for this comparison were obtained from the 2025 submissions to the Climate Secretariat. The values for Germany were obtained from the 2025 and 2026 submissions.

Basically, the IEFs for the other pools do not differ widely in terms of trend and level from those of neighbouring countries. In cases where they are at the edge of the relevant range, an equivalent figure in at least one other central European neighbouring country can always be found.

Table 420: Carbon-stock changes in living biomass in Settlements of various countries, in [t C ha^{-1} a^{-1}]

	4.E.1. - Settlements Remaining Settlements	4.E.2 - Land Converted To Settlements	4.E.2.1 - Forest Land Converted To Settlements	4.E.2.2 - Cropland Converted To Settlements	4.E.2.3 - Grasslands Converted To Settlements	4.E.2.4 - Wetlands Converted To Settlements	4.E.2.5 - Other Land Converted To Settlements
Belgium	NA	-0.652	-5.122	-0.009	-0.085	NO	NO
Denmark	NA	-0.301	-4.378	-0.114	-0.03	-0.436	NO
France	-0.034	-0.863	-3.695	-0.121	-0.127	-0.052	0.007
United Kingdom	NA, NO	-0.594	-3.051	-0.187	-0.063	-1.404	NO
Netherlands	NA	-0.548	-2.902	-0.257	-0.41	NE, NO	NE, NO
Austria	NA	-0.016	-2.444	0.281	0.159	NO	NO
Poland	0.048	-4.702	-42.25	-0.03	-0.149	NO	NO
Switzerland	0.003	-0.462	-4.009	-0.175	-0.107	-0.017	NA
Czech Republic	NO	-0.703	-6.051	-0.236	-0.349	NO	NO
Germany, 2023	NO	0.882	-1.099	1.312	0.87	0.306	0.68
Germany, 2024	0.026	-0.648	-3.002	0.022	-0.893	-2.28	0.147

Germany: 2023 and 2024; other countries: 2023

Positive: carbon removal by sink; negative: carbon emission by source; Source: (UNFCCC, 2023c)

Table 421: Carbon-stock changes in dead organic matter in Settlements of various countries, in [t C ha^{-1} a^{-1}]

	4.E.1. - Settlements Remaining Settlements	4.E.2 - Land Converted To Settlements	4.E.2.1 - Forest Land Converted To Settlements	4.E.2.2 - Cropland Converted To Settlements	4.E.2.3 - Grasslands Converted To Settlements	4.E.2.4 - Wetlands Converted To Settlements	4.E.2.5 - Other Land Converted To Settlements
Belgium	NA	-0.044	-0.373	NO	NO	NO	NO
Denmark	NA	-0.013	-0.276	NA	NA	NA	NA
France	0	-0.093	-0.449	0	0	NA	NA
United Kingdom	NA, NO	-0.164	-0.993	IE, NA	IE, NA	-0.362	NO
Netherlands	NA	-0.077	-1.008	NA	NA	NA	NA
Austria	NO	-0.098	-1.109	NO	NO	NO	NO
Poland	0.001	-0.073	-0.667	NO	NO	NO	NO
Switzerland	NA	-0.073	-0.843	NA	NA	NA	NA
Czech Republic	NO	-0.032	-0.407	NO	NO	NO	NO
Germany, 2023	IE	-0.013	-0.137	IE	IE	IE	IE
Germany, 2024	IE	-0.013	-0.154	IE	IE	IE	IE

Germany: 2023 and 2024; other countries: 2023

Positive: carbon removal by sink; negative: carbon emission by source; Source: (UNFCCC, 2023c)

Table 422: Carbon-stock changes in mineral soils in Settlements of various countries, in [t C ha^{-1} a^{-1}]

	4.E.1. - Settlements Remaining Settlements	4.E.2 - Land Converted To Settlements	4.E.2.1 - Forest Land Converted To Settlements	4.E.2.2 - Cropland Converted To Settlements	4.E.2.3 - Grasslands Converted To Settlements	4.E.2.4 - Wetlands Converted To Settlements	4.E.2.5 - Other Land Converted To Settlements
Belgium	NA	-0.788					
Denmark	NA	-0.638	2.978	-0.805	-0.955	0.001	NA
France	0	-1.097	-2.115	-0.781	-1.503	-0.065	0.708
United Kingdom	-0.237	-4.341	-8.329	-1.916	-4.818	NO	NO
Netherlands	NA	-0.343	0	0	-0.628		
Austria	NA	-1.938	-2.867	-1.407	-2.276		

	4.E.1. - Settlements Remaining Settlements	4.E.2 - Land Converted To Settlements	4.E.2.1 - Forest Land Converted To Settlements	4.E.2.2 - Cropland Converted To Settlements	4.E.2.3 - Grasslands Converted To Settlements	4.E.2.4 - Wetlands Converted To Settlements	4.E.2.5 - Other Land Converted To Settlements
Poland	NO	-1.612	0	0	0		
Switzerland	0.067	-0.423	0	0	0		
Czech Republic	NO	-0.135	-0.291	-0.056	-0.43	NO	0
Germany, 2023	NO	-0.314	-0.501	-0.201	-0.397	-0.641	-0.012
Germany, 2024	0.002	-0.057	-0.602	-0.17	-0.41	-0.658	0.035

Germany: 2023 and 2024; other countries: 2023

Positive: carbon removal by sink; negative: carbon emission by source; Source: (UNFCCC, 2023c)

Table 423: Carbon-stock changes in organic soils in Settlements of various countries, in [t C ha^{-1} a^{-1}]

	4.E.1. - Settlements Remaining Settlements	4.E.2 - Land Converted To Settlements	4.E.2.1 - Forest Land Converted To Settlements	4.E.2.2 - Cropland Converted To Settlements	4.E.2.3 - Grasslands Converted To Settlements	4.E.2.4 - Wetlands Converted To Settlements	4.E.2.5 - Other Land Converted To Settlements
Belgium	NO	NO					
Denmark	NA	NA	NA	NA	NA	NA	NA
France	NO	NO	NO	NO	NO	NO	NO
United Kingdom	-1.046	-1.685	-0.195	NO	NO	NO	NO
Netherlands	-3.9	-3.888	0	0	-3.891		
Austria	IE	NO	NO	NO	NO		
Poland	-5	-5					
Switzerland	-2.84	-4.707					
Czech Republic	NO	NO	NO	NO	NO	NO	0
Germany, 2023	-5.144	-7.796	-7.322	-7.872	-7.832	-7.498	-8.032
Germany, 2024	-4.578	-2.005	-6.318	-7.947	-6.976	-6.382	-7.908

Germany: 2023 and 2024; other countries: 2023

Positive: carbon removal by sink; negative: carbon emission by source; Source: (UNFCCC, 2023c)

6.8.5 Category-specific recalculations (4.E)

This year's submission includes category-specific recalculations for the entire period 1990-2024. The emissions were recalculated in order to take account of new and improved data sources, the introduction of new methods, changes in methods, and error corrections made as part of ongoing inventory improvements. The corresponding measures are listed in Chapter 6.1.3.4.2 and all affected the results of the emissions calculations for the *Settlements* land-use category:

In Table 424 (areas) and Table 425 (emissions), the results of the current recalculations for the Settlements category are compared with the corresponding results in the previous year's submission.

The very small differences between the area data of the current and previous year's submissions are due mainly to the following two factors:

- Introduction of the new land-use subcategories, particularly the subcategory *Photovoltaic areas* to be reported under *Settlements*.
- Integration of the newly added data of the last time series year as an update to the map data used to determine activity data. It is assumed that the most recent data is the highest quality and therefore the previous time series is adjusted if necessary (cf. also Chapters 6.3.1 ff).

The CO_2 emissions of the 2026 submission show a marked increase compared with the previous year's submission, resulting in a reversal of the function of the land-use category, from a sink to a source. This is largely attributable to changes in the method used to determine biomass in settlement areas, and to the revised sealing factor (cf. Chapter 6.1.2.3.7).

The differences between submissions with regard to methane and nitrous oxide emissions are mainly caused by modifications to the hydrological model used to determine groundwater levels in organic soils (cf. Chapter 6.1.2.2.2).

Table 424: Comparison of area data for the Settlements category (4.E) as reported in the current and previous year's submissions, in [kha]

CRF	Submission	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
4.E	2025	4,062	4,076	4,091	4,331	4,502	4,717	4,836	4,859	4,882	4,905
	2026	3,845	3,985	4,139	4,307	4,494	4,711	4,835	4,859	4,884	4,908
	Difference	-216	-91	48	-24	-8	-6	-2	0	2	3
	in %	-5.33	-2.24	1.17	-0.55	-0.17	-0.13	-0.03	0	0.03	0.06

Table 425: Comparison of greenhouse gas emissions in the Settlements (4.E) category as reported in the current and previous year's submissions, in [kt CO_2-eq.]

CRF	GHG	Submission	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
4.E	CO_2	2025	324.2	325.0	295.7	2,227.2	-3,588.3	-1,648.4	-1,118.1	-996.1	-477.2	-472.7
		2026	3,141.5	3,314.4	3,493.6	3,785.6	3,989.9	4,652.3	4,609.5	4,242.2	4,493.5	4,223.3
		Difference	2,817.3	2,989.4	3,198.0	1,558.4	7,578.2	6,300.7	5,727.6	5,238.2	4,970.6	4,696.0
		in %	869.0	919.8	1,081.6	70.0	-211.2	-382.2	-512.3	-525.9	-1,041.7	-993.5
	CH_4	2025	41.8	38.9	37.2	38.7	43.8	56.1	35.9	61.4	35.3	104.2
		2026	53.8	56.6	57.3	54.2	58.0	51.6	49.7	83.2	39.0	124.5
		Difference	12.1	17.7	20.1	15.4	14.2	-4.5	13.8	21.9	3.7	20.3
		in %	28.9	45.5	54.2	39.8	32.5	-8.1	38.6	35.7	10.5	19.5
	N_2O	2025	91.3	90.8	90.3	238.8	190.8	201.4	183.9	176.3	179.7	173.1
		2026	136.1	144.9	155.5	167.6	180.9	200.4	183.0	174.4	180.5	172.7
		Difference	44.8	54.1	65.3	-71.2	-10.0	-0.9	-0.9	-2.0	0.8	-0.4
		in %	49.1	59.6	72.3	-29.8	-5.2	-0.5	-0.5	-1.1	0.4	-0.2

6.8.6 Category-specific planned improvements (4.E)

In addition to the planned measures listed in Chapter 6.1.2.1.9, most of which are medium-term measures, there are no specific measures currently planned to improve the methods used for Settlements.

6.9 Other Land (4.F)

6.9.1 Category description (4.F)

Since, by definition, the areas in the land-use category Other Land consist of areas that are not managed, the sizes of these areas are included solely for the purpose of completing the area matrix. Emissions as defined in the IPCC Guidelines cannot occur and cannot therefore be

reported. For this reason, NO is entered in all relevant cells of CRF 4.F, with the exception of the space for the area of the remaining category.

6.9.2 Methodological issues (4.F)

In emissions calculation, Other Land areas are taken into account solely as the initial land-use category in connection with land-use changes to other categories. No conversions back to Other Land take place since, by definition, land that has been used once can no longer be returned to an unused land-use category.

The carbon stocks of the biomass and dead organic matter categories in the Other Land category are zero.

The carbon stocks of mineral soils in the Other Land category are listed in Chapter 6.1.2.

Organic soils in the Other Land category are not drained.

6.9.3 Uncertainties and time series consistency (4.F)

The uncertainties for the activity data were determined in accordance with the 2006 IPCC Guidelines (IPCC, 2006a). Additional relevant information is provided in Chapter 6.1.2.1. The total uncertainty about the areas of the land-use category Other Land is around 1% for the year 2024.

The time series is complete and consistent.

6.9.4 Category-specific QA/QC and verification (4.F)

Details regarding this year's reviews are provided in Chapter 6.1.3.

6.9.5 Category-specific recalculations (4.F)

This year's submission includes category-specific recalculations for the entire period 1990-2024. The emissions were recalculated in order to take account of new and improved data sources, the introduction of new methods, changes in methods, and error corrections made as part of ongoing inventory improvements. The corresponding measures are listed in Chapter 6.1.3.4.2 and only affected the results of the emissions calculations for the Other Land land-use category in terms of the area data:

The very small differences between the area data reported in the current and previous year's submissions are due mainly to the introduction of the new land-use categories and updating of map data as a result of integrating the newly added data from the last time series year used to determine activity data. It is assumed that the most recent data is the highest quality and therefore the previous time series is adjusted if necessary (cf. also Chapters 6.3.1 ff).

In Table 426, the results of the current recalculations of the areas in the category Other Land are compared with the corresponding areas reported in the previous year's submission.

Table 426: Comparison of area data for the Other Land category (4.E) as reported in the current and previous year's submissions, in [kha]

CRF	Submission	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
4.F	2025	65.6	60.4	55.4	46.2	41.5	39.6	37.6	37.5	37.4	37.4
	2026	83.4	76.5	69.7	63.0	56.5	50.7	43.5	43.1	42.7	42.3
	Difference	17.9	16.1	14.3	16.9	15.0	11.0	5.9	5.6	5.2	4.9
	in %	0.2	0.2	0.2	0.3	0.3	0.2	0.1	0.1	0.1	0.1

6.9.6 Category-specific planned improvements (4.F)

Not applicable, since no greenhouse gas sources and sinks are reported in this category.

6.10 Harvested wood products (4.G)

6.10.1 Category description (4.G)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
-/T	4 G, Harvested Wood Products		CO_2	-1294.86	-0.11	407.62	0.06	-131.48

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS/Tier 2	IS/NS	D

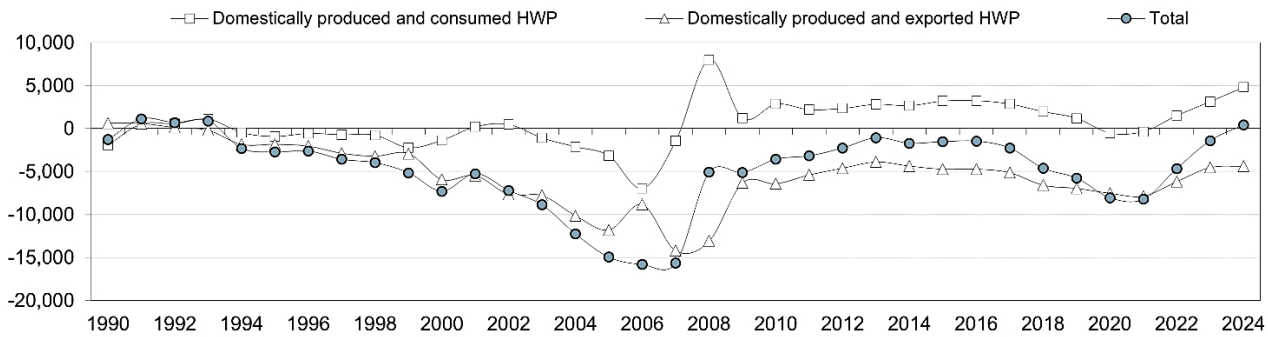
The source category Harvested Wood Products (HWPs) is a key category in terms of trend.

The contribution of HWPs in land-use sectors in Germany in terms of greenhouse emissions by sources and removals by sinks was estimated with the WoodCarbonMonitor model (Rüter, 2017) using the prescribed approach on the basis of production data for wood products . The estimate thus covers all HWPs that are produced in Germany and which consist of wood originating from domestic harvest that is used as material (not for energy).

The calculation follows the methodological requirements of Chapter 2.8 of the 2013 IPCC KP Supplement (IPCC, 2014) and Chapter 12 of the IPCC 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2019) for the production approach.

In the interest of transparency, pursuant to CRF Table 4.Gs1, wood products for material use are divided into products that, following their production, are consumed in Germany, and products that have subsequently been exported. The carbon storage effect of wood in solid waste disposal sites is not taken into account. The biomass from short-rotation plantations is used exclusively for energy purposes in Germany (cf. category 1.A, Chapter 3.2) and is thus not reported under Harvested Wood Products (HWPs).

Figure 102: Net CO_2 emissions and removals in HWPs, in [kt CO_2]

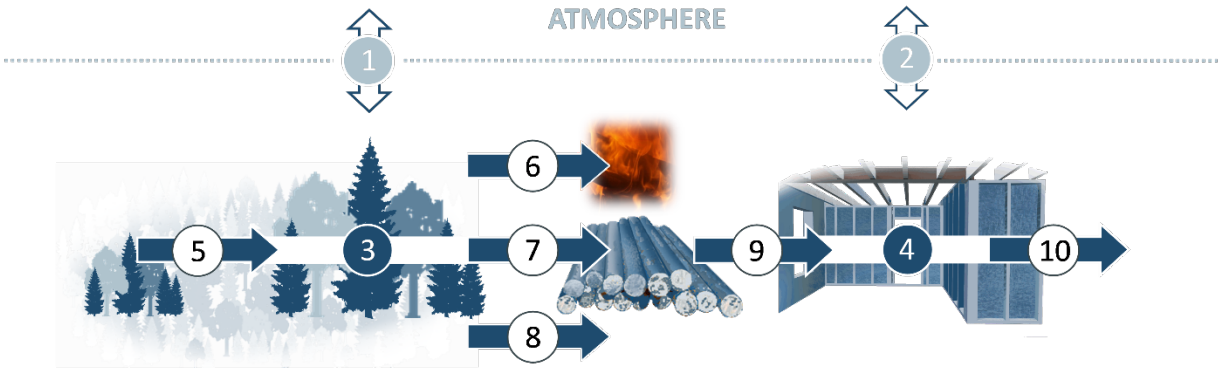


Source: own illustration, Thünen-Institut

Figure 103 presents an overview of the carbon flows associated with forests and wood use for the reporting year 2024, which are reported as “gains” and “losses” in the defined carbon pools for forests (here: only living biomass (3); cf. Chapter 6.4.2.2) and harvested wood products (4).

The atmospherically relevant CO_2 emissions and their removals (living biomass 1 and harvested wood products 2) are determined on the basis of the changes in these defined stocks.

Figure 103: Carbon flows and carbon stocks, and their CO_2 emissions and removals throughout the Forest and wood chain



CO_2 emissions and removals in the carbon pools FOREST[a] and HARVESTED WOOD PRODUCTS		[in kt CO_2e]
1	FOREST[a]	1,773
2	HARVESTED WOOD PRODUCTS	408
Magnitude of the defined carbon pools[e]		[in kt C]
3	FOREST[af]	1,172,971
4	HARVESTED WOOD PRODUCTS [g]	293,462

Carbon flows [b] from and to the carbon pools		[in kt C]
5	gains (FOREST)	14,067
6	losses (FOREST) *(harvested wood for mainly energy use[c])*	-7,236
7	losses (FOREST) *(harvested wood for mainly material use[d])*	-13,025
8	losses (FOREST) (*remaining harvest[e]*)	-8,762
9	gains (HARVESTED WOOD PRODUCTS)	10,858
10	losses (HARVESTED WOOD PRODUCTS)	-10,969

[a] here: living biomass only
[b] during the inventory year (gains positive, losses negative)
[c] based on the difference between StBA-harvest statistics (industrial roundwood) and calibrated roundwood removals in cubic metres (m^3)
[d] based on the harvest statistics (saw and pulp logs) of the Federal Statistical Office (Statistisches Bundesamt, StBA) (m^3)
[e] based on calibrated harvest time series in reserve solid cubic metres (RSCM)
[f] based on National Forest Inventory 2022 (BWI2022), s. www.bwi.info
[g] here: at the end of the inventory year

WoodCarbonMonitor © S. Rüter, 2025

Source: own illustration, Thünen-Institut

Furthermore, both gains (5) of living biomass stocks in forests (i.e. on existing Forest Land and on forest lands subject to land-use changes) and their losses are shown. The related carbon flows differentiate between the use of raw wood, which mainly entails the use of wood for energy purposes (6), the harvest of round wood for further processing into wood products (7) and the remainder of the raw wood removals which are not used (8) (cf. also Figure 94). The estimated carbon removal based on the quantities of raw wood harvested for material use is based on data on the production of stem-wood (i.e. sawlogs and veneer logs) and industrial roundwood taken from logging statistics (Statistisches Bundesamt, FS 3, R 3.3.1), broken down into four main tree or wood species groups and are reported in cubic metres of harvested timber. Carbon-stock decreases of the living biomass pool in forests that are primarily due to wood energy use and which are not reported under HWPs (production approach), cover the other use of raw wood in cubic metres of harvested timber and part of the bark. The data on the removal and use of raw wood come from the forest inventories (cf. Chapter 6.4.2.1.1), which are calibrated using the time series of the logging statistics by main tree type groups, as described in Chapter 6.10.2.1.

The calculation of the carbon flows (9 and 10) associated with the carbon stock in HWPs as well as the resulting changes of the stock that are reported in CRF Table 4.Gs1 are described in the following Chapter 6.10.2.

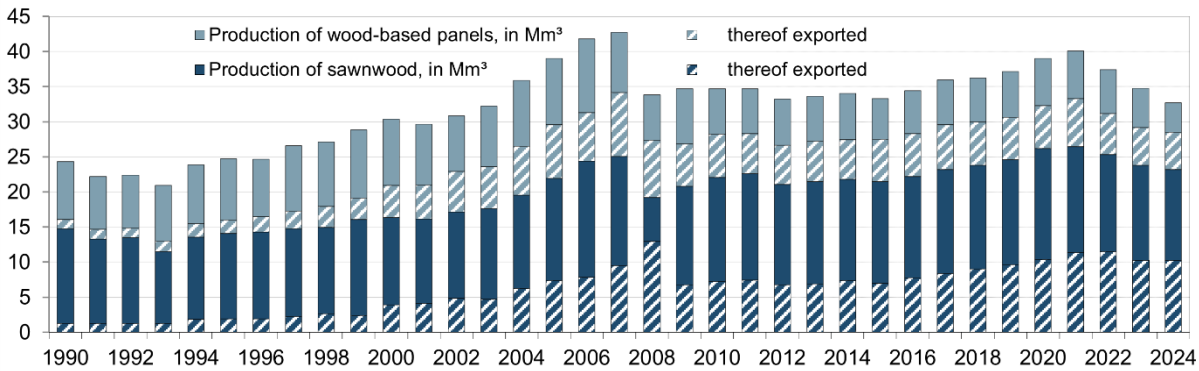
6.10.2 Methodological issues (4.G)

6.10.2.1 Activity data

Figure 104 shows the development of production quantities in the semi-finished product categories sawn wood and woodbased panels, broken down by the wood quantities remaining in Germany (production, less exports) and the quantities exported (exports), since 1990. The figure is based on data of the Food and Agriculture Organization of the United Nations (FAO) (FAO, 2025). These time series correspond to the data proposed in the 2019 Refinement to the 2006 IPCC Guidelines (IPCC, 2019) for estimating the HWP contribution for the production approach following a Tier 1 calculation.

At the time this report was prepared (10/2025) in line with the defined routine inventory-preparation procedure (cf. Chapter 1.2.3) the activity data on HWPs needed for the calculation were not available yet for 2024 (cf. (FAO, 2022)). For this reason, the missing FAO data for production of wood products in 2024 are estimates based on a trend extrapolation approach as suggested by the Technical Expert Review Team (TERT) in the 2025 Comprehensive Review of National GHG Inventory Data (EEA, 2025). Based on this suggestion, the trend within the time series of the national harvest statistics (Statistisches Bundesamt, FS 3, R 3.3.1) was used to derive the missing datasets for the semi-finished product categories, sawn wood and wood-based panels. Detailed data for the years 2019-2024 were only used for the product group coniferous sawn wood, as all of the relevant reporting data from the national production statistics in the manufacturing sector (Statistisches Bundesamt, 2025b) are freely available and not subject to confidentiality (cf. Chapter 6.10.6). Export data for 2024 were also missing from the FAOSTAT database, but these were carried forward from the previous year instead. The time series of national harvest statistics on the production of stem-wood (i.e. sawlogs and veneer logs) was used to calculate the feedstock factor for industrial roundwood (see below). The missing data for wood pulp and recovered paper (cf. Figure 107) - the raw materials processed to make paper and paperboard - were derived from the information in the German performance report on paper (Papierindustrie, 2025). For this purpose, the changes in production and trade volumes relative to the previous year were adopted and applied to the FAO data for 2023. The same procedure was followed to determine the production quantity of the semi-finished-product group paper and paperboard in 2024.

Figure 104: Sawn wood and wood-based panels produced in Germany [Mm³] (FAO, 2022)



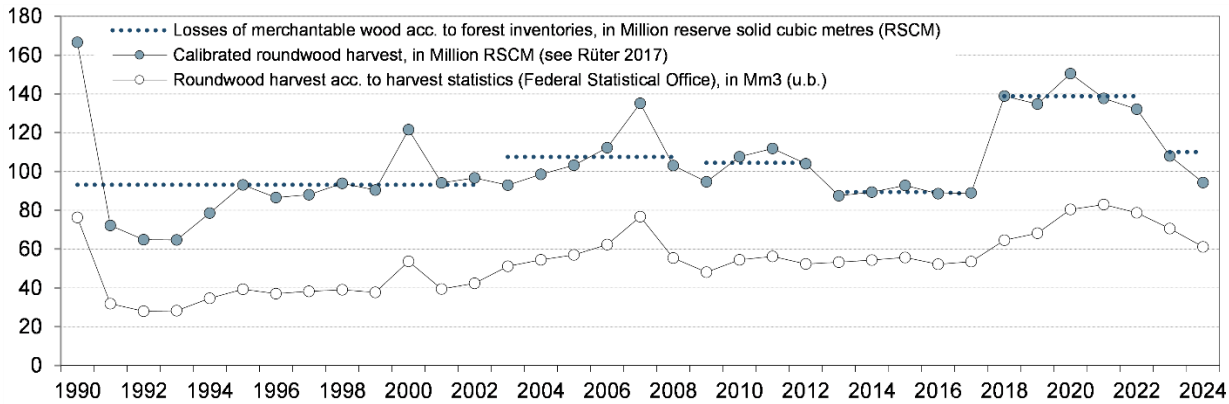
Source: own illustration, Thünen-Institut

In line with the IPCC guidelines for the production approach, the feedstock fraction in HWPs from domestically harvested wood on existing forest areas was calculated based on the described time series for production and trade of semi-finished wood products and the corresponding feedstock data.

To this end, and in a first step, the data from the forest inventories about the loss of raw wood from forests (cf. Chapter 6.4.2.1.1) were calibrated in accordance with the methodological guidelines of the IPCC (2014) with the data of the national harvest statistics for the four recorded groups of wood species, beech, oak, pine and spruce (Statistisches Bundesamt, FS 3, R 3.3.1) in order to map the annual fluctuations in the total loss of raw wood from the existing stock of living wood biomass within the inventory periods (Figure 105). This makes it possible firstly to draw a distinction in the quantities of wood which enter dead wood pool; secondly, it permits a quantification of the non-used raw wood and the harvesting losses and bark as a component of the loss expressed in reserve solid cubic metres (Figure 106). The raw wood that leaves the forest area and is used is expressed in cubic metres of harvested timber, i.e. without bark, and shows that the statistics underestimate the annual harvest of roundwood. The reasons for this statistical underestimation of the timber harvest are mainly that some wood is used for firewood – for example, by private households (private, small-scale wood buyers), and that most of this wood is not covered by the statistics. Furthermore, the harvest of wood for energy has only been recorded in statistics since 2006 (Statistisches Bundesamt, FS 3, R 3.3.1).

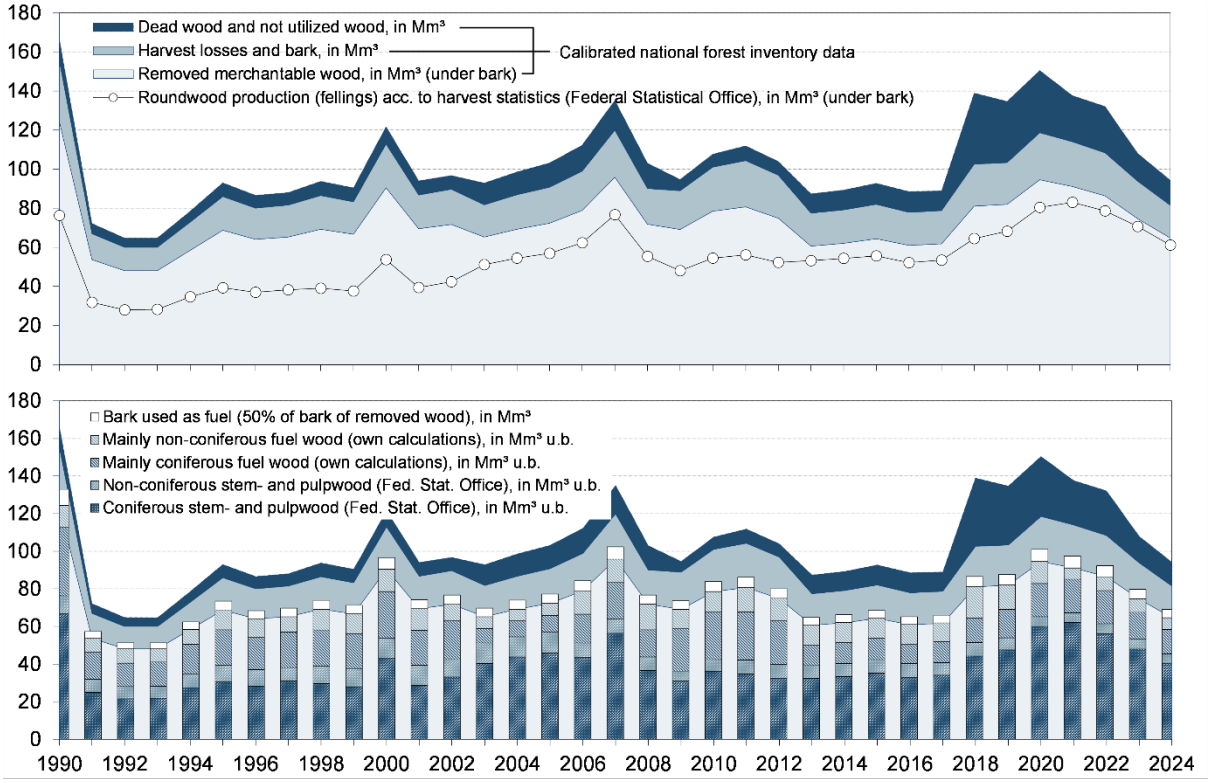
For 2023 and 2024, which were not covered in the last inventory (NFI 2022), the loss of raw wood over the entire inventory period (2013-2022) was extrapolated and then calibrated with the logging statistics.

Figure 105: Calibration of the raw wood loss according to forest inventory data using harvest statistics [million reserve solid m³]



Source: own illustration, Thünen-Institut

Figure 106: Unused and used raw wood losses according to forest inventory data and harvest statistics [Mm³]



Source: own illustration, Thünen-Institut

Alongside the formation of the interannual fluctuations of raw wood use, the calibration of the forest inventory data makes it possible to assign the carbon contained in the products to the relevant land-use classes from which the raw material derives. This is necessary to assign the quantities of harvested raw wood firstly to Forest Land remaining Forest Land (category 4.A.1, Chapter 6.2.1), and secondly to those areas subject to land-use changes from Forest Land to other categories. Wood from areas subject to a land-use change from Forest Land to other categories is, in line with the requirements of EU Regulation 2018/841[94] and EU Regulation 2023/839[95] and the guidance of the IPCC, included on the basis of an "instantaneous oxidation" assumption (cf. Chapter 2.8.3, IPCC (2014) and 12.4.1.2, IPCC, 2019), so that ultimately the annual share of harvested timber from Forest Land remaining Forest Land $f_{FLrFLM}(i)$ (cf. Table 427) is calculated using the inventory information available for Germany and Equation 12.10 (IPCC (2014): 12.25).

Table 427: Annual share of harvest originating from Forest Land remaining Forest Land

Period	$f_{FLrFL}(i)$
1990-2002	0.9937
2003-2008	0.9914

[94] Regulation (EU) 2018/841 of the European Parliament and of the Council of 30 May 2018 on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry in the 2030 climate and energy framework, and amending Regulation (EU) No 525/2013 and Decision No 529/2013/EU

[95] Regulation (EU) 2023/839 of the European Parliament and of the Council of 19 April 2023 amending Regulation (EU) 2018/841 as regards the scope, simplifying the reporting and compliance rules, and setting out the targets of the Member States for 2030, and Regulation (EU) 2018/1999 as regards improvement in monitoring, reporting, tracking of progress and review. Official Journal of the European Union, L 107/1 of 21 April 2023

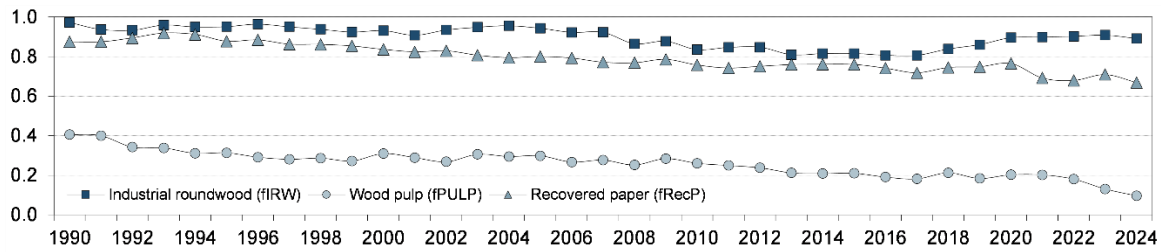
Period	$f_{FLrFL}(i)$
2009-2012	0.9906
2013-2017	0.9860
2018-2022	0.9926

This calibration also ensures methodological consistency with the projected time series of the reported FRL (Rock et al. (2021)). Further details of the calibration of the raw wood loss using the time series for raw wood logging according to the provisions of the IPCC (2014) can be found in Rüter (2017).

In order to determine the carbon pool inflow for the production approach in accordance with Equation 12.7 of the 2019 Refinement to the IPCC 2006 Guidelines (cf. (IPCC, 2019): 12.23), in a second step, the respective domestic feedstock factors $f_R(i)$ were determined on the basis of equation 12.8 (IPCC, 2019: 12.24); these factors for the semi-finished product categories sawn wood and wood-based panels are based on the data on the feedstock category industrial roundwood described above. For the calculation of the fraction of the feedstock coming from domestic harvest in the product category paper and paperboard, the use of recovered paper in paper production was taken into account alongside the feedstock category wood pulp as the recovered paper fraction in paper and paperboard that is produced in Germany exceeds 70%. As in the previous reporting years, the fraction *p* of recovered paper used in paper products was determined by means of the proportion of the calculated consumption of wood pulp and recovered paper in Germany. Along with the relevant factors for industrial roundwood (f_{IRW}) and wood pulp (f_{PULP}), which were calculated pursuant to Equations 2.8.1 and 2.8.2 of the IPCC KP Supplement (IPCC (2014): 2.115), a factor for recovered paper (f_{RecP}) was also determined based on the same approach as for those factors and using the activity data described above (Figure 107).

As a result of using the time series for harvest of industrial roundwood (stem-wood/logs and pulpwood) from the national logging statistics rather than the corresponding FAO data, there are only minor changes to the feedstock factors $f_R(i)$ in comparison with the preceding year.

Figure 107: Development of the domestic feedstock factor $f_R(i)$ for the raw material categories considered (FAO, 2022, 2025)



Source: own illustration, Thünen-Institut

6.10.2.2 Emission factors

The carbon outflows from the carbon pool are calculated with the default values listed in Table 12.3 of the 2019 Refinement to the IPCC 2006 Guidelines (IPCC, 2019).

6.10.2.3 Calculation method used

To calculate the contribution of HWPs used as material to the delayed release of CO_2 emissions on the basis of carbon pool changes, Germany uses the exponential decay function for the

product categories described in Table 12.1 of the IPCC 2019 Refinement. This corresponds to the standard method described in the IPCC guidelines (Equations 12.1, 12.2 and 12.3, IPCC (2014): 12.16-17). For the carbon conversion calculation of the HWP category wood-based panels, the detailed factors and, for the HWP category paper and paperboard, the aggregated conversion factors listed in Table 12.1 (IPCC, 2014) are used. The carbon quantities in the product categories non-coniferous and coniferous sawn wood are calculated by the factors described in Rüter (2011) (cf. also UNFCCC (2011b)) in order to represent the tree species that are typically used in Germany for the production of sawn wood correlating with the roundwood harvest statistics (Statistisches Bundesamt, FS 3, R 3.3.1). For coniferous sawn wood, the factor amounts to 0.225 t C/m^3, while for non-coniferous sawn wood it is 0.335 t C/m^3.

Since time series on HWP and the feedstock categories used have only been available with sufficient data quality since the reunification of Germany in 1990, and in order to reduce uncertainties associated with the data, the initial value of the carbon stock in HWP is calculated on the basis of Equation 12.4 (IPCC, 2014) where $C(t_0)$ = 1990.

Further details on the method used is provided in Rüter (2017).

6.10.3 Uncertainties and time series consistency (4.G)

The time series for HWP activity data from the UN FAO database are consistent. At the time this report was prepared (10/2025) in line with the defined routine inventory-preparation procedure (cf. Chapter 1.2.3), the activity data on HWPs needed for the calculation were not available yet for 2024 (cf. (FAO, 2022)). For this reason and as described in Chapter 6.10.2.1, the data sets for the semi-finished-product categories sawn wood, wood-based panels, paper and paperboard and for industrial round wood, wood pulp and recovered paper had to be estimated using a trend extrapolation approach (EEA, 2025). As the German Council of Experts on Climate Change has found, there are major modelling uncertainties as a result of this outdated data (cf. (ERK, 2024)). To reduce these uncertainties and increase consistency with the calculations, individual time series were converted to use data from the national statistics (cf. Chapters 6.10.2.1 and 6.10.6)

Apart from this, the uncertainties of these time series amount to -25/+5% according to information from the IPCC (IPCC, 2014).

6.10.4 Category-specific QA/QC and verification (4.G)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

The WoodCarbonMonitor calculation model was previously used in 2011 to determine the HWP contribution to the forest management reference level for the second commitment period under the Kyoto Protocol for other EU Member States as well. Following cross-checking against national data and any existing models, 16 additional countries used the data for their submissions to the Climate Secretariat (Belgium, Bulgaria, the Czech Republic, Denmark, Estonia, France, Greece, Hungary, Italy, Latvia, Lithuania, the Netherlands, Poland, Romania, Slovakia and Spain). An international team of experts at the Secretariat then evaluated these data together with the model and its underlying assumptions (Rüter (2011) and UNFCCC (2011b)).

The subsequent adjustment of the reported time series to the agreed calculation rules for harvested wood products in accordance with Decision 2/CMP.7 was also accompanied by the model during the preparation of Chapter 2.8 “Harvested Wood Products” of the 2013 IPCC KP Supplement (IPCC, 2014) and (Rüter, 2017), cf. Chapters 3.2.2, 4.4 and Annex).

In the context of evaluation of the EU Member States' FRL projections pursuant to Regulation 2018/841 (European Parliament (EP), 2018), the model was repeatedly used in 2019 in combination with the G4M model in order to cross-check the country-specific HWP calculations and their underlying data and assumptions on behalf of the EU Commission (Forsell et al. (2018) and Forsell et al. (2019)). Furthermore, repeated assessments and calibrations were carried out within the framework of EU projects by using the GLOBIOM equilibrium model operated by the International Institute for Applied Systems Analysis (IIASA) (Rüter et al. 2016 and Rüter & Fulvio, 2025).

Additional general information about the quality control (QC) and quality assurance (QA) that have also been carried out for HWP is provided in Chapter 6.1.3.

6.10.5 Category-specific recalculations (4.G)

The activity data on wood products for 2023 that are needed for the calculation were repeatedly not yet available in the FAOSTAT database at the time of the compilation of this report (10/2025). In result, the activity data for 2024 were determined as per the description provided in Chapter 6.10.2.1. To enhance the consistency of the calculations, the time series in the national harvest statistics on roundwood, which, due to the availability of data from the 2022 NFI, were recalculated and calibrated by tree type for the entire period (cf. Figure 105), has already been used since the 2024 reporting year to calculate the roundwood volumes from existing forest areas ($f_{FLrFL}(i)$). It is now, for the first time, also being used to calculate the feedstock factors $f_R(i)$ in order to determine the domestically harvested roundwood that is further processed into semi-finished wood products. This results in changes which affect the entire time series for CO_2 emissions and removals in the HWP category.

Table 428: Comparison of the HWP CO_2 emissions and their removals in the 2024 and 2025 submissions

	Net emissions [kt CO_2]	1990	1995	2000	2005	2010	2015	2020	2023
Sub 2025	From domestically used sawn wood	-1,697	2	160	-1,490	-492	24	-1,615	-256
	From exported sawn wood	45	-411	-1,919	-4,443	-3,214	-2,603	-5,050	5,649
	From domestically used wood materials	-600	-689	-1,075	-1,347	2,803	2,605	1,256	1,589
	From exported wood materials	181	-371	-2,660	-5,120	-2,550	-1,712	-1,730	-1,355
	From domestically used paper and paperboard	334	-189	-335	-349	262	399	151	218
	From exported paper and paperboard	396	-1,022	-1,241	-2,184	-824	-487	-476	849
Sub 2026	From domestically used sawn wood	-1,686	-33	84	-1,506	-321	132	-1,833	-271
	From exported sawn wood	46	-416	-1,943	-4,450	-3,128	-2,551	-5,191	-4,781
	From domestically used wood materials	-593	-709	-1,110	-1,319	2,893	2,661	1,160	1,946
	From exported wood materials	182	-388	-2,726	-5,163	-2,475	-1,676	-1,846	-1,040
	From domestically used paper and paperboard	352	-183	-347	-347	266	393	143	1,449
	From exported paper and paperboard	404	-1,020	-1,254	-2,182	-816	-494	-489	1,282

The CO_2 emissions and their removals of -4,604 kt CO_2 from harvested wood products reported in the preceding year for the year 2023 were corrected to -1,135 kt CO_2 (EEA 2025, p. 15) in the

course of the Comprehensive Review of National GHG Inventory Data (EEA, 2025) in 03/2025 due to updated values provided in the FAO database in 12/2024 . As a consequence of this years' category-specific recalculation, CO_2 emissions and their removals decreased to -1,415 kt CO_2.

6.10.6 Category-specific planned improvements (4.G)

In 2024, the Council of Experts on Climate Change examined the CRF category 4.A Forest Land in the LULUCF sector and also touched on the CRF HWP category (4.G). It found that the Thünen-Institute of Wood Research "due to legal requirements regarding the confidentiality of individual reporting numbers of the production statistics in accordance with section 16 of the Federal Statistics Act has no access to existing data on wood products of the Federal Statistical Office" which could be used in place of the FAO data. This results in major uncertainties (cf. Chapter 6.10.5). "A calculation using more specific national activity data, as envisaged by the IPCC (IPCC, 2014) and with related conversion factors already available [at the Thünen-Institute of Wood Research] is therefore not possible." (Council of Experts on Climate Change, 2024). The "general review of the legal basis for data access and flows" recommended by the Council of Experts, which should "[therefore] be considered by the legislature with a view to "[granting] access to relevant data for all federal authorities involved in emission calculations" has yet to be undertaken. Nevertheless, efforts continue to be made to improve the calculation of the underlying data basis (cf. Chapter 6.10.2.1 and 6.10.3). This is also true of the recording of the dynamism over time of the use of raw wood which is lost due to calamities (e.g. in 1990) but has not, or not yet, been used for further processing into wood products used as a material (cf. notes in the context of the ESD review in 02/2024 and (Rüter & Stümer, 2024).

The recent evaluation of the latest forest inventory data, made it possible to continue to differentiate the loss of raw wood by tree type group into a) those quantities of raw wood which enter the deadwood pool and b) those which are mainly used for energy purposes or are available as material for further processing into HWPs. In order to maintain the consistency of the time series, in a further step the current raw wood loss, which is extrapolated for the period after the last forest inventory in line with the procedure described above, has to be differentiated on the basis of information about the nature of the calamity since suddenly accruing damaged timber cannot always be processed and used, or only in exceptional circumstances (cf. 1990) (cf. Figure 106). At the same time, it is necessary to note that Germany uses the corresponding chapters of the 2013 IPCC KP Supplement (IPCC, 2014) and the 2019 Refinement (IPCC, 2019) as a methodological basis for the calculation of the category in order to comply with the legal requirements for the balancing of HWPs in the inventory (i.e. EU Regulation 2018/841 and EU Regulation 2023/839[96]). The availability of transparent data is cited here as a basic prerequisite for such a calculation, , not least in order to comply with one of the core principles governing the handling of measures in the LULUCF category: not to overestimate the carbon storage effects of the pool and not to underestimate emissions[97].

Where previous reports have listed further planned improvements in this chapter, those improvements are presented as an overview in Table 473 in Chapter 10.4. Completed improvements are listed in Table 472 in the same chapter.

[96] Regulation (EU) 2023/839 of the European Parliament and of the Council of 19 April 2023 amending Regulation (EU) 2018/841 as regards the scope, simplifying the reporting and compliance rules, and setting out the targets of the Member States for 2030, and Regulation (EU) 2018/1999 as regards improvement in monitoring, reporting, tracking of progress and review. Official Journal of the European Union, L 107/1 of 21 April 2023

[97] UNFCCC (2002a) Report of the COP on its seventh Session, held at Marrakesh from 29 October to 10 November 2001. The Marrakesh Accords: Decision 11/CP.7 on Land use, land use change and forestry. Addendum, *FCCC/CP/2001/13/Add.1*.

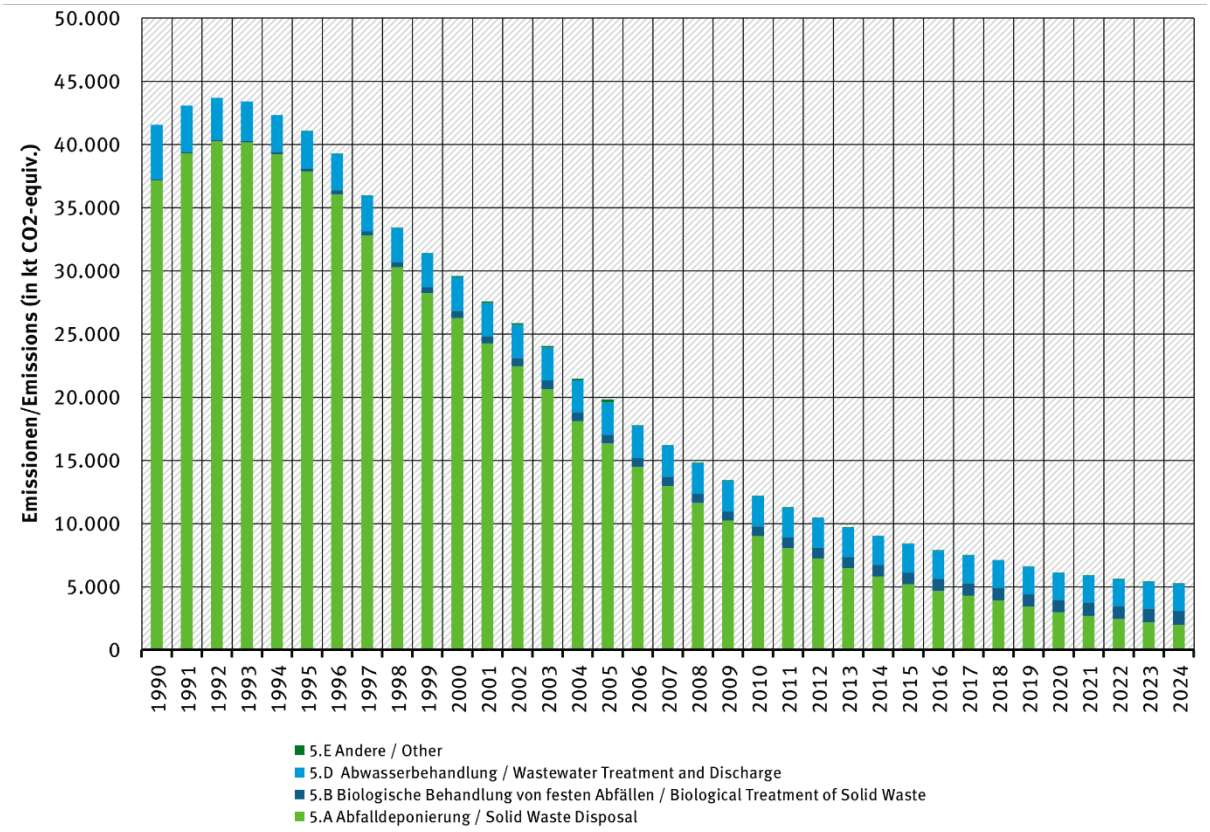
6.11 Other sectors (4.H)

In 4.H, N_2O emissions caused by cultivation of organic soils and originating in the category *Settlements* (108.8 kt CO_2-eq. according to IPCC AR5 for 2021) are provisionally reported in Table 4 (II) because the CRF Tables of the CRF Reporter do not allow for these emissions. CO_2 and CH_4 emissions are provisionally reported in Table 4 E as "included elsewhere" (IE). In the current NIR, the results are listed in the chapter on Settlements (Chapter 6.8.1).

7 Waste and Wastewater (CRF Sector 5)

7.1 Overview (CRF Sector 5)

Figure 108: Overview of greenhouse gas emissions in CRF Sector 5



Source: own illustration, German Environment Agency

7.2 Solid waste disposal on land (5.A)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
L/T	5 A, Solid Waste Disposal		CH_4	37191.25	2.88	1997.16	0.29	-94.63

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 2	NS	CS

The category “Solid waste disposal on land” is a key category for CH_4 emissions in terms of emissions level and trend.

Only managed disposal in landfills (5.A.1) is relevant for the purposes of German emissions reporting under CRF 5.A. “Wild” or illegal dumping of solid waste (CRF 5.A.2) is prohibited by law in Germany.

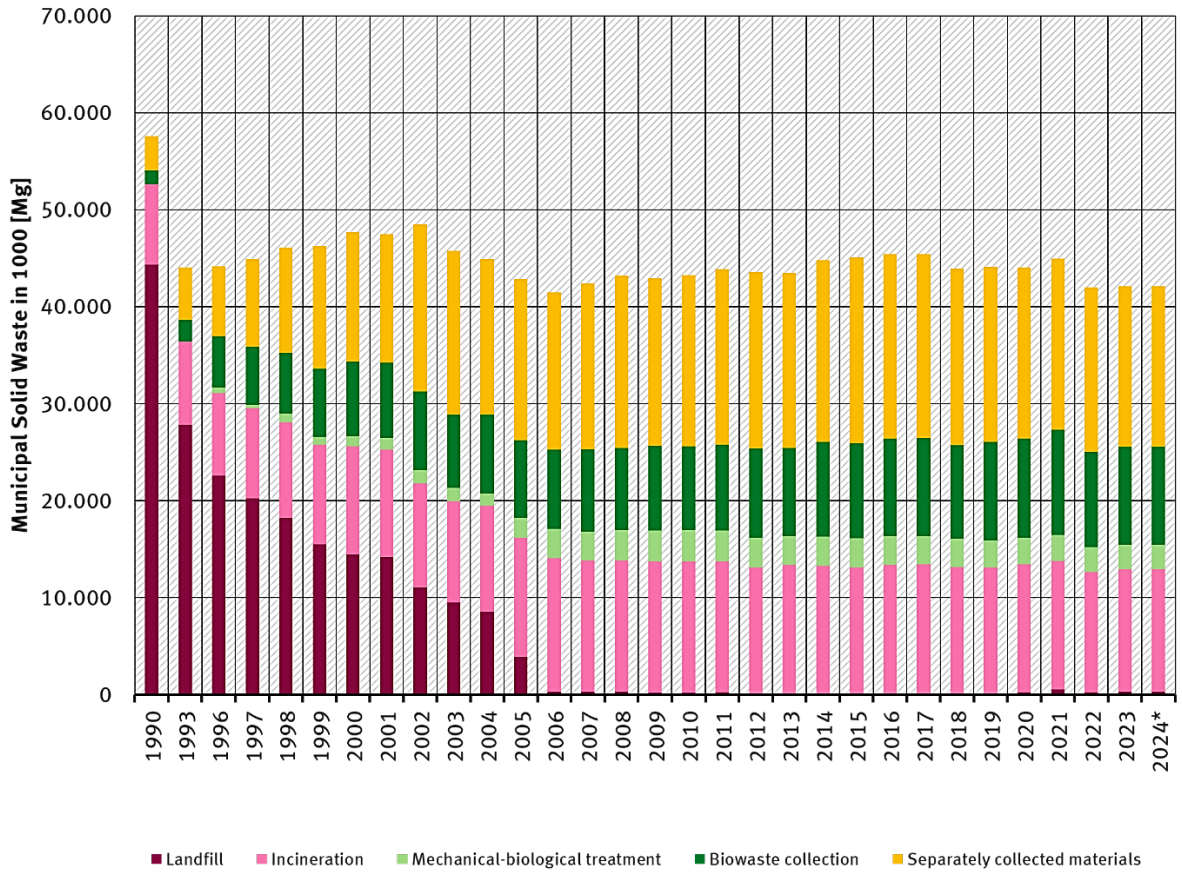
7.2.1 Managed disposal in landfills – (5.A.1) landfilling of settlement waste (5.A.1)

7.2.1.1 Category description (5.A.1)

Since 1990, and even prior to that, a number of legal regulations have been enacted and organisational measures initiated in the waste management sector in Germany, which have had a significant impact on the development of emissions from waste disposal sites. This includes increased collection of biowaste from households and businesses, increased collection of other recyclable materials such as glass, paper/cardboard, metals and plastics, and separate collection and recycling of packaging. In addition, incineration of settlement waste has been expanded and mechanical-biological treatment of residual waste introduced. As a result of all these measures, the volume of landfilled municipal waste decreased sharply from 1990 to 2006 (cf. Figure 79). The export of mixed municipal waste had only a minor impact on this decrease. Figure 79 clearly shows that in Germany today, more than half of the municipal waste generated is recycled (separate collection of recyclables and organic waste) rather than incinerated or landfilled. However, this change has only a very minor impact on total emissions from landfills in the current reporting year, as these are primarily determined by waste disposed of in the past.

In 2004, about 330 landfills for settlement waste were in operation in the Federal Republic of Germany. Strict legal requirements already stipulated technical equipment for the collection and treatment of landfill gas at that time, ensuring a significant reduction in methane emissions from these facilities. Due to the new, more stringent requirements of the Ordinance on Environmentally Compatible Storage of Waste from Human Settlements (Abfallablagerungsverordnung) and the Landfill Ordinance (Deponieverordnung), more than half of the landfills were closed by June 2005, meaning that only around 150 municipal waste landfills are currently still in operation. Since June 2005, it has also been illegal to landfill biodegradable waste, which means that waste that produces significant amounts of methane has not been landfilled since then. To comply with these requirements, municipal waste and other biodegradable waste must be pre-treated using thermal or mechanical-biological processes. Wastes landfilled since 2006 contain only very small amounts of waste with methane formation potential (e.g. treatment residues from mechanical biological treatment and low wood content from processed construction waste) and therefore contribute very little to landfill gas formation. As landfill gas formation in older landfills tapers off, methane emissions from landfills will again decrease significantly and stabilise at a very low level in the long term.

Figure 109: Changes in pathways for management of settlement waste since 1990



Source: own illustration, German Environment Agency
Source for 2024: Estimate based on previous year
Source: 1990: StatBA, Fachserie 19, Reihe 1.1, 1990, Table 4.1, (Statistisches Bundesamt, 1994)
Source for 1996-1998: StatBA, Fachserie 19, Reihe 1, 1996-1998, Table 4, (Statistisches Bundesamt, 2002)
Source for 2003: StatBA, Fachserie 19, Reihe 1, 2003, Table 1.2, (Statistisches Bundesamt, 2005)
Source from 2022 onward: StatBA, waste disposal: Germany, years, installation type – direct transmission to UBA

By reducing annual landfill methane emissions from around 1400 kt CH4 in the early 1990s to around 80 kt in 2023, Germany's waste management sector has made an important contribution to climate change mitigation. Experience gained by Germany's waste management sector shows that reductions of landfilled quantities of biodegradable waste can provide significantly higher contributions to climate change mitigation than collection and treatment of landfill gas.

7.2.1.2 Methodological issues (5.A.1)

The method presented in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* ((IPCC, 2006a): Chapter 3.2.1.1) for calculation of CH_4 emissions from landfills is based on the "first order decay" (FOD) method. The relevant detailed method used in Germany lies between Tier 2 and Tier 3. The Tier 3 method requires national activity data and country-specific values for DOC, DOC and half-lives (k values). Germany currently uses national activity data. To some extent, the DOC, DOC_F and k values it uses are country-specific values. The remaining values correspond to the default values of the IPCC Guidelines, but have also been confirmed as correct and valid for Germany in a research project.

The following section describes the FOD method and the relevant parameters used for determining methane formation in landfills. The FOD method uses the following equations:

Equation 94: (2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 3.2.1.1, Equation 3.6)

$$CH_4\ erzeugt\ im\ Jahr\ t\ \left(\frac{kt}{Jahr}\right) = DDOCm\ decomp_t\ \times F \times 16/12$$

where:

- CH_4 produced in year t = Quantity of CH_4 produced by biologically degradable waste
- DDOCm $decomp_T$ = Mass of degradable DOC degraded anaerobically in year T
- F = Fraction of CH_4 in landfill gas
- 16/12 = Stoichiometric factor for conversion of C to CH_4
- t = Inventory year

Within this system,

Equation 95: (2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 3.2.1.1, Equation 3.2)

$$DDOC_m = W \times DOC \times DOC_f \times MCF$$

where:

- DDOCm = Mass of the anaerobically biodegradable, deposited DOC, (kt)
- W = Mass of waste deposited, kt
- DOC = Share of biologically degradable organic carbon in the year of disposal (kt C/kt waste)
- DOCf = Share of DOC that is biologically degradable under anaerobic conditions
- MCF = Methane correction factor for the share of DOC that is biodegraded under aerobic conditions for year x

In western Germany (the former Federal Republic of Germany), only controlled landfill disposal of waste has been permitted by law since 1972. As part of German reunification, these standards were transferred to the new German federal states in 1989/90. The inventory calculation takes into account all waste disposed of since 1950, regardless of whether it is located in landfills that have already been decommissioned or are still in operation.

For the emission contributions of all waste landfilled between 1950 and 1972, an MCF of 0.6 is calculated (default value for unclassified landfills, see Chapter 7.2.1.2.3). For the period 1973-1989, the same MCF of 0.6 was used for the new German federal states, and an MCF of 1 was used for the old German federal states. For the emissions calculation in the inventory, data from this period were used to obtain a weighted MCF that reflects the various waste fraction's percentage contributions to the total for Germany as a whole. The emissions from waste landfilled since 1990 have been calculated with an MFC of 1.

Germany uses the IPCC Waste Model, which was developed on the basis of Equations 3.4 and 3.5 of the 2006 IPCC Guidelines (IPCC, 2006a). Using this approach, the total amount of degradable DOC in the landfills is calculated for each individual year in order to calculate the amount of DOC that is degraded to CH_4 and CO_2 each year:

Equation 96: (2006 IPCC Guidelines, Chapter 3.2.1.1, Equation)

$$DDOCma_t = DDOCmd_t + (DDOCma_{t-1} * e^{-k})$$

where:

- t = Inventory year
- DDOCmat = DDOCm accumulated in the landfill at the end of year t, kt
- $DDOCma_{t-1}$ = DDOCm accumulated in the landfill at the end of year t-1, kt
- $DDOCmd_t$ = DDOCm deposited in landfill in year t, kt
- K = Reaction constant - Decomposition rate (1/year) = $\ln(2)/t_{1/2}$ ($year^{-1}$)
- $t_{1/2}$ = Half-life (years)

Equation 97: (2006 IPCC Guidelines, Chapter 3.2.1.1, Equation 3.5)

$$DDOCmdecomp_t = DDOCma_{t-1} \times (1 - e^{-k})$$

where:

- t = Inventory year
- DDOC $decomp_t$ = DDOCm that decomposes in the landfill in year t, kt

A multi-phase model was used, which calculates different half-lives for the individual waste fractions and then adds them together.

From the final CH_4 emissions result, methane that is recovered and then flared or used for energy recovery is deducted, and a correction factor is applied that accounts for methane oxidation in landfill covering layers as shown by Equation 3.1 (IPCC, 2006a):

Equation 98: (2006 IPCC Guidelines, Chapter 3.2.1.1, Equation 3.1):

CH_4 emitted in year t (kt/Jahr) = (CH_4 produced in year t – R(t)) • (1- OX)

where:

- R(t) = CH_4 recorded in year t
- OX = Oxidation factor (fraction)

With the IPCC Waste Model, users can define a time period during which landfilled waste has not yet begun producing gas, i.e. a period of delay until gas formation begins. The 2006 IPCC Guidelines (IPCC, 2006a) recommend 6 months as a standard value for this delay period. As a result of discussions with national waste experts and on the basis of measurements of CH_4 formation following landfilling, a delay period value of 3 months was defined. This change has only a slight effect on emissions calculations.

For the calculation, the quantities of settlement waste (MSW_T), and the fraction of settlement waste that is landfilled (MSW_F), must be determined. For the FOD method, settlement waste production quantities have to be determined for the past few decades. Landfilled settlement

waste should be estimated according to the 2006 IPCC Guidelines (ibid.) differentiated by waste type, as the emissions calculations are based on the fact that the individual waste types have different DOC, DOC_f and k values.

7.2.1.2.1 Quantities of landfilled waste

The FOD model calculates emissions from landfilled settlement waste, landfilled industrial waste and landfilled sewage sludge.

The quantities of this landfilled waste are obtained from the statistics of the Federal Statistical Office. Data until the year 2018 were published by the Federal Statistical Office, in Fachserie 19, Reihe 1 (Statistisches Bundesamt, jährlich - FS 19, R. 1). After that year, publication of series FS 19, R1 was discontinued. The data for the period as of 2019 that are required for reporting are published by the Federal Statistical Office in GENESIS-Online and provided in parallel to the German Environment Agency in an unchanged table format for reporting purposes. For this purpose, a comprehensive survey is conducted, based on annual surveys of the type, origin and destination of waste and biennial surveys of certain equipment characteristics of the waste facilities surveyed. The activity data for the current report year in each case have to be estimated, since official waste statistics are published with a one-year time lag. Estimates are carried out by extrapolating from the data of the last two previous years. In each case, such estimates are replaced in the following year with the figures from survey statistics. Recalculations for the year prior to the past year thus have to be carried out on an annual basis.

The surveys of landfilled quantities of settlement waste in the old German federal states began in 1975 on the basis of the Environmental Statistics Act of 1974. Waste quantities for the period from 1950 to 1975 were derived on the basis of population data.

For the new German federal states, data on landfilled quantities of settlement waste, differentiated by federal state, are available for the years 1990 and 1993. For the 1980s in the former GDR, (Andreas, 2000) presented data that provide information about per-capita landfilled quantities of waste, waste composition, landfill types and types of waste storage. The per-capita quantities of landfilled waste in the former GDR, at 190 kg/person, were considerably lower than the corresponding quantities in the old German federal states (330 kg/person and year). The reason for this was that larger percentages of waste were recycled in the former GDR. In 1990, the year of reunification, the amount of waste sent to landfill in the new federal states rose sharply, with per capita figures even exceeding those in the old federal states. This was because, on the one hand, the existing recycling systems collapsed that year and, on the other hand, there was a flood of new products available, which led to high replacement purchases and a sharp increase in the amount of packaging waste. Since 1990, per-capita quantities of landfilled waste in both parts of Germany have slowly converged.

The inventory calculations include data, covering the entire period as of 1950 on landfilled sewage sludge quantities of the old and new German federal states (the former Federal Republic of Germany and the former GDR). No statistical data are available on landfilling in the new German federal states/the former GDR. The waste composition (including the sewage sludge fraction) was estimated on the basis of findings of a research project that in the 1990s studied waste inventories of GDR landfills.

In the former GDR, all non-recycled waste quantities were landfilled.

The quantities of industrial waste landfilled between 1975 and 1996 were derived on the basis of total quantities of landfilled waste. While the total quantities include industrial waste, the total waste figures are not broken down to show industrial waste separately. Since 1996, the

Federal Statistical Office has published differentiated data on landfilled industrial waste. The inventory takes account of the landfilled waste quantities from industrial sectors as follows:

- Waste from agriculture, horticulture, forestry, fisheries and food processing
- Waste from wood processing
- Waste from production of pulp, paper and cardboard
- Waste from the textile industry
- Packaging waste, absorbent and filtration materials, wiping cloths and protective clothing
- Wood fractions in construction and demolition waste (data since 1975)

Comparisons between waste production and production data for the sectors in question for the period 1996 to 2002 did not show any satisfactory statistical correlations. While production figures increased, waste production figures decreased – considerably, in part – as a result of changes in production processes. Due to the lack of statistical correlation, the quantities of wood from construction and demolition waste sent to landfill remained constant between 1950 and 1975. Changes in assumptions regarding industrial waste between 1950 and 1970 have only a very marginal effect on emissions in the base year.

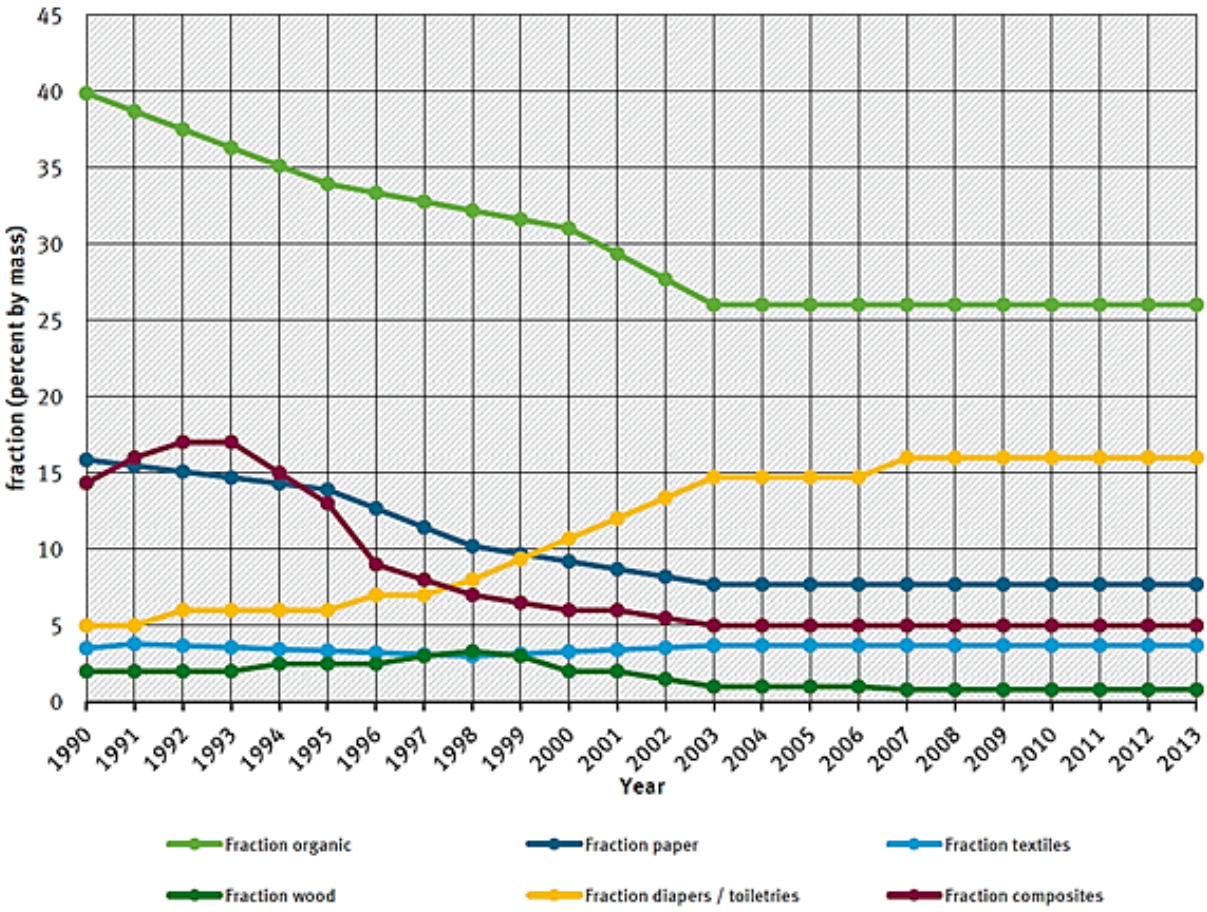
For the entire period as of 1950 and for all relevant types of waste, including sewage sludges, complete and seamless data series are thus available that are based on the best available sources for the various sub-periods concerned.

7.2.1.2.2 Waste composition

For the inventory calculations pursuant to the FOD method, landfilled waste has to be divided into the landfill waste fractions organic waste, garden and park waste, paper, wood, diapers and textiles, composite materials, sewage sludge and MBT output (cf. also Chapter 7.2.1.2 in this regard). To some extent, waste statistics include separate listings for these categories. However, these statistics also include landfilled quantities of mixed settlement waste that, for calculation purposes, have to be subdivided into the aforementioned fractions. To this end, numerous studies of the components of mixed settlement waste were evaluated with a view to determining the historical development of waste fractions (organic waste, garden and park waste, paper, wood, diapers and textiles, composite materials). In the years 1980 and 1985, mixed waste compositions were determined for the entire territory of the former Federal Republic of Germany (Barghorn et al., 1986; Greiner et al., 1983). For the subsequent period, there are a large number of studies on individual cities, counties or federal states, some of which have already been evaluated and summarised in comprehensive studies. Evaluation of these studies made it possible to prepare waste composition time series for household waste, household waste-like commercial waste and bulky waste (which are listed separately in national statistics) for the period from 1980 to 2013 (cf. Figure 110). In 2014, existing evaluations of waste composition studies were reviewed and six additional, more recent studies of residual waste composition in the period 2006 through 2013 were evaluated. These more recent studies confirmed existing assumptions regarding the composition of mixed waste fractions and thus the data were carried forward for the period as of 2014 without change. As a result of the legal changes described above, landfilling of untreated mixed settlement waste has decreased sharply since 2005 (from 5.8 million tonnes in 2004 to 2,000 tonnes in 2013). For this reason, the exact composition of residual waste for the period from 2005 onwards is also less relevant.

For waste composition in the new German federal states, the figures provided by (Andreas, 2000) for the 1980s in the former GDR were adopted (composition of household waste: 28% vegetable waste, 14% paper/paperboard, 2.3% wood, rubber, composites, 3% textiles; household waste accounted for only 16% of total landfilled waste quantities, however). Quantities of settlement waste landfilled in the former GDR contain smaller fractions of biodegradable materials and large inorganic fractions (primarily ash from household combustion systems). Food waste was collected and used as feed; feed tended to be scarce during certain periods of time. Paper was collected and was also a scarce resource. Wood and paper were often burned in ovens for the purposes of heating and cooking. The SERO recycling system efficiently collected the country's relatively small fractions of plastic packaging. Glass was included in deposit systems and was also collected. Overall, the former GDR's economy was subject to scarce resources, which led to efficient waste recycling.

Figure 110: Trends in household waste composition between 1990 and 2013



Source: own illustration, German Environment Agency

The waste quantities stored in landfills are recorded by the Federal Statistical Office in terms of separate fractions based on waste codes. For the emissions calculation, all waste types that can contribute to landfill gas formation are taken into account, and each waste type is separately assessed in terms of its waste composition. Table 429 shows the waste types that are relevant for landfill gas formation (wood fractions of construction and demolition waste are taken into account). The recorded quantities of landfill gas are based on official statistical data.

Since 1 June 2005, only waste with a total carbon content ≤ 3% and mechanically and biologically treated settlement waste can be landfilled in Germany. Since that time, landfilled

waste quantities have decreased very sharply and now make only very small contributions to gas formation. Table 429 outlines the development of quantities of landfilled biodegradable waste. No data is yet available for the current inventory year, which is why the development of waste quantities and compositions for the last two years is extrapolated on a linear basis and recalculated for the following year.

Table 429: Quantities of biodegradable waste landfilled, by waste fraction, in [kt]

Waste fraction	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024
Organic fraction	16844	7515	3202	813	6	1	1	4	0	0	0
Garden and park waste	0	0	54	26	0	0	0	0	0	0	0
Paper	9095	4372	1421	426	7	1	5	12	10	8	7
Wood	2658	1889	1037	238	0	0	0	69	0	0	0
Diapers + textiles	3572	2082	2241	519	5	2	1	10	2	1	1
Composite materials	5587	2644	621	155	1	0	0	0	0	0	0
Sewage sludge	2494	1024	452	634	27	81	29	49	62	37	37
Output from MBT facilities	0	0	370	1170	991	714	505	466	430	398	366

In 2011/12, the residual gas emissions from landfill storage of mechanically and biologically treated waste were quantified in an expert assessment (Stegmann, 2012). The assessment confirmed the low emissions contributions from landfilling of MBT waste that had been determined in emissions calculations, thereby confirming the national values used in calculating emissions. The mechanical-biological (waste) treatment (MBT) process is described in Chapter 7.6.1.

In line with the recommendations provided in the 2010 inventory review (paragraph 146, (UNFCCC, 2010a), additional information has been provided since the 2011 report. Table 430 shows the landfilled quantities of settlement waste, and Table 431 shows the total quantities of settlement waste – in each case, per capita and day – for the period as of 1990.

Landfilling of settlement waste has decreased sharply in Germany since 2005, since almost all of this waste is now managed in incineration systems (waste incineration systems or co-combustion in industrial combustion systems) and in mechanical-biological treatment (MBT) facilities. This trend is reflected in the per-capita quantities of settlement waste that are landfilled. At the same time, the quantities of settlement waste produced per capita have remained constant, however.

Table 430: Per-capita quantities of landfilled settlement waste, in [kg/capita/day]

1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024
1.60	0.85	0.55	0.18	0.04	0.03	0.02	0.03	0.02	0.02	0.02

Table 431: Per-capita quantities of produced settlement waste, in [kg/capita/day]

1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024
NA	1.71	1.78	1.57	1.68	1.72	1.68	1.70	1.61	1.62	1.63

7.2.1.2.3 MCF (methane correction factor)

Until the first Waste Management Act was introduced in 1972, waste in the Federal Republic of Germany was mostly disposed of in unregulated landfills, which were closed after 1972. After 1972, waste was stored in managed landfills. For the old German federal states, a default MCF value of 0.6 is therefore used for "unclassified landfills" ("nicht zugeordnete Deponien") for the period through 1972 (Chapter 3.2.3 (IPCC, 2006a). After 1972, the default value for regulated anaerobic landfills – 1 – is used.

Data are available from a 1989 survey of the territory of the former GDR that covered 120 managed landfills, around 1,000 regulated storage sites and around 10,000 unregulated dumps ((Institut für Umweltschutz, 1990): p. 56, Table 12). Consequently, for the territory of the former GDR, an MCF of 0.6 (default value for unclassified landfills) was assumed for the period 1950 through 1989; Chapter 3.2.3, (IPCC, 2006a). Upon German reunification, the Federal Republic of Germany's waste laws were extended to the territory of the new German federal states, and transitional regulations were introduced to ensure that facilities – including both decommissioned operational facilities where waste was or is generated or disposed of were recorded and that the necessary remediation measures were initiated ((BMU, 1990); p. 46). Unregulated landfills were closed in 1990, facilities permitted to remain open were secured, remediated and modernised/expanded in accordance with the standards of German waste law, and sites for new facilities were sought.

As of 1990, the Federal Statistical Office has collected statistics on both parts of Germany. For the calculation for the period after 1990, an MCF of 1 (default value for unregulated anaerobic landfills) is used for all of Germany's territory. Experts of the German Environment Agency consider the IPCC default value for regulated anaerobic landfills to be a suitable value for landfills in Germany.

7.2.1.2.4 DOC

Both national data and IPCC default factors are used for DOC, the proportion of degradable organic carbon in waste. All DOC values refer to wet waste, since the statistical data for waste quantities landfilled in Germany are collected on wet waste. Table 432 provides an overview of the DOC values used.

Based on review results from the ARR 2015/2016 and 2018, Germany made intensive efforts to identify the sources for the data reported in Chapter Table 432:

- For garden and park waste, paper and paperboard, wood and straw, and textiles and diapers, IPCC default values are used (Table 2.4, Chap. 2.3. 1(IPCC, 2006a). For this waste, no sufficiently reliable national values are available. The default values are seen as realistic in terms of order of magnitude by experts of the Öko-Institut Institute for Applied Ecology and of the German Environment Agency.
- Until the 2022 report, a national value of 18% was used for the DOC for the organic fraction (Wallmann, 1999). More recent studies of landfills; (Stegmann et al., 2023) pp. 172 - 173) have shown that the default value of 15% correlates better with actual landfill gas formation. Since the 2023 report, calculations have therefore been carried out with a DOC of 15%.
- The Guidelines provide no default values for composite materials. In the context of a research project for preparation of the ICR 2010, the relevant national value was estimated by the research contractor (Öko-Institut) at 10%. During the ICR, that value was accepted by the responsible IPCC expert.

- For sewage sludge, the 2006 IPCC Guidelines (Chap. (IPCC, 2006a)2.3.2, provide a default DOC of 50% for dry matter. From the 1980s until 2005, virtually all of the sewage sludge that was landfilled was mechanically dewatered sludge with an average dry matter content of about 30%. From this average DM content of landfilled municipal and industrial sewage sludge, and the default value for dry sewage sludge, an average DOC value of 15% was derived.
- The Guidelines provide no default values for mechanically and biologically treated waste (MBT waste). A study commissioned by the German Environment Agency (Stegmann, 2012) found that mechanical-biological treatment greatly reduces the DOC content of waste. Following this treatment, a landfill fraction contains less than 10% of the DOC content (as a percentage) it originally had prior to treatment. MBT facilities treat the entire range of residual settlement waste and household waste-like commercial waste. The average DOC of this waste is estimated at 23%. The national DOC value for landfilled MBT waste, 2.3%, is the value that remains, on average, following a 90% reduction as a result of treatment.

Recent research results ((Stegmann et al., 2023), pp. 172 - 173) largely confirm the DOC values used; an adjustment is recommended only for the DOC value for the organic fraction (see above).

Table 432: DOC values used

Fraction	DOC values			Source
	IPPC 2006 Default (wet waste)	Used		
		until the 2022 NIR	from the 2023 NIR onwards	
Organic fraction	15%	18%	15%	(Wallmann, 1999) (Stegmann et al., 2023), p. 172 - 173)
Garden and park waste	20%	20%		Table 2.4, Chap. 2.3.1, (IPCC, 2006a)
Paper and paperboard	40%	40%		Table 2.4, Chap. 2.3.1, (IPCC, 2006a)
Wood and straw	43%	43%		Table 2.4, Chap. 2.3.1, (IPCC, 2006a)
Textiles	24%	24%		Table 2.4, Chap. 2.3.1, (IPCC, 2006a)
Diapers	24%	24%		Table 2.4, Chap. 2.3.1, (IPCC, 2006a)
Composite materials	NA	10%		In-Country Review, 2010 (Öko-Institut)
Sewage sludge	50% (dry)	15%		Calculated from IPCC default for sewage sludge, based on dry matter
Waste from MBT facilities	NA	2.3%		National value; (Stegmann, 2012)

7.2.1.2.5 DOC_f

Up to and including the 2022 reporting period, DOC_f, the DOC fraction that can be converted to landfill gas, was assumed to be 50% for all waste fractions. This value was within the IPCC defaults(Chapter 3.2.3, (IPCC, 2006a)).

The DOC_f for the wood and straw fraction was adjusted to the default value of 0.1 from the 2019 refinement of the IPCC Guidelines (IPCC, 2019) in the 2023 report. Studies conducted in Germany have also confirmed this value (Stegmann et al., 2023). Consequently, the biological

availability and carbon degradation under anaerobic environmental conditions are so low that the DOC_f value for wood (straw quantities are less important in relation to landfilling) had to be decreased from 50% to 10% (Stegmann et al., 2023), p. 26). The study confirmed the DOC_f for the organic fraction and for garden and park waste, paper and paperboard, textiles, diapers, composite materials, sewage sludge and MBT waste

Table 433: DOC_f values used

Fraction	DOC_f values		Source
	IPPC 2006 Default (wet waste)	National value used	
Organic fraction	0.5	0.5	(Wallmann, 1999)(Wallmann, 1999)(Wallmann, 1999) (Stegmann et al., 2023), p. 172 - 173)
Garden and park waste	0.5	0.5	Chap. 3.2.3, (IPCC, 2006a) and (Stegmann et al., 2023), p. 172 - 173)
Paper and paperboard	0.5	0.5	Chap. 3.2.3, (IPCC, 2006a) and (Stegmann et al., 2023), p. 172 - 173)
Wood and straw	0.5	0.1	(Stegmann et al., 2023), p. 172 - 173)
Textiles	0.5	0.5	Chap. 3.2.3, (IPCC, 2006a) and (Stegmann et al., 2023), p. 172 - 173)
Diapers	0.5	0.5	Chap. 3.2.3, (IPCC, 2006a) and (Stegmann et al., 2023), p. 172 - 173)
Composite materials	0.5	0.5	Chap. 3.2.3, (IPCC, 2006a) and (Stegmann et al., 2023), p. 172 - 173)
Sewage sludge	0.5	0.5	Chap. 3.2.3, (IPCC, 2006a) and (Stegmann et al., 2023), p. 172 - 173)
Waste from MBT facilities	0.5	0.5	Chap. 3.2.3, (IPCC, 2006a) and (Stegmann et al., 2023), p. 172 - 173)

7.2.1.2.6 F = Fraction of CH_4 in landfill gas formed

To calculate methane formation, the IPCC default value for F of 50% is used for the entire time series. This refers to the proportion of methane in landfill gas, i.e. in the gas that is formed when organic carbon is broken down anaerobically. On average, 60% of the biogas from residual waste decomposition facilities consists of methane. This high methane content is due to the fact that the water content in the bioreactor is very high and that some of the CO_2 produced during decomposition dissolves in the water, causing the methane content in the gas phase to rise. Since the water content in an average landfill site is much lower than in a regulated process in a bioreactor, the methane fraction F must be adjusted downwards slightly. Experts therefore regard 50% as plausible. F should not be confused with the methane fraction in extracted landfill gas. This changes over time due to external influences, e.g. the input of ambient air into the landfill body (cf. Table 435).

7.2.1.2.7 Half-life

The calculation model is a multi-phase model that takes into account the different half-lives and the resulting k values (decomposition rates) of the various waste fractions. Table 434 shows the half-lives and the decomposition rates (k value) used for the waste fractions. To comply with the recommendations in the 2010 inventory review (paragraph 146, FCCC/ARR/2010/DEU), additional information has been provided for reporting since 2011. The constant half-life that

characterises a first-order reaction – and, thus, the FOD method used in this context – corresponds to the time required for the degradable organic carbon in the waste ($DDOC_m$) to decompose to half its initial mass. The mathematical relationship between the half-life and the decomposition rate is shown in the following equation.

Equation 99: (2006 IPCC Guidelines)

$$k = ln\,2 / t_{1/2}$$

For the 2023 report and on the basis of recent studies and evaluations, the half-lives and resulting k values for the paper/paperboard and wood fractions were adjusted (Stegmann et al., 2023), Chapter 8.3, p. 145). As a result, the paper fraction in the landfill generally biodegraded much faster than the default half-life of 12 years would suggest. Numerous studies of landfills in Germany have confirmed that landfill bodies contain much less paper than would be calculated based on an assumed half-life of 12 years. To adapt to the conditions observed in the landfill body, the half-life for paper was reduced from 12 to 7 years, which means a change in the k value from 0.058 to 0.099 (Stegmann et al., 2023).

Exploratory drilling and digging at landfills as well as laboratory studies have shown that the wood fraction hardly decomposes at all under anaerobic conditions. This is especially true when large pieces of wood are involved that are not accessible for microorganisms. According to recent findings and to supplementary laboratory studies, biodegradation of wood takes considerably longer than expected given the existing half-life of 23 years. Wood degrades very slowly – if at all – in anaerobic environments. For this reason, the relevant half-life was increased from 23 years to 50 years, which corresponds to a change in the k value from 0.030 to 0.014 (Stegmann et al., 2023).

For the calculation, the IPCC default values are used for organic waste (food waste), garden/park waste, textiles/diapers and sewage sludge for the entire time series. For composite materials and waste from mechanical-biological treatment (MBT facilities), national values are used, since the Guidelines provide no default values. Research projects (Stegmann et al., 2023) confirm these national values. Due to mathematical inaccuracies between half-lives and k values (for organic matter and sewage sludge) in the IPCC guidelines (both 2006 and 2019 refinements), there are slight differences between a calculation of methane formation based on k values and half-lives – the German approach was confirmed as correct in ARR 2022.

Table 434: Half-lives and decomposition rates of waste fractions

	Half-life (years)			Decomposition rate (k value)		
		National value			National value	
	IPCC default*	until the 2022 NIR	from the 2023 NIR onwards	IPCC Default*	until the 2022 NIR	From the 2023 NIR onwards
Organic fraction	4	**4**		0185	**0.173**	
Green waste/park waste	7	**7**		0.1	**0.099**	
Paper/paperboard	12	12	**7**	0.06	0.058	**0.099**
Wood	23	23	**50**	0.030	0.030	**0.013**
Textiles/diapers	12	**12**		0.06	**0.058**	

	Half-life (years)		Decomposition rate (k value)	
Composite materials	--	**12**	---	**0.058**
Sewage sludge	4	**4**	0.185	**0.173**
Waste from MBT facilities	--	**12**	--	**0.058**

* for temperate, wet climate zones

7.2.1.2.8 Landfill gas use

The "TA Siedlungsabfall" of 1993[98] made gas collection one of the prerequisites for licensing of landfills for settlement waste. The amended version of the Environmental Statistics Act (UStatG) of 2005 mandates that in future the Federal Statistical Office must take account of and publish levels of landfill gas collection in its surveys. For the years 2004, 2006 and 2008, only data on landfill gas collection and use in the landfilling and decommissioning phases were published in the Fachserie 19 of 12 July 2012. Data on gas collection for the entire landfill stock (excluding historical deposits, which are regulated by the Federal Soil Protection Act), i.e. including landfills in the post-closure phase, were collected for the first time for the year 2010. To calculate the quantities of landfill gas collected, the Federal Statistical Office collects data on the volume of landfill gas collected and the methane content in vol.%. The collected quantities of methane are calculated from these data for purposes of climate reporting in the NIR.

In recent years, the methane concentrations in collected landfill gas (Table 435) have decreased. Presumably, these decreases are due to oxidation effects in landfill bodies in which atmospheric oxygen is drawn in as a result of degassing. Also, the unintended intake in of atmospheric nitrogen dilutes the flow of extracted gas. These two effects are mutually reinforcing as the formation of gas decreases.

Table 435: Methane fraction in collected landfill gas

	2006	2008	2010	2012	2014	2016	2018	2020	2022
Landfilling and decommissioning phase	50%	49%	48%	48%	47%	45%	42%	41%	39%
Post-closure phase	NA	NA	42%	40%	38%	32%	32%	32%	27%

Source: (Statistisches Bundesamt, 2-Jährig)

In Germany, landfill operators are subject to monitoring obligations under the Landfill Ordinance (Deponieverordnung) that require them to measure collected quantities of landfill gas and the methane concentrations in the gas and to document these measurements in annual reports. The resulting data are then collected by the Federal Statistical Office at two-year intervals on the basis of the Environmental Statistics Act (Umweltstatistikgesetz).
For this reason, at least since 2010, it has not been necessary to recalculate the collected landfill gas from energy data.

Until the year 2010, total quantities of collected landfill gas were determined by combining data from the energy sector and from Fachserie 19 as a result of the above-described data gaps.

The quantities of collected methane listed in Table 436 include both the landfill gas quantities used for energy generation and those flared off.

[98] Technical instructions on recycling, treatment and other management of settlement waste (Third general administrative provision on the Waste Act (Abfallgesetz)) of 14 May 1993

Table 436: Methane collected from landfills, in kilotonnes [kt]

	Methane formation	COLLECTED METHANE QUANTITY			Collection rate in %
		Landfilling and decommissioning phase	Post-closure phase	Total quantity	
1990	1567			91	5.8
1991	1662			101	6.1
1992	1709			111	6.5
1993	1714			120	7.0
1994	1685			129	7.7
1995	1640			138	8.4
1996	1581			150	9.5
1997	1507			206	13.6
1998	1423			221	15.5
1999	1343			222	16.6
2000	1265			223	17.6
2001	1183			221	18.7
2002	1109			218	19.7
2003	1035			215	20.8
2004	965	236	11	247	25.6
2005	897			247	27.6
2006	818	231	11	242	29.6
2007	735			220	30.0
2008	662	190	11	201	30.4
2009	597			191	32.0
2010	539	171	11	181	33.6
2011	487			167	34.3
2012	441	140	14	154	35.0
2013	401			143	35.9
2014	364	121	13	134	36.8
2015	332			126	37.9
2016	303	107	11	118	39.0
2017	277			107	38.6
2018	253	85	12	97	38.2
2019	232			96	41.4
2020	213	84	11	95	44.6
2021	196			89	45.6
2022	181	72	12	84	46.6
2023	167			79	47.6
2024	154	-	-	75	48.6

Source: (Statistisches Bundesamt, jährlich - FS 19, R. 1)

The data include gaps, since official statistical data are available only for certain individual years; these gaps were closed via interpolation/extrapolation and qualified estimates.

For the years up to and including 1998, gas collection rate percentages from earlier estimates continued to be used (for sources and data derivation, see NIR (UBA et al., 2012)), and the

amount of methane collected was calculated from methane formation and the respective collection rate percentage.

For the years 1999 through 2003, the collection rate percentages were interpolated from the values for 1998 (old method) and 2004. The recovered quantities of methane were calculated from the total methane formation and the respective recovery rate percentage.

For the years 2004, 2006 and 2008, the Federal Statistical Office only has figures for the decommissioning phase. To determine the total amount of methane collected from all landfills, the methane quantities from landfills in the post-closure phase determined for 2010 were added to the annual values for the landfilling and decommissioning phases for 2004, 2006 and 2008.

For the even years as of 2010, the Federal Statistical Office has complete data on landfill gas collection from all landfills. Since the Federal Statistical Office carries out data collection only every other year, the landfill gas collection rates (percentages) were interpolated between the previous and subsequent years, and the collected gas quantities were calculated from the gas formation and the collection rate (percentage). For the current year, the collection rate percentage is usually extrapolated from the last two years. The figures are then recalculated as soon as the underlying statistics are updated.

7.2.1.2.9 Flares

In 2022, a total of 84 Gg methane was collected, together with landfill gas. Of that quantity, a fraction of about 27 Gg, which was not suitable for energy-related use, was burned off in flares. In Germany, landfill gas flares are subject to very stringent requirements under the Technical Instructions on Air Quality Control (TA-Luft): Combustion in an insulated high-temperature flare, dwell time at least 0.3 seconds at a combustion temperature of over 1000°C. Landfill gas flares therefore achieve nearly complete combustion and have correspondingly low methane emissions. Manufacturers of these flares guarantee a combustion efficiency greater than 99.9%. In the assessment of experts of the German Environment Agency, formation of N_2O in the combustion process is not expected due to the high temperatures involved, and the emissions of nitrogen occur under these reaction conditions as NO and NO_2.

Since the greenhouse gas emissions from the category landfill gas flares in 5.A account for less than 0.05% of the total inventory (without LULUCF) and since they do not exceed 500 kt CO_2 equivalents (significance thresholds pursuant to FCCC/SBSTA/2013/L.29/Add.1) and since annual recording cannot be assured (in accordance with FCCC/SBSTA/2013/L.29/Add.1, para 37), these emissions are therefore not reported (IPCC, 2006a). A one-time quantitative estimation of the emissions from landfill gas flares that are thus not being included in the inventory yields a figure of around 0.75 kt CO_2 equivalent. In addition, a compilation of all sources listed as *not estimated* is provided in Chapter 1.7.2 of this report.

7.2.1.2.10 Oxidation factor

As to the factor determining the proportion of CH_4 that is oxidised in landfill covering layers, the IPCC default value of 0.1 was adopted for the entire time series. Experts of the German Environment Agency consider the IPCC default value for the oxidation factor to be realistic in terms of its order of magnitude

7.2.1.2.11 Methane emissions

Methane emissions from landfills have decreased sharply in Germany since the early 1990s. Recyclable waste had to be increasingly separated and non-recyclable residual waste had to be treated thermally or mechanically-biologically before disposal in landfills. For this reason,

landfilling of biologically degradable waste has continually decreased; since 2005, landfilling of this type of waste has no longer been permitted.

7.2.1.3 Uncertainties and time series consistency (5.A.1)

Over the long, 30-year period covered by the activity data, inconsistencies in the time series are unavoidable, since the waste categories and survey methods changed several times as a result of improvements in legislation and waste statistics. In Germany, particular problems arise mainly as a result of German reunification and the merging of two different economic and statistical systems. For this reason, considerable effort has to be invested in reviewing data consistency and allocations to the reported categories, in the interest of making time series as consistent as possible.

Uncertainties for the selected methane formation parameters

Based on the extensive country-specific evaluations and the adjustment of the parameters for methane formation, the uncertainties regarding gas formation can be estimated as follows (Stegmann et al., 2023), Chapter 9, p. 183):

- Uncertainties related to DOC_f:
- ± 20% for default values; ± 10% after adjustment of values
- Uncertainties related to methane formation potential of DDOCM
- ± 20% for default values; up to -40% for wood, depending on the type of wood
- Uncertainties related to MCF = 1 for the Federal Republic of Germany after 1972 and for the entire national territory as of 1990:38% -38%, +0%
- Uncertainties related to MCF = 0.6 for the Federal Republic of Germany until 1972 and for the entire national territory until 1989: ±25%
- Uncertainties related to the methane fraction in landfill gas F = 0.5: +30%, -0%
- Uncertainties related to k value:
  - Organic fraction (food waste) and sewage sludge: +25%, -0%
  - Paper and paperboard: +45%, -0%
  - Wood and straw: +45%, -0%
  - Textiles, disposable nappies/diapers, composite materials: +40%, -0%

According to a qualified estimate by experts of the German Environment Agency, the uncertainties for the total methane emissions from landfills amount to ± 20%.

7.2.1.4 Category-specific QA/QC and verification (5.A.1)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

For verification of the results, the implied emission factors (IEFs) derived in the GHG locator were compared with those of other countries. An international comparison of 2022 reporting shows that Germany had the second-highest value, 0.47. This comparatively high figure can be explained by the sharp decline in the amount of biodegradable waste landfilled since the 1990s

and by gas formation, which is almost entirely from waste landfilled before (cf. Chapter 7.2.1.2.2).

Internationally, landfilling of biologically degradable waste is still widely practised. Very few countries have reduced landfilling of biologically degradable waste to the extent that Germany has. At about the same time that Germany introduced legislation on waste, Austria and Switzerland adopted similar laws. Austria and Japan rank third and fourth respectively in the IEF comparison and have relatively high values similar to Germany at 0.28 and 0.20 respectively.

7.2.1.5 Category-specific recalculations (5.A.1)

Because the Federal Statistical Office's waste statistics are published with a one-year time lag for data on quantities and compositions of landfilled waste and because data on collected quantities of landfill gas are collected at two-year intervals, recalculations have to be carried out annually for the year prior to the previous year. In addition, the data for the current report year have to be estimated. In the following year, the data estimated this way are replaced with the latest official data.

Table 437: Recalculation: methane formation in landfills [kt]

Year	2023
2026 NID	166.857
2025 NID	166.839

Table 438: Recalculated methane emissions from landfills, in kilotonnes [kt]

Year	2023
2026 NID	78.710
2025 NID	80.183

7.2.1.6 Category-specific planned improvements (5.A.1)

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in Table 468 in Chapter 10.4. Improvements that have been completed are listed in Table 467 in the same chapter. No additional improvements are planned at present.

7.3 Biological treatment of solid waste (5.B)

In category 5.B, emissions from composting systems (5.B.1) and digestion of biowaste in biogas plants (5.B.2) are reported. Both facility types in category 5.B treat separately collected biowaste and produce compost or digestates that are used in the agricultural or horticultural sectors. This is the difference with regard to the mechanical-biological treatment covered in category 5.E. Those facilities handle mixed settlement waste (residual waste). The residues from those facilities are either landfilled or incinerated.

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
-/T	5 B, Biological Treatment of Solid Waste		CH_4	59.39	0.01	918.33	0.13	1446.32
-/-/2	5 B, Biological Treatment of Solid Waste		N_2O	19.67	0.01	194.29	0.03	887.61

The category "Biological treatment of solid waste" is a key category for CH_4 emissions in terms of trend, and a key category for N_2O emissions pursuant to Approach 2 trend analysis.

7.3.1 Composting facilities (5.B.1)

7.3.1.1 Category description (5.B.1)

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 2	NS	CS
N_2O	Tier 2	NS	CS

In the Federal Republic of Germany, biodegradable waste is separately collected and treated. The emissions reported under 5.B.1 originate in composting facilities that primarily compost biowaste separately collected from households, along with garden and park waste Compost that is produced from this waste is used in either agriculture or horticulture.

In addition to centralised composting of separately collected organic waste, there is also private composting in people's own gardens (home composting). For this area, no reliable data are available on the relevant quantities and the emissions produced. For this reason, we do not report on these emissions.

7.3.1.2 Methodological issues (5.B.1)

Nitrous oxide and methane emissions from composting of kitchen and green waste are reported in accordance with the 2006 IPCC Guidelines (IPCC, 2006a). However, we use our own national emission factors, which were obtained via a research project (Cuhls et al., 2015).

The methane and nitrous oxide emissions are calculated in accordance with the following formula:

$$E = M * EF$$

- E = Emissions in kg
- M = Mass of biowaste [kt]
- EF = Emission factor [kg/kt]

Activity data

Since 1980, the Federal Statistical Office has regularly collected and published data, in various forms on waste quantities managed in composting facilities ((Statistisches Bundesamt, 2-Jährig), GENESIS-Online, Table 32111-0003)[99]. For this purpose, a comprehensive survey of waste treatment facilities is carried out. Currently, the quantities of biowaste treated in composting systems are calculated by adding the waste quantities on the lines "biowaste composting systems" ("Bioabfallkompostierungsanlagen"), "garden-waste composting systems" ("Grünabfallkompostierungsanlagen") and "sewage sludge composting systems" ("Klärschlammkompostierungsanlagen"). Also, the waste fraction that is composted in "other biological treatment facilities" is calculated and added to the above results. For this calculation, the percentage share of the compost produced in these systems in relation to the total output of

[99] https://www-genesis.destatis.de/genesis//online?operation=table&code=32111-0003&bypass=true&levelindex=0&levelid=1630573034654#abreadcrumb

"other biological treatment facilities" (compost and digestates) listed in Table 7.3 (Federal Statistical Office, direct data transfer), is applied to the input waste quantity.

In the years 1990 through 2005, statistical surveys of waste quantities were less detailed than they are today. In addition, they were not always carried out the same way or at different yearly intervals. For this reason, individual values had to be interpolated differently in some cases or extrapolated into the past.

The activity data for the current report year have to be estimated, since official waste statistics are published with a two-year time lag. For this reason, the total amount of waste used in composting plants is extrapolated based on the trend of previous years and replaced by the statistically collected figure in the following year. Recalculations are thus required annually. Prior to deciding on this approach, the effects of this extrapolation method were also assessed when applied separately to each type of treatment facility. Because the trends are unclear, fluctuations – wide fluctuations, in some cases – can occur in the calculated activity data. Where they occur, experts do not consider them valid. If, on the other hand, only the total amount of waste is extrapolated, this produces a value which, according to expert estimates, is likely to be closer to the expected future value.

Emission factors

Emission factors for composting of biowaste were determined as part of a research project (Cuhls et al., 2015). As part of this project, emissions measurements were carried out at 19 composting plants for methane, nitrous oxide and ammonia. Aggregated emission factors for the facility inventory in Germany were derived from the measurement results and the results of literature research. The factors take account both of the different facility technologies used in Germany and of the different types of biowaste used as input materials. In individual facilities, very high emissions measurements resulted, and thus the average value is very high. At most facilities several different measurement phases were carried out to take account of different atmospheric/meteorological conditions (summer/winter) and to rule out the possibility that such conditions were the reason for especially high or low values. As part of a peer review (research contractor, the German Environment Agency and experts), the very high measurements were identified as outliers and classified as non-representative. For this reason, it was agreed with the research contractor (Cuhls et al.) to use the median values as the emission factors. All measured emission values were included in the derivation of the median values. The process of deriving the EFs began with determination of individual EFs for each different treatment technology. Each treatment technology was then weighted according to the amount of waste treated in the relevant facilities in Germany (Cuhls et al., 2015), and the various EFs were combined with the currently used EFs using the weighting factors determined. The following table from (Cuhls et al., 2015) shows the various treatment technologies' shares of biowaste management in Germany.

Table 439: Various waste treatment technologies' shares of biowaste management in Germany

Method:	KOA g	KOA g	KOA tg	KOA sM	KOA o	KOA o	VA	VA + NR g	VA + NR o	Total
Input:	Bio + Grün	Bio + Grün	Bio + Grün	Bio + Grün	Bio + Grün	Grün	Bio + Grün	Bio + Grün	Bio + Grün	
Product	FrischK	FertigK	FertigK	FertigK	FertigK	FertigK	Gärprod.	Gärprod. FertigK	Gärprod. FertigK	
	Millions of Mg/a	Millions of Mg/a	Millions of Mg/a	Millions of Mg/a	Millions of Mg/a	Millions of Mg/a	Millions of Mg/a	Millions of Mg/a	Millions of Mg/a	Millions of Mg/a

Method:	KOA g	KOA g	KOA tg	KOA sM	KOA o	KOA o	VA	VA + NR g	VA + NR o	Total
Amount of waste	2.00	0.95	0.63	0.13	1.47	2.40	0.17	0.60	0.26	8.61
Share	23.2%	11.0%	7.3%	1.5%	17.1%	27.9%	2.0%	7.0%	3.0%	100%
Recovered waste	Total KOA: 7.58						Total VA: 1.03			KOA + VA 8,61
Share of total	88%						12%			100%
Products	1.20	0.38	0.25	0.06	0.59	1.20	0.17	0.24	0.10	4.19
Share	28.6%	9.0%	6.0%	1.4%	14.1%	28.7%	4.1%	5.7%	2.4%	100%

Source: Annual quantities of managed biowaste and green waste and of compost and digestate products produced in millions of Mg, based on the input material in its delivered state ((Cuhls et al., 2015); Table 5-1, p. 75)

The abbreviations have the following meanings:

KOAg = composting plant closed (in vessel)

KOAo = composting plant open

KOAtg = composting plant partly closed

KOAsM = composting plant with semipermeable membrane

VA = digestion plant

VA + NRg = digestion plant with closed post composting of the digestate

VA + NRo = digestion plant with open post composting of the digestate

Input Bio = biowaste from households

Input Grün = green waste

FrischK = fresh compost

FertigK = mature compost

Gärprod. = digestate

Gärprod. FertigK = post composted digestate

The following table shows the various composting methods and their average emission factors.

Table 440: Comparison of the average emission factors of various composting methods

	Emission factors					CO_2-eq. (AR4)
	Total C g/Mg	CH_4 g/Mg	NMVOC g/Mg	NH_3 g/Mg	N_2O g/Mg	kg/Mg
[1] Delivery and processing (Anl + Aufb)						
Value range (min - max)	47 - 290	18 - 240	34 - 150	3.8 - 7.4	1.4 - 31	0.86 - 15
Mean	170	140	86	5.6	14	7.6
Median	170	150	78	5.6	12	7.1
Number of sample facilities	2	2	2	1	2	2
Number of measurement phases	4	4	4	2	4	4
[2] Closed composting systems (fresh compost) (KOA g (FrischK))						
Value range (min - max)	110 - 1,200	150 - 1,500	2.5 - 110	15 - 120	18 - 200	9.2 - 88
Mean	470	630	49	60	87	42
Median	440	450	56	42	79	35
Number of sample facilities	4	4	4	3	4	4
Number of measurement phases	7	7	7	5	7	7

	Emission factors					CO_2-eq. (AR4)
	Total C	CH_4	NMVOC	NH_3	N_2O	
	g/Mg	g/Mg	g/Mg	g/Mg	g/Mg	kg/Mg
[3] Closed composting systems (mature compost) (KOA g (FertigK))						
Value range (min - max)	30 - 9,300	50 - 11,000	0.65 - 1,100	3.4 - 93	7.7 - 300	5.6 - 360
Mean	2,300	2,500	390	32	77	86
Median	690	790	95	15	41	36
Number of sample facilities	3	3	3	3	3	3
Number of measurement phases	6	6	6	4	6	6
[4] Partly closed composting systems (mature compost) (KOA g (FertigK))						
Value range (min - max)	720 - 4,400	830 - 4,800	100 - 750	16 - 61	43 - 150	38 - 170
Mean	2,800	3,000	470	38	92	100
Median	1,000	1,200	140	23	62	54
Number of sample facilities	4	4	4	3	4	4
Number of measurement phases	7	7	7	5	7	7
[5] Composting facilities with semipermeable membranes (KOA sM)						
Value range (min - max)	250 - 770	200 - 500	100 - 400	5 - 50	10 - 50	8.0 - 27
Mean	530	300	300	10	16	12
Median	530	300	300	10	16	12
Number of sample facilities	1	1	1	1	1	1
Number of measurement phases	1	1	1	1	1	1
[6] Open composting facilities that handle biowaste and park/green waste (KOA o (Bio+Grün))						
Value range (min - max)	740 - 4,800	730 - 5,500	190 - 690	12 - 1,400	2.1 - 270	30 - 150
Mean	2,400	2,700	370	450	79	91
Median	1,700	1,800	370	370	53	97
Number of sample facilities	5	5	5	5	5	5
Number of measurement phases	11	11	11	11	11	11
[7] Open composting facilities that handle park/green waste (KOA o (Bio+Grün))						
Value range (min - max)	610 - 9,500	540 - 12,000	200 - 500	1.1 - 340	17 - 60	19 - 300
Mean	3,700	4,300	490	170	31	120
Median	2,300	2,400	490	170	24	73
Number of sample facilities	4	4	4	3	4	4
Number of measurement phases	4	4	4	3	4	4

Source: Derivation of emission factors, and determination of CO_2 equivalents for digestion plants as a function of the waste treatment technology used – Emission factors during the treatment process ((Cuhls et al., 2015); Table 5-2, p. 81)

The following emission factors were determined for composting of biowaste (Cuhls et al., 2015), p. 136; page 142 in the English version):

$EF\text{-}CH_4$ = 1,400 g CH_4/t biowaste

$EF\text{-}N_2O$ = 49 g N_2O/t biowaste

It should be noted that the study's findings included the result that C and N content levels do not play a relevant role in the emissions of CH_4 and N_2O. At the beginning of the study, green waste and kitchen waste were considered separately due to their different C and N content levels. However, the study found that neither of the two content levels is a relevant emissions driver. The conditions under which waste is treated are the most important factor driving emissions from composting systems. And aeration and temperature are the key factors with regard to formation of CH_4 and N_2O during the composting process. Moisture concentrations also play a role. Consequently, the research project differentiates not between the different types of waste, but between the different types of treatment technologies. In simple composting plants without forced aeration, kitchen waste cannot be treated on its own due to its high moisture content and low content of structure-forming components. The waste that is composted in these facilities usually consists of green waste (garden and park waste) – or mixtures of this waste and small fractions of kitchen waste. Kitchen waste, on the other hand, is usually composted in closed systems with forced aeration.

Following a change in reporting procedures in 2023, national emission factors now only include emissions from treatment in composting plants. Since this change, the emissions that occur in connection with spreading of compost are reported in categories 3.D.a.2.c and 3.D.b. This change addresses review result A.8 (Table 5, 2020 ARR), which had led to multiple discussions between the responsible experts in the areas of agriculture and composting. As a result, it was decided that emissions from spreading compost should be reported from a technical perspective in agriculture and not in composting. The emission factor for methane does not change as a result of this shift, as methane emissions during and after compost spreading are generally negligible. As described above, the new emission factor for nitrous oxide applies only for treatment. It is considerably lower than the previously used factor, which also included spreading of compost. Emissions from the storage of compost on the premises of the treatment facility are included in the emission factors used here.

Pursuant to Cuhls et al., the N_2O emission factor for composting biowaste amounts to 49 g N_2O/t biowaste, which is slightly below the range of the IPCC default factor, 60 - 600 g. The default factor for composting is 300 g N_2O/t biowaste (Vol. 5, Chap. 4.1.3.1

7.3.1.3 Uncertainties and time series consistency (5.B.1)

Activity data

The uncertainties for the composted waste quantities (2%) are considered to be very low, since the quantities are based on an exhaustive survey.

Emission factors

The uncertainties for the emission factors are high. They depend on the type of facility/plant in question, on waste composition and on the effectiveness of the biofilters used. The figures provided in the literature and by other countries vary widely. The uncertainties were determined on the basis of the measurement results of the aforementioned research project ((Cuhls et al., 2015), p. 120), from which a log normal distribution can be derived. The following uncertainties were determined: for CH_4, +272% to -87%; for N_2O, +123.5% to -64%.

7.3.1.4 Category-specific QA/QC and verification (5.B.1)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

The activity data are based on figures from federal waste statistics. More comprehensive or accurate data is not available.

The emission factors were determined on the basis of an evaluation of the available literature, as well as on the basis of measurements. A literature review conducted by (Oonk & Lambert, 2017) also failed to yield any recent data on emissions from biowaste treatment facilities and confirmed the emission factors used by Germany. A survey carried out for 2025 emissions reporting showed that there currently seem to be no more recent studies on emission factors.

The emission factor used for methane, at 1.4 g CH_4/kg waste, is lower than the default value of 4 g. However, it lies within the range for that value, 0.03 to 8 g CH_4/kg waste. In addition, the emission factor used for nitrous oxide, at 0.049 g N_2O/kg waste, is also lower than the default value, 0.3 g, and it lies slightly below the range for the default value, 0.06 to 0.6 g N_2O/kg waste. An important reason why the emission factor is lower is that treatment facilities in Germany have high technical standards (active ventilation, temperature monitoring and control, regular turning of compost heaps).

For the same reason, the IEFs for CH_4 and N_2O lie well within the lower third of the ranges for reporting countries (GHG Locator 2023). The IEF for methane is of the same order of magnitude as the values for Italy and for Belgium and the Netherlands. The IEF for nitrous oxide is the lowest of the values of the reporting countries. The reasons for this were explained in the previous paragraph.

A comparison of the emission factors used (cf. Table 441) with technologically comparable countries (Austria, Belgium, Switzerland and Italy) carried out for the 2022 reporting shows that the German CH_4 EF is in the middle range. For nitrous oxide, the EF is somewhat lower, but still of the same order of magnitude as those of Belgium and Switzerland.

Table 441: Comparison of emission factors for composting, in [g/t]

	Germany	Austria	Belgium	Switzerland	Italy
Methane CH_4	1,400	1,820	750	1,840	1,630
Nitrous oxide N_2O	49	250	100	90	600

Source: For Germany, current submission; for other countries, the 2020 report (UNFCCC, 2020)

7.3.1.5 Category-specific recalculations (5.B.1)

In each case, when the inventory data for the current year are prepared, the most recent available statistical data on input quantities of waste are the data for the previous report year; the Federal Statistical Office's waste statistics are published with a two-year time lag. For this reason, the current report year is extrapolated as described above. This extrapolation is replaced in the following year by the data collected statistically at that time. For this reason, annual recalculations for the previous year are necessary. The volume of composted waste in 2023 was slightly lower than in the previous year. However, the decline was not as significant as estimated in the previous report. As a result, the emissions are slightly higher in 2023 than reported last year. At the same time, due to policy measures, biowaste quantities are increasingly shifting away from pure composting towards digestion with the extraction of

biogas. This resulted in a significant increase in the volume of waste in the 5.B.2 organic waste fermentation plant in 2023.

Table 442: Recalculations in CRF 5.B.1 for the year 2023

Description	Units	submission	2023
Waste quantities managed in composting systems (TOTAL)	[kt]	2026	8,115
		2025	7,948
CH_4 emissions	[t]	2026	11,361
		2025	11,128
N_2O emissions	[t]	2026	398
		2025	389

7.3.1.6 Category-specific planned improvements (5.B.1)

No improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

7.3.2 Digestion plants (5.B.2)

7.3.2.1 Category description (5.B.2)

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 2	NS	CS
N_2O	Tier 2	NS	CS

In the Federal Republic of Germany, biodegradable waste is collected and treated separately. The emissions reported under 5.B.2 come from biowaste digestion plants that primarily digest separately collected biowaste from households, food waste from cafeterias and restaurants and biowaste from food production and processing. They do not include emissions from the digestion of sewage sludge. In some biowaste digestion plants, manure (especially slurry) is also digested. The relevant quantities are removed from the calculation of the input waste, however, since their emissions are already included in CRF category 3 B.

Digestion processes are specifically used to produce biogas and thus to generate an energy source (in contrast to composting). For this reason, most of the biogas produced this way is collected and used for energy generation, and only a small fraction is flared off. Both gas quantities are measured directly at the plants and recorded for statistical purposes at two-year intervals. The results are shown in the annual waste statistics (Statistisches Bundesamt, direct data transfer, Table 1.5). Methane emissions from combustion of biogas for energy generation are reported in the section for the energy sector in 1.A.1.a.

The resulting digestates are used in either agriculture or horticulture. Digestion of biowaste in biogas plants has been statistically recorded only since 1999 (Statistisches Bundesamt, ibid.). However, reports have indicated since 1998, based on expert estimates, that the activity data for that year were half as large as those for 1999. In previous years, organic waste digestion was

virtually negligible, but has since gained in importance. Since the 2015 NIR, the inventory therefore now also reports on biowaste digestion in biogas plants in accordance with the 2006 IPCC Guidelines.

7.3.2.2 Methodological issues (5.B.2)

Nitrous oxide and methane emissions from the digestion of biowaste are reported in accordance with the 2006 IPCC Guidelines. However, we use our own national emission factors, which were obtained in a research project (Cuhls et al., 2015).

The methane and nitrous oxide emissions are calculated in accordance with the following formula:

$$EM = M \times EF$$

where:

- EM = Emissions in kg
- M = Mass of biowaste [kt]
- EF = Emission factor [kg/kt]

The quantities of gas from biowaste digestion that are used for energy generation and the gas quantities that are flared off are also reported; since 2004, these data have been directly recorded in waste statistics at two-year intervals (Statistisches Bundesamt, direct data transfer, Table 1.5).

Activity data

Since 1999, the Federal Statistical Office has regularly collected and published data, in various forms on waste quantities managed in biowaste digestion plants ((Statistisches Bundesamt, 2-Jährig), GENESIS-Online, Table 32111-0003)[100]. For this purpose, a comprehensive survey of waste treatment facilities is conducted. Currently, the quantities of biowaste treated in digesting systems are calculated by adding the lines “biogas and digesting plants” (“Biogas- und Vergärungsanlagen”) and “combined composting and digestion plants” (“Kombinierte Kompostierungs- und Vergärungsanlagen”). Also, the waste fraction that is digested in “other biological treatment facilities” is calculated and added to the above results. For this calculation, the percentage share of the digestates produced in these plants in the total output of “other biological treatment plants” (compost and digestates) from Table 7.3 (Federal Statistical Office, direct data transmission) is used and applied to the amount of waste used

Any quantities of manure (especially slurry) that goes into these biowaste digestion plants are deducted from the total quantities of waste in these plants, since such manure (and slurry) is already included in CRF category 3B. The quantity recorded in the waste statistics under waste code 020106 is deducted from the total quantity here. This approach, which is designed to prevent double counting, was coordinated with the experts responsible for category 3.

In the years 1990 through 2005, statistical surveys of waste quantities were less detailed than they are today nor were they always carried out the same way or at the same yearly intervals.

[100] https://www-genesis.destatis.de/genesis//online?operation=table&code=32111-0003&bypass=true&levelindex=0&levelid=1630573034654#abreadcrumb

For this reason, individual values had to be interpolated differently in some cases or extrapolated into the past.

The activity data for the current report year have to be estimated, since official waste statistics are published with a two-year time lag. For this reason, the total quantity of waste input into digesting systems is extrapolated based on the trend of previous years and replaced by the figure collected for statistical purposes in the following year. A similar procedure is carried out for the quantities of gas that are collected and flared off. Recalculations are thus required annually.

Prior to deciding on this approach, the effects of this extrapolation method were also assessed when applied separately to each type of treatment facility. As a result, unclear trends can lead to significant fluctuations in the calculated activity data, which are classified as invalid from an expert perspective. If, on the other hand, the total amount of waste is extrapolated, this produces a value which, according to expert estimates, is likely to be closer to the expected future value.

Emission factors

Emission factors for digestion of biowaste were determined as part of a research project (Cuhls et al., 2015). In this project, emissions measurements, covering methane, nitrous oxide and ammonia were carried out at 16 digesters. Aggregated emission factors for the facility inventory in Germany were derived from the measurement results and the results of literature research. The factors take account both of the different facility technologies used in Germany and of the different types of biowaste used as input materials. In individual facilities, very high emissions measurements resulted, and thus the average value is very high. At most facilities several different measurement phases were carried out to take account of different atmospheric/meteorological conditions (summer/winter) and to rule out the possibility that such conditions were the reason for especially high or low values. As part of a peer review (research contractor, the German Environment Agency and experts), the very high measurements were identified as outliers and classified as non-representative. For this reason, it was agreed with the research contractor (Cuhls et al., 2015) to use the median values as the emission factors. All measured emission values were included in the derivation of the median values. The EFs themselves were derived by first determining EFs for each treatment technology. Each treatment technology was then weighted according to the amount of waste treated in the relevant facilities in Germany (Cuhls et al., 2015), and the various EFs were combined with the currently used EFs using the weighting factors determined. The following table from (Cuhls et al., 2015) shows the various treatment technologies' shares of biowaste management in Germany.

Table 443: Various waste treatment technologies' shares of biowaste management in Germany

Method:	KOA g	KOA g	KOA tg	KOA sM	KOA o	KOA o	VA	VA + NR g	VA + NR o	Total
Input:	Bio + Grün	Bio + Grün	Bio + Grün	Bio + Grün	Bio + Grün	Grün	Bio + Grün	Bio + Grün	Bio + Grün	
Product	FrischK	FertigK	FertigK	FertigK	FertigK	FertigK	Gärprod.	Gärprod. FertigK	Gärprod. FertigK	
	Millions of Mg/a	Millions of Mg/a	Millions of Mg/a	Millions of Mg/a	Millions of Mg/a	Millions of Mg/a	Millions of Mg/a	Millions of Mg/a	Millions of Mg/a	Millions of Mg/a
Amount of waste	2.00	0.95	0.63	0.13	1.47	2.40	0.17	0.60	0.26	8.61

Method:	KOA g	KOA g	KOA tg	KOA sM	KOA o	KOA o	VA	VA + NR g	VA + NR o	Total
Share	23.2%	11.0%	7.3%	1.5%	17.1%	27.9%	2.0%	7.0%	3.0%	100%
Waste managed	Total KOA: 7.58						Total VA: 1.03			KOA + VA 8,61
Share of total	88%						12%			100%
Products	1.20	0.38	0.25	0.06	0.59	1.20	0.17	0.24	0.10	4.19
Share	28.6%	9.0%	6.0%	1.4%	14.1%	28.7%	4.1%	5.7%	2.4%	100%

Source: Annual quantities of managed biowaste and green waste and of compost and digestate products produced in millions of Mg, based on the input material in its delivered state ((Cuhls et al., 2015); Table 5-1, p. 75)

The abbreviations have the following meanings:

- KOAg = composting plant closed (in vessel)
- KOAo = composting plant open
- KOAtg = composting plant partly closed
- KOAsM = composting plant with semipermeable membrane
- VA = digestion plant
- VA + NRg = digestion plant with closed post composting of the digestate
- VA + NRo = digestion plant with open post composting of the digestate
- Input Bio = biowaste from households
- Input Grün = green waste
- FrischK = fresh compost
- FertigK = mature compost
- Gärprod. = digestate
- Gärprod. FertigK = post composted digestate

The following table shows the various digestion techniques and their average emission factors.

Table 444: Comparison of the average emission factors of various composting methods

	Emission factors					CO2-eq.
	Total C g/Mg	CH4 g/Mg	NMVOC g/Mg	NH3 g/Mg	N2O g/Mg	(AR4) kg/Mg
[8] Digestion plants (VA)						
Value range (min - max)	60 - 3,800	63 - 3,200	0 - 1,700	2.6 - 10,000	0.84 - 69	1.8 - 90
Mean	900	910	230	780	15	27
Median	520	460	98	18	9.7	16
Number of sample facilities	12	12	12	12	12	12

	Emission factors					CO2-eq.
Number of measurement phases	19	19	18	16	19	19
[9] Digestion plants with closed post-rotting process (VA + NR g)						
Value range (min - max)	260 - 4,800	190 - 5,600	16 - 850	20 - 600	25 - 350	20 - 230
Mean	2,300	2,600	340	140	66	84
Median	1,800	2,000	320	76	43	67
Number of sample facilities	6	6	6	6	6	6
Number of measurement phases	13	14	13	13	14	14
[10] Digestion plants with open post-rotting process (VA + NR o)						
Value range (min - max)	1,600 - 14,000	2,100 - 16,000	14 - 2,200	31 - 2,300	21 - 170	57 - 430
Mean	6,100	7,400	510	480	75	210
Median	5,100	6,200	360	86	74	190
Digestion plants (VA):						
Number of sample facilities	11	11	11	11	11	11
Number of measurement phases	17	17	16	14	17	17
Open post-rotting of digestates (NR o):						
Number of sample facilities	3	3	3	3	3	3
Number of measurement phases	6	6	6	6	6	6

Source: Derivation of emission factors and determination of CO_3 equivalents for digestion plants as a function of the waste treatment technology used – Emission factors during the treatment process ((Cuhls et al., 2015); Table 5-2, p. 82)

The following emission factors were determined for digestion of biowaste (Cuhls et al., 2015), p. 136; page 142 in the English version):

$EF\text{-}CH_4$ = 2,800 g CH_4/t biowaste

$EF\text{-}N_2O$ = 45 g N_2O/ t biowaste

Following a transition in the framework of the 2023 report, the national emission factors now contain only the emissions from treatment in digesting systems. Since that transition, the emissions that occur in connection with spreading of digestates are reported in categories 3.D.a.2.c and 3.D.b. This change addresses review result A.8 (Table 5, 2020 ARR), which had led to multiple discussions between the responsible experts in the areas of agriculture and digestion. As a result of those discussions, it was decided that, from a technical standpoint, emissions from spreading of digestates should be reported in the agricultural sector, and not under digestion per se. The emission factor for methane has not changed as a result of this change, since the methane emissions that occur during and after spreading of digestates are generally negligible. As described above, the new emission factor for nitrous oxide applies only for treatment. It is considerably lower than the previously used factor, which also included spreading of digestates. Emissions from storage of liquid and composted digestates on the premises of the treatment facility are included in the emission factors used here. Pursuant to

Cuhls et al., the N_2O emission factor for anaerobic digestion of biowaste amounts to a total of 45 g N_2O/t biowaste.

The IPCC provides no N_2O default factor for anaerobic digestion as it is assumed that N_2O emissions are negligible.

Information on emissions from the digestion of energy crops and manure in the agricultural sector is provided in chapters 5.1.3.6.5 (category 3.B) and 5.1.4(categories 3.D and 3.J).

7.3.2.3 Uncertainties and time series consistency (5.B.2)

Activity data

The uncertainties for the waste quantities treated in digestion plants are considered to be very low (2%), since the quantities are based on an exhaustive survey. This also applies to the statistical data collected on the gas quantities from biowaste digestion facilities that are used and on those that are flared off.

Emission factors

The uncertainties for the emission factors are high. They depend on the type of facility/plant in question, on waste composition and on the effectiveness of the biofilters used. The figures provided in the literature and by other countries vary widely. The uncertainties were determined on the basis of the measurement results of the aforementioned research project ((Cuhls et al., 2015), p. 120), from which a log normal distribution can be derived. The following uncertainties were determined: for CH_4, +179% to -76%; for N_2O, +185.5% to -77%.

7.3.2.4 Category-specific QA/QC and verification (5.B.2)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

The activity data consist of figures from federal waste statistics. More comprehensive or accurate data is not available.

The emission factors were determined on the basis of an evaluation of the relevant available literature, as well as on the basis of measurements. A literature review conducted by Oonk and Lambert (2017) also failed to yield any recent data on emissions from biowaste treatment facilities and confirmed the emission factors used by Germany. A survey carried out for the 2025 emissions reporting showed that there currently seem to be no more recent studies on emission factors.

The emission factors for methane and nitrous oxide that were determined in the research project include both anaerobic treatment of biowaste and aerobic final composting of digestates. For this reason, the value used for methane, at 2.8 g CH_4/kg waste, is considerably higher than the default value of 1 g CH_4/kg waste. However, it does lie within the range for that value, 0 to 8 g CH_4/kg waste. The Guidelines provide no emission factor for nitrous oxide – presumably because they consider only the relevant anaerobic process.

A comparison of the CH_4 IEF (GHG Locator) with the IPCC default values shows that the former is considerably larger than the latter. This is because, according to the IEF calculation routine specified in the CRF, the IEF is calculated as follows: IEF = (CH_4 emissions + CH 4 recovered + CH_4 flared off)/annual quantity of waste in digestion plants. However, the CH_4 emissions figure, which is relevant for the GHG calculation, is based almost entirely on emissions that occur during treatment. The data on quantities of CH_4 that are recovered and flared off are almost irrelevant for the emission calculation, since they are used for energy generation or are

negligibly low. This means that the CRF's IEF calculation method is misleading, or at least unhelpful for comparing countries, as countries that do not capture and flare CH_4 at all achieve the EF defaults. Countries that collect CH_4 and use it for energy generation do not achieve the default values. They exceed them by far, since the recovered and flared-off quantities of CH_4 naturally far exceeds the amount of CH_4 emitted diffusely. This assessment is confirmed by a look at the IEFs of the reporting countries (GHG Locator 2023) – the values span an extremely wide range and are impossible to compare.

A comparison of German emission factors for methane emissions from biowaste digestate plants with technologically comparable countries (Italy and Portugal) carried out for the 2022 report shows that, with emission factors of 2,000 g per tonne of biowaste, these are slightly below the value of 2,800 g per tonne used in Germany.

None of the countries reports on nitrous oxide emissions from digestion plants.

Table 445: Comparison of emission factors for digestion, in [g/t]

	Germany	Italy	Portugal
Methane CH_4	2,800 (5.7%)	2,000	2,000
Nitrous oxide N_2O	45	-	-

Source: For Germany, current submission; for other countries, the 2022 submission (UNFCCC, 2020)

7.3.2.5 Category-specific recalculations (5.B.2)

In each case, when the inventory data for the current year are prepared, the most recent available statistical data on input quantities of waste are the data for the previous report year; the Federal Statistical Office's waste statistics are published with a two-year time lag. For this reason, the current report year is extrapolated, as described above. This extrapolation is replaced in the following year by the data collected statistically at that time. For this reason, annual recalculations for the previous year are necessary. This year's recalculation led to a slight reduction in the waste quantities undergoing digestion – and, consequently, to slightly lower GHG emissions. The upward trend in biowaste digestion was therefore not quite as pronounced as had been assumed in the previous report. Due to political measures to improve separate collection, a further increase in the volume of biowaste is to be expected in the future. Furthermore, it can be assumed that the separately collected organic waste will increasingly be treated in digestion plants and less in pure composting plants.

Table 446: Recalculations in CRF 5.B.2 for the year 2023

Description	Units	Submission	2023
Waste quantities managed in biogas and digestion plants (TOTAL)	[kt]	2026	7,262
		2025	7,416
CH_4 emissions	[t]	2026	20,333
		2025	20,765
N_2O emissions	[t]	2026	327
		2025	334

7.3.2.6 Category-specific planned improvements (5.B.2)

No improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

7.4 Waste incineration (5.C)

In Germany, plant-based waste incineration either involves complete energy use or is classified as cremation. In order to prevent double counting, the emissions that occur during waste incineration with energy use are reported in the energy section (CRF 1.A.1.a, Chapter 3.2.4). In 5.C, only emissions of NO_X, SO_2, CO and NMVOC from crematoriums (facilities) and NO_X, SO_2, CO and NMVOC from celebratory bonfires (open burning) are reported.

7.4.1 Crematoriums

Gas	Method used	Source for the activity data	Emission factors used
NO_x, SO_2, CO, NMVOC	Tier 1	AS	D

The data on cremations are calculated from figures of the Federal association of German funeral homes (Bundesverband Deutscher Bestatter e.V.) and from the official death rates for Germany (Statistisches Bundesamt, 2025d). Due to the overall decline in mortality rates in 2024, with the percentage of cremations remaining constant (BDB, 2025) and thus a slight decrease in absolute numbers (cf. Table 447), emissions are also reported to be slightly lower. Since the CRT Reporter requires the units “kt” to be used for the activity data, the CRT tables contain a calculated figure. To show due respect, the calculation is not described in detail here, but is carried out in a similar way to other publications.

The following figures provide an overview of the actual numbers of cremations involved:

Table 447: Calculated number of cremations in Germany, in [1000]

1990	1995	2000	2005	2010	2015	2020	2024
169	316	328	365	427	574	710	762

Source: Own calculations

No recalculations were required for the activity data.

No greenhouse gas emissions were calculated, but the precursor substances NO_X, SO_2, CO and NMVOC are taken into account. The EFs from the EMEP Guidebook are used to calculate these emissions (EMEP/EEA Guidebook 2023, 2023). Changes were made to the EFs for Pb, Cd, PCB and Hg, but not in relation to greenhouse gas emissions.

7.4.2 Celebratory bonfires and similar open burning

Gas	Method used	Source for the activity data	Emission factors used
NO_x, SO_2, CO, NMVOC	Tier 1	M, Q	D

The open burning of wood and green waste for traditional purposes, such as Easter bonfires, produces biogenic carbon dioxide emissions as well as NO_X, SO_2, CO and NMVOC emissions.

The number of celebratory bonfires was determined in a project carried out by experts (Wagner & Steinmetzer, 2018) with surveys of municipalities and statistical extrapolations for Germany for the year 2016. Based on the expert opinion, a downward trend is assumed for the entire period in question.

Unlike campfires, which tend to be used in private settings, Easter bonfires take place in more public settings. The calculations are considered separately and the campfires are modelled with a steady decline. The Easter fires follow an approach based on general percentage reductions and additional deductions in line with current developments (e.g. high risk of forest fires, increased activity again since 2022).

No recalculations were required.

No further improvements are planned at present.

7.5 Wastewater handling (5.D)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
L/T	5 D 1, Domestic Wastewater	0	CH_4	3725.66	0.29	926.91	0.14	-75.12
-/T	5 D 1, Domestic Wastewater	0	N_2O	515.78	0.04	1131.75	0.16	119.42
-/-	5 D 2, Industrial Wastewater	0	CH_4	10.36	0.01	56.61	0.01	446.30
-/-	5 D 2, Industrial Wastewater	0	N_2O	28.09	0.01	24.01	0.01	0.00

The category Wastewater treatment – domestic wastewater is a key category for CH_4 emissions in terms of level and trend, and a key category for N_2O emissions in terms of trend. Due to the sharp decline in emissions since 1990 and the resulting very low emission levels, the Single National Entity has decided, for reasons of resource prioritisation, not to implement the more stringent methodological requirements for this category that are required for the key categories.

7.5.1 Domestic wastewater handling (5.D.1)

Approximately 97% of municipal wastewater in Germany is discharged through public sewer systems, based on the number of connected inhabitants. Approximately 99% of the wastewater derived this way (based on the population) is treated in centralised wastewater treatment plants – the small remaining amount is treated in industrial or foreign centralised wastewater treatment plants. The remaining 3% of the population are served by other types of wastewater treatment systems (small wastewater treatment plants, cesspools and septic tanks). All of the aforementioned forms of wastewater treatment (centralised wastewater treatment plants, small wastewater treatment plants, cesspools and septic tanks) fall under municipal wastewater treatment. In addition to domestic wastewater, municipal wastewater treatment plants also treat indirect discharges of industry and commerce (amounting to about 30% of wastewater, with respect to the connected numbers of inhabitants or population equivalents) and precipitation water from mixed sewer systems.

Most of the municipal wastewater treatment plants in Germany use the activated sludge process. Also, about 97% of the wastewater produced in Germany is treated in plants that are equipped with denitrification systems. In most cases, the primary sludge produced in pre-clarification and the excess sludge resulting from the activated sludge process are either stabilised in digestion

towers located on site or are moved to be stabilised at other wastewater treatment plants. These towers are designed to produce sewage gas, which is used for energy generation. The resulting sewage sludge is usually dried and then incinerated – ideally, for the purpose of recovering valuable raw materials such as phosphorous. The use of sewage sludge in soil, mostly in agriculture, is declining. In 2023, 1.63 million tonnes of sewage sludge were disposed of, of which 81% was incinerated and 13% was used as fertiliser (material recycling in agriculture) (see Table 452).

According to the IPCC Guidelines, the relevant greenhouse gases for municipal wastewater treatment are methane and nitrous oxide. Sludge treatment was identified as the main source of methane, while the activated sludge process was identified as the main source of nitrous oxide. However, there is scope to improve the availability of data both nationally and internationally for these areas.

Only a very small share of Germany's total emissions comes from municipal wastewater treatment. The sector's emissions show a decreasing trend. With respect to the year 1990, the sector's emissions (CO_2 equivalents) have decreased by approx. 52%. In the view of the German Environment Agency, this is mainly due to an increase in the connection rate to municipal wastewater treatment and the abolition of open sludge digestion. With the 2024 GHG inventory report, the share of nitrous oxide emissions in total emissions rose significantly in the current years as a result of an adjustment to the associated emission factors, while it fell significantly in the base year. As a result, total emissions in this category fell from an initial level of approximately 75% in 1990 to the figure above. The downward trend remains, albeit somewhat less sharply.

Until 1990, Germany was divided into the Federal Republic of Germany and the German Democratic Republic. The special circumstances arising from this division and the differences between the two countries are described in the relevant sections of this report.

7.5.1.1 Methane emissions from municipal wastewater treatment (5.D.1 domestic wastewater handling)

7.5.1.1.1 Category description (5.D.1 wastewater handling)

Gas	Method used	Source for the activity data	Emission factors used
CH_4	D/CS	NS	D/CS
N_2O	D/CS	NS	D/CS

The category "Wastewater treatment – Domestic wastewater handling" is a key category for CO_4 emissions in terms of trend.

The wastewater from 97% of Germany's population is treated in centralised municipal wastewater treatment plants (Statistisches Bundesamt, 2024b). This produces methane through anaerobic metabolic processes within the wastewater treatment system. All process steps in wastewater treatment are likely to contribute to emissions, but sludge digestion and digested sludge storage account for the largest share. Depending on the technical degree of sludge digestion and the storage time, emissions may also occur during the storage of digested sludge. With well-digested sludge (e.g. with a good technical degradation rate in digestion of approx. 95%), further methane emissions are low. That is why, in terms of reduction, it is crucial to increase the degree of degradation during digestion as much as possible. This also significantly

reduces the potential for further methane emissions in the process stages that follow sludge digestion, i.e. thickening, sludge storage tanks and dewatering (DWA, 2022).

The other wastewater is treated in small wastewater treatment plants or is collected, for later transport to wastewater treatment plants, in cesspools or septic tanks with no drainage. In cesspools and septic tanks, processes (partly aerobic, partly anaerobic) can occur that lead to methane formation.

The organic loads discharged into cesspools and septic tanks have decreased since 1990, since the rate of connection to wastewater treatment plants has continually increased during this period as a result of requirements imposed by the EU Urban Waste-Water Treatment Directive (cf. Art. 3 & 7 of 91/271/EEC, (BML, 1991)).

Until the early 1990s, open sludge digestion was used for sludge stabilisation in the German federal states of the former GDR. Following a period of gradual reduction, open sludge digestion was completely pin 1994 phased out (cf. Chapter 7.5.1.2.1). As a result, this sector's CH_4 emissions show a sharply decreasing trend.

7.5.1.1.2 Methodological issues (5.D.1 Domestic wastewater handling)

Equation 6.1 (IPCC (2006a): Vol. 5, Chapter 6.2.2.) recommended by the IPCC for calculating CH4 emissions from municipal wastewater is not applicable in Germany, as explained below. Of the *fractions of the population (U_i)* presented in Table 6.5 of the IPCC Guidelines (ibid.), two groups (*rural and urban-high*) contribute to emissions. In addition, the primary and secondary sludge is used to generate CH_4 in digestion towers. The methane produced is captured, which means that the total amount of CH_4 produced is far higher than the CH_4 emissions calculated using Equation 6.1, and therefore the value calculated using the IPCC equation would also be negative. In addition, sewage sludge is used (usually in thermal utilisation or, depending on the location, in agriculture or landscaping) only after the sewage gas from it has been recovered, i.e. after it has been fully digested. For this reason, it cannot be referred to as "*sludge removed*" as defined in the Guidelines, since the sewage sludge is already fully digested and no longer has any BOD5 (cf. also Chapter 7.5.1.2.1). Furthermore, the data available in Germany on the numbers of people connected to cesspools and septic tanks are much more precise than the values for U_i and $T_{i,j}$ (*degree of utilisation of treatment system*) that can be derived with Table 6.5 of the IPCC Guidelines. All in all, the 2006 Guidelines method is too limited to be suitable for the actual situation in Germany. For the reasons described above, the IPCC method from 1996 is used instead of the IPCC equation from 2006, although it has been supplemented to meet the requirements of the IPCC Guidelines from 2006.

Until the 2023 NIR, the calculation of methane emissions from wastewater treatment plants was based on a limited number of measurements from Becker et al. (2012). An emission factor of 0.26 kg methane per year and inhabitant can be derived from the data in this publication. The study covered only a very limited number of measurements. For this reason, the resulting EF was more a result of sampling than it was a representative emission factor. On the basis of international publications, an emission factor of 0.5 kg of methane per year and inhabitant was derived (the derivation is unpublished to date) that, in light of current data, adequately reflects the situation in Germany. Due to the limited comparability of measurements taken at individual plants and the different sampling and detection methods used, a high degree of uncertainty is to be expected.

By far the largest share of wastewater in Germany is treated with the same treatment goals and, in terms of biological wastewater treatment, with largely the same equipment in municipal

wastewater treatment plants. The above-mentioned emission factor is therefore applied to all wastewater treatment plants.

As virtually all inhabitants (approx. 97%) in Germany are connected to one of the approx. 8,700 wastewater treatment plants (Statistisches Bundesamt, 2024a) as of 2022, the total population is used as the activity rate. Because the total population figure is used in the calculation and because small wastewater treatment plants and cesspools and septic tanks are taken into account, the result may safely be considered conservative. Any emission factor for small wastewater treatment plants would probably be lower, because these plants lack sludge treatment. While wastewater from cesspools and septic tanks is taken to municipal wastewater treatment plants – meaning that it also has to be considered here – this wastewater is already partly digested by the time it reaches such treatment plants. This results in an overlap between the emission values from wastewater treatment plants and cesspools and septic tanks, which cannot be quantified precisely due to a lack of data. However, the relevance of this overlap is very low and therefore negligible. The trend in emission factors since 1990 is based on a technical paper (Grün et al., 2013) whose specific observations for the *"Emscher System"* (North Rhine – Westphalia) have been generalised and, on the basis of expert estimates by the authors of the study, classified as representative for Germany as a whole. This is considered plausible due to the very similar state of wastewater treatment technology and plant management at municipal wastewater treatment plants. The technical article assumes, primarily on the basis of a consideration of sludge digestion and preliminary sedimentation, that emissions will be cut in half as a result of improvements in plant technology and plant management in the period 1990 through 2020. According to (Becker et al., 2012), 90% of the methane emissions in this area are emitted from sludge treatment. Consequently, the described trend can also be applied to methane emissions. It must be noted that this development was derived solely from the aforementioned improvements to wastewater treatment plants (such as optimised operational management); it does not take account of the specific emissions reductions resulting from conversions of previously open sewer systems in the Emscher catchment basin. This means that the special aspects of the Emscher systems (in comparison to the average German wastewater treatment plants) is not included in the trend analysis. For calculation of the individual emission factors for the years as of 1990, the above-mentioned emission factor for the year 2011 is used as a fixed starting value. The publications considered refer to measurements that were carried out between 2007 and 2019. Most of the measurements were carried out in the period 2010-2013. It was therefore decided to leave the base value at the 2011 level. The emission factor for 1990 is determined using a linear equation and the assumption that the value for 2020 is half the value for 1990. The emission factors for the other years can be determined using linear interpolation. As of 2020, the emission factor used, 0.385 kg per year and inhabitant, is carried forward as it is not considered realistic to expect endless improvement through plant optimisation based on the aforementioned study. Because the calculation method described here that is used to determine the emission factor for emissions from wastewater treatment plants makes use of real measurements, there is no reason to apply a methane conversion factor (MCF).

The organic load of cesspools is determined in accordance with the IPCC method by multiplying the number of people connected to cesspools (P) by the average organic load per inhabitant. The average daily organic load is assumed to be 60 g BOD_5 per inhabitant (Gujer, 2006). This is the specific value for Germany, but it is also used as a statistical average throughout Europe (BML, 1991). The IPCC default value for Germany, at 62 g, is of the same order of magnitude (2006 IPCC Guidelines, (2006 IPCC, (IPCC, 2006a): Volume 5, Chapter 6, Table 6.4).

Methane emissions from cesspools and septic tanks are also determined in accordance with the IPCC method. The IPCC default value for methane-producing capacity (0.6 kg CH_4/kg BOD_5) was used. Pursuant to IPCC (IPCC (2006a): Vol. 5, Chapter 6.1, page 6.7), the methane conversion factor (MCF) depends on temperature. No significant methane production occurs at temperatures below 15°C.

Table 448: Soil temperature [1m] in °C, average monthly values for Germany

Monthly average [°C]	January	February	March	April	May	June
2012-2017	5.4	4.2	5.6	8.4	12.1	15.7
2018-2023	5.8	5.1	5.8	8.7	12.4	16.7
Monthly average [°C]	**July**	**August**	**September**	**October**	**November**	**December**
2012-2017	17.9	18.5	16.8	13.5	10.0	6.9
2018-2023	18.8	19.4	17.6	14.0	10.5	7.0

In light of the long-term mean soil temperature in Germany (DWD, 2024a) at a depth of 1 m, the soil temperature in summer months ranges between 15 and nearly 20°C. Methane thus can form during summer months, since the relevant cesspools and septic tanks are looked at around this depth. In accordance with (Gibbs & Woodbury, 1993), the MCF for this period (about 4 months) is conservatively estimated to be 0.35. Throughout the rest of the year, the temperatures are below – significantly in some cases – the IPCC's 15°C boundary. They drop to about 5°C. In accordance with (Gibbs & Woodbury, 1993), the MCF for this period (about 8 months) is conservatively estimated to be 0.1 (according to the IPCC, an MCF of 0 would be justified). The wastewater temperature can vary significantly depending on the temperature of drinking water and what the water is used for. There are no comprehensive or generally valid data on this. In view of the low wastewater inflow, in comparison with the storage volume of cesspools and septic tanks, it can be assumed that the wastewater temperature quickly aligns with the soil temperature. The research project on cesspools and septic tanks did not result in any changes from the approach described here for determining the MCF for cesspools and septic tanks (Lange et al., 2021). Furthermore, since the cesspools and septic tanks are regularly emptied for disposal of the wastewater in the wastewater treatment plant and therefore no sludge accumulation occurs, it is assumed that the values used can be considered realistic to conservative. The figures provided by Gibbs and Woodbury (1993) refer to studies on methane formation in animal manure (slurry). Since no similar data, either national or international, for human excretions are available, and since the IPCC default values are not applicable to the situation in Germany, the MCF values determined in that study (ibid.) are assumed to be applicable for determining a national MCF. In this context, the MCF describes the methane formation potential achieved by the waste management system used. Systems for slurry storage usually consist of unmixed systems with regular but discontinuous waste addition and withdrawal. This appears to be sufficiently comparable to cesspools and septic tanks. The effect of the substrate also relates solely to technical aspects with regard to the MCF. Since a substrate's methane formation potential is described by B_o, a comparison of the dry matter (mass fraction) is sufficient here. The mass percentage is assumed to be 5% for swine slurry and 7.5% for cattle slurry (Wendland & Attenberger, 2009). The percentage for thickened primary sludge from wastewater treatment is about 5-10% (DWA, 2007). It can be assumed that the values in raw wastewater, even in areas with lower water use that are not connected to the public sewer system, are considerably below the aforementioned values – and, thus, also below the values for slurry dry matter. This seems plausible given that this wastewater has inflows of

grey water and toilet wastewater and that straw bedding is used in animal husbandry. Consequently, it is safe to say that, as a result of the thinner suspension involved (which implies lower oxygen consumption), anaerobic conditions arise more slowly in such wastewater than they do in stored slurry, and conversion to methane is correspondingly delayed. Furthermore, cesspools and septic tanks are ventilated only through a ventilation opening, while storage tanks for slurry are often completely open. As a result, the described approach is likely to be a conservative one. Review of the MCF reported in Thünen-Report No. 77 (Haenel et al., 2020)), for storage of swine slurry (0.25), highlights the conservative nature of the MCF chosen here (0.35). Since no specific data regarding the transferability of this result are available, the uncertainty is estimated to be 20% (cf. Chapter 7.5.1.1.3). A research project completed in 2018 (unpublished) explored whether any better data, either national or international, are available for derivation of a country-specific MCF. To this end, an extensive literature review was conducted and national manufacturers of cesspools and septic tanks and national scientific and university institutions were asked whether any measurements on methane formation in cesspools and septic tanks were available. The study found that the very few measurements published in the international literature do not support any conclusions with regard to derivation of a national MCF. Furthermore, neither the manufacturers nor the surveyed institutions have any information regarding methane formation. For this reason, the MCF presented here will continue to be used in future, at least until suitable measurements become available. The research project on cesspools and septic tanks (Lange et al., 2021) also did not produce any new findings in this regard.

The above-mentioned conditions and temperature distribution in the soil yield a mathematically averaged MCF for Germany of 0.183.

The MCF is determined as follows:

$$MCF = (0.35 * 4 \text{ months} + 0.1 * 8 \text{ months})/12 \text{ months}$$

(Gibbs and Woodbury 1993) use an estimate of 0.35 for temperatures > 15 C and an estimate of 0.1 for temperatures < 15 C

The emissions are calculated as follows:

$$CH_4 = BOD_{5Year} \times B_o \times MCF$$

$$BOD_{5Y} = P_{\text{Cesspools, septic tanks}} \times BOD_5 \times 365 \times 0.001$$

where

- CH_4 = Resulting methane emissions in kg/year
- MCF= Methane correction factor, 0.183
- Bo = Default – max. CH_4 Formation capacity, 0.6 kg CH_4/kg BOD_5
- P cesspools, septic tanks= Number of people connected to cesspools or septic tanks
- BOD5Year= BOD5 in g/year
- BOD5= 60 g/day x no. of people

Calculation pursuant to more stringent requirements (higher-Tier methods or higher hierarchical levels), as required for key categories, is not feasible, since the substance flows for cesspools and septic tanks without drainage are not separately recorded.

With regard to verification of the MCF used, cf. Chapter 7.5.1.1.4.

The following table presents inhabitant data for Germany as a whole and for inhabitants connected to cesspools and septic tanks. The values were documented every five years for the period 1990–2015 and continuously from 2017 onwards, and serve to ensure the transparency of the calculations described in this section.

Table 449: Inhabitants of Germany as a whole, and inhabitants connected to cesspools and septic tanks

Year	Inhabitants (1000s of people)		Year	Inhabitants (1000s of people)	
	Cesspools and septic tanks	Germany as a whole		Cesspools and septic tanks	Germany as a whole
1990	8234.425	79753.227	2021	397.715	83237.124
2000	1266.667	81456.617	2022	398.072	83118.501
2010	575.000	80284.071	2023	398.429	83456.045
2020	397.357	83155.031	2024	398.787	83577.140

Total methane emissions from municipal wastewater treatment are calculated by adding together the detailed emissions from wastewater treatment plants, cesspools and septic tanks and open sludge digestion (cf. Chapter 7.5.1.2.2.3).

7.5.1.1.3 Uncertainties and time series consistency (5.D.1 wastewater treatment)

The following uncertainties are used:

- EF CH_4 from sewage plants (derived from fluctuation ranges from the underlying research project) = -90/+400%
- MCF (expert estimate) = ± 20%
- P (expert estimate) =± 3%
- $P_{\text{cesspools and septic tanks}}$ (expert estimate) = ± 3%
- BOD_5 (IPCC (2006a): Vol. 5, Table 6.7) = ± 30%
- B_0 (IPCC (2006a): Vol. 5, Table 6.7) = ± 30%

The activity data for organic loads in cesspools and septic tanks are based on figures of the Federal Statistical Office (Statistisches Bundesamt, 2024b). Every three years, the Federal Statistical Office conducts a survey – without any indication of uncertainties – of the numbers of inhabitants who are not connected to the public sewer system and whose wastewater is disposed of in cesspools and septic tanks. Data for interim years are interpolated on a linear basis or extrapolated. No other data sources are available. The results of these surveys can be considered very precise, since the surveys are exhaustive.

As described in section 7.5.1.1.2, the MCF value was adapted to the climatic conditions (long-term average soil temperature at a depth of 1 metre) in Germany. The uncertainty for the value is ± 20% (expert estimate by the German Environment Agency). The uncertainties for BOD_5 and B_0 were stipulated pursuant to (IPCC (2006a): Vol. 5, Table 6.7).

Until 1995, data for the old and new federal states were determined separately; since then, a single value for all of Germany has been determined. This does not affect the consistency of the time series.

7.5.1.1.4 Category-specific QA/QC verification (5.D.1 Wastewater handling)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

For the derivation of country-specific emission factors (applied from NID 2024) for direct methane and nitrous oxide emissions from wastewater treatment, a wide-ranging review of international publications on the issue was carried out, and the findings were placed in the German context and published (publication forthcoming).

Since the above-mentioned research project (unpublished; cf. Chapter 7.5.1.1.2) did not succeed in determining a country-specific MCF for calculating emissions from cesspools and septic tanks, and since the reference source currently used (Gibbs & Woodbury, 1993) seems problematic from a scientific perspective, the national MCF derived from that source was subjected to multi-step verification.

In a first step, verification was carried out on the basis of the considerations and information provided in the IPCC Refinements (2019) (IPCC, 2019), which has not yet entered into force, and with use of the references cited in that source. Even when that source's constraints are applied – 12°C as the temperature limit for biological activity; use of air temperature instead of soil temperature; and use of an MCF of 0.4 (the lower bound for cesspools and septic tanks) – the MCF for Germany would only differ slightly, at 0.225 (0.4*5 months + 0.1*7 months = 0.225). The study cited in the Refinements (Leverenz & Tchobanoglous, 2011) calculated an MCF of 0.22. This value is only slightly higher than the MCF derived for Germany, 0.183, and it supports the basic plausibility of that value. At the same time, a number of fundamental aspects apply in Germany that imply that the country's MCF should be lower than the MCF determined by Leverenz. In all likelihood, the slight discrepancy is due to differences in climatic conditions, since the average annual air temperatures in Germany are lower overall than those in San Francisco, California. Also, in Germany cesspools and septic tanks are installed underground. The minimum installation depth for them is 0.5 m. At that depth, only their vent pipes (which rise above the ground surface) are in contact with the atmosphere for purposes of gas balancing – air currents from outside to the inside of the container are therefore not to be expected and the influence of any oxygen that may enter remains extremely low. Furthermore, temperatures within the tank would not at all be affected by the typically high air temperatures in summer. In addition, the average ground temperatures in Germany in the summer are lower on the whole than air temperatures, meaning they would be lower still than the air temperatures in San Francisco. Influxes of warm water are considered to be of little relevance, as they have a low overall volume and, in addition, the cooling effect of the surrounding soil is significantly higher than that of the surrounding atmosphere and is considered to be of little relevance within the German Environment Agency. In addition, the study of LEVERENZ et al. (Leverenz & Tchobanoglous, 2011) considers systems with connected ground irrigation. The systems used in Germany, by contrast, are drainless systems that have to be emptied by tank trucks at more frequent intervals. This means, as shown in (Leverenz & Tchobanoglous, 2011), that it takes several months before methanogenesis becomes possible and therefore a lower MCF can be expected if they are frequently emptied.

The results of (Leverenz & Tchobanoglous, 2011) were confirmed, in the following year by (Diaz-Valbuena et al., 2011), which also cite a BOD_5 load of 85 to 90 g BOD_5/inhabitant/day The German BOD_5 value is 60 g BOD_5/inhabitant/day, a level at which even less organic material is available for methanogenesis. In the overall view of the calculations and reasons given, we consider the German MCF to be confirmed.

In a second approach, the MCF was verified on the basis of alternative activity data. Instead of calculating the annual organic load using BOD_5=60 g/d*PE, a calculation was made based on the specific wastewater volume per inhabitant in the decentralised area (83 l/d*PE) and an average BOD_5 inflow concentration (750 mg/l) (BDZ, 2017). The alternative activity data were obtained from a study of small wastewater treatment plants. It may be assumed that, because removal of wastewater from cesspools and septic tanks is subject to charges, users of these systems use less water than do users of small wastewater treatment plants. Consequently, the upper value for the BOD_5 concentration was adopted. The values obtained this way are nearly identical to the values obtained for reporting purposes.

Table 450: Verification of CH_4 from cesspools and septic tanks, in kilotonnes [kt]

CH_4 from cesspools and septic tanks	2020	2021	2022	2023	2024
via BOD_5 load/inhabitant (Gujer)	0.955	0.956	0.957	0.958	0.959
via BOD_5 concentration and wastewater production (BDZ)	0.991	0.992	0.993	0.994	0.995

For the derivation of the EF for methane emissions from centralised wastewater treatment, all available data sources were used. The derivation cannot be verified due to a lack of alternative data sources.

The IPCC Guideline is not applicable for the calculation of emissions from centralised wastewater treatment systems. A comparison with the IPCC method and default values yields approximately triple the emissions for cesspools and septic tanks. However, this approach is considered unsuitable because methanogenesis is limited by the ambient temperature, which is why a country-specific MCF has been derived. Here, too, a method based on measurements and specific to Germany is used.

In a third approach, the MCF for cesspools and septic tanks was verified by means of a general comparison with the approaches taken by other countries. This comparison considers the entire wastewater treatment sector as a whole; the MCF (where available in the reports considered) is one aspect of the consideration.

A comparison of the IEF for methane emissions in municipal wastewater treatment for the reporting year 2021 with international IEFs (GHG Locator 2023; (UNFCCC, 2023a); latest available status; according to the UNFCCC, now discontinued) is consistent with most other countries. The German values are of about the same magnitude as the values of comparable countries, such as Austria and Switzerland. The methodology used for Germany from NID 2024, which has been further adapted on a country-specific basis, makes an increase in the IEF likely for Germany in future comparisons. On the other hand, a similar development resulting from adapted methodologies for Austria and Switzerland from report year 2021 can bring the IEF situations closer together.

The method used and the resulting emission factors were compared with the methods and factors of countries that have similar wastewater system standards. In each case, the 2024 NID was considered. At the same time, the method reported in the 2025 NID was used for Germany. Overall, the parameters used show good comparability. The following specific results emerged:

- Austria (Anderl et al., 2025): The methodology for Austria was adapted with NID 2025. In addition to direct emissions from cesspools and septic tanks, direct emissions from wastewater treatment plants and sludge treatment, as well as indirect emissions from discharge into water bodies, are now also reported. Furthermore, the methodology for

cesspools and septic tanks was changed to the default EF of the IPCC refinements, based on the COD load. For wastewater treatment, the default EF of the IPCC refinements and the organic load based on a COD balance are used. For emissions from sludge treatment, an EF of 10 kg CH_4/kg sewage sludge (dry matter) is applied for anaerobic sludge treatment. Austria's calculations are largely based on the IPCC 2019 Refinements. As the refinements are not yet mandatory and have not yet been implemented in Germany, no methane from effluent is reported here. As the methodology used for Germany differs considerably and the emission factors use population figures as a reference value, a direct comparison is not possible. A rough comparison of methane emissions based on total population figures shows that approximately 0.01 t CO2-eq/capita is reported for Germany and approximately 0.02 t CO2-eq/capita for Austria.

- Switzerland (Röthlisberger et al., 2025): Emissions from central wastewater treatment plants are considered collectively for municipal and industrial wastewater. Calculations are made with the IPCC method and country-specific emission factors. Methane emissions are also taken into account for the effluents and for the sewage system. For centralised wastewater treatment (including sludge treatment), an EF of 0.62 kg CH_4/inhabitant*a is specified. This results in an EF of 0.4 kg CH_4/EW*a, converted to 120 g CSB/EW*d. The EF for Germany is close to this value.

7.5.1.1.5 Category-specific recalculations (5.D.1 Wastewater handling)

The statistically recorded population data for the total population of Germany was adjusted for 2022 and 2023 and has risen slightly. For 2022, the previously extrapolated value for inhabitants connected to cesspools and septic tanks was replaced by a statistically collected value. Due to adjusted interpolation and extrapolation, the number of inhabitants connected to cesspools and septic tanks changed from 2020 onwards. The slight downward trend in this value that had previously emerged was not confirmed by the statistical data. The number of inhabitants connected to cesspools and septic tanks has thus risen slightly. Consequently, there were also slight changes in the calculated interim results and auxiliary variables, with the result that emissions from cesspools and septic tanks (approx. 10% for 2023) and wastewater treatment plants, and thus also the total emissions of the sector (approx. 1% for 2023), are slightly higher than calculated last year.

Table 451: Recalculation of CH_4 emissions due to adjusted population figures in total and with a connection to cesspools and septic tanks

Description	Units	NID	2020	2021	2022	2023
Total inhabitants of Germany	[1000s of persons]	2026	83,155,031	83,237,124	83,118,501	83,456,045
		2025	83,155,031	83,237,124	82,711,282	82,711,282
Inhabitants connected to cesspools and septic tanks	[1000s of persons]	2026	397,357	397,715	398,072	398,429
		2025	386,533	376,067	365,600	355,133
Organic load Germany overall	[kt/a]	2026	2,367.424	2,369.761	2,366.384	2,375.994
		2025	2,367.424	2,369.761	2,354.790	2,354.790
Organic load for cesspools and septic tanks	[kt/a]	2026	8.702	8.710	8.718	8.726
		2025	8.465	8.236	8.007	0.008
Implied emission factor	[kg/kg]	2026	0.0004036005	0.0004035650	0.0004045041	0.0004032297
		2025	0.0003926064	0.0003815986	0.0003733365	0.0003626483
	[kt]	2026	0.955	0.956	0.957	0.958

Description	Units	NID	2020	2021	2022	2023
CH_4 from cesspools and septic tanks		2025	0.929	0.904	0.879	0.854
CH_4 from wastewater treatment facilities	[kt]	2026	31.983	32.014	31.969	32.098
		2025	31.983	32.014	31.812	31.812
CH_4 total	[kt]	2026	32.938	32.971	32.926	33.057
		2025	32.912	32.919	32.691	32.666

7.5.1.1.6 Planned improvements, category-specific (5.D.1 Wastewater handling)

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

7.5.1.2 Methane emissions from municipal sludge treatment (5.D.1 Sludge treatment)

7.5.1.2.1 Category description (5.D.1 Wastewater handling)

As a general rule, the treatment of municipal sewage sludge comprises two treatment stages:

- Dewatering via mechanical processes (chamber filter press, cyclone); evaporation in sludge dewatering basins or sludge drying beds
- Stabilisation: Aerobic stabilisation (open pool with oxygen input); or anaerobic stabilisation in digestion tower
- (until 1993: open sludge digestion)

The secondary sludge (excess sludge) occurring in wastewater treatment and the primary sludge are anaerobically treated, together, in digestion towers and thus anaerobically stabilised. This produces digested sludge, which usually leaves the wastewater treatment plant as sewage sludge after further processing or after completion of the wastewater treatment. Digestion of sewage sludge ensures that the sewage sludge no longer contains any readily biodegradable substances and has been completely digested. It is assumed that digested sludge produces no further methane emissions. The emissions from sludge treatment are an integral component of the emission factor described in 7.5.1.1.2. Consequently, all of the emissions originating in sewage sludge are taken into account in 5.D.1. It is assumed that no emissions occur in other sectors. No information is available with regard to the quantities of sludge involved prior to digestion.

The purpose of sludge stabilisation is to prevent unregulated sludge digestion. In large systems, digestion is anaerobic. In smaller ones, sludge may be digested aerobically. Alternatively, the sewage sludge is transported to larger facilities equipped with digestion for anaerobic stabilisation [101]. The amount of digester gas produced via anaerobic sludge stabilisation depends especially on the composition of the sewage sludge, the temperature and the reaction conditions. Gas produced this way is usually recovered for energy generation in combined heat/power generating systems (CHP). It is reported under 1.A.1.

[101] In 2023, digester gas was produced in 1,276 wastewater treatment plants Statistisches Bundesamt. (2017). Persönliche Mitteilung von Herrn Kaiser; E 207: Deutschland - Erhebung über Gewinnung, Verwendung und Abgabe von Klärgas. In, Statistisches Bundesamt. (ab 2012). Persönliche Mitteilung von DESTATIS-Mitarbeitern aus FG E 207: Deutschland - Erhebung über Gewinnung, Verwendung und Abgabe von Klärgas; jährlich. In..

With reference to population figures, mechanical *dewatering* + treatment in a digestion tower (with dehydration before or after the digestion tower treatment) currently represents the main treatment method (exception: small, rural wastewater treatment plants). Moreover, sewage sludge is generally stabilised prior to subsequent use.

Until the early 1990s, open sludge digestion was still being used for sludge stabilisation in the new federal states, which led to methane emissions. Open sludge digestion is no longer practised. It was phased out gradually, and was then completely discontinued in 1994. However, emissions from open sludge digestion are still the reason why NO is reported in the CRF under this item instead of IE (for energy-related use under 1.A.1 – see above), because this technology and the associated emissions existed up to and including 1993.

The sewage sludge and the treated wastewater are the final products of wastewater treatment.

In Germany, sewage sludge produced after biological wastewater treatment is usually first dried (mechanical drying, solar drying, etc.), if necessary after dewatering and stabilisation, and then sent for disposal in the following ways:

- Thermal utilisation: No methane emissions occur. Thermal utilisation requires energy inputs and is thus allocated to CRF 1.
- Recycling for substance recovery: The material recycling of sewage sludge includes, in particular, its use as a secondary raw material fertiliser in agriculture pursuant to the Ordinance on Sewage Sludge (Klärschlammverordnung) and the Fertiliser Ordinance (Düngemittelverordnung) as well as its use in landscaping measures and other areas of application that are negligible.

Table 452: Use of digested sewage sludge (dry matter), in [t]

Dry matter DM [t])	2020	2021	2022	2023	2024
Total quantity	1,740,556	1,717,803	1,667,083	1,629,897	1,629,897
Thermal utilisation	1,334,994	1,364,890	1,336,621	1,320,434	1,320,434
- Mono-incineration	507,929	525,763	583,780	656,344	656,344
- Co-incineration	795,819	810,977	725,634	622,229	622,229
- Unknown	31,246	28,150	27,207	41,861	41,861
Landfill	0	0	0	0	0
Recycling for substance recovery	388,886	335,641	322,861	296,930	296,930
- Agriculture	259,851	226,747	231,112	212,899	212,899
- Landscaping measures	25,181	17,576	13,278	12,801	12,801
- Composting & humification	0	0	78,471	71,230	71,230
- Other	103,854	91,318	0	0	0
Other direct recovery/other disposal	16,676	17,272	7,601	12,533	12,533

The activity data for sewage sludge use are based on data of the Federal Statistical Office (Statistisches Bundesamt, jährlich). This report used to be produced every three years, but as of 2023 appears annually. The figures for interim years have been taken to date from the publication “Wasserwirtschaft Öffentliche Abwasserentsorgung Klärschlammverwertung aus der biologischen Abwasserbehandlung” (“Water resources sector, public wastewater

management, use of sewage sludge from biological wastewater treatment". No data are available for the period prior to 1998 and for the years 1999-2000, 2002-2003 and 2005. Interpolation is not possible because it is not possible to calculate a total of 100% due to a statistical change from 2007 onwards. No data are available for the current inventory year; for this reason, only the data of the previous years can be presented here. For 2013, the Federal Statistical Office reported for the first time in this regard, under "substance recovery" ("Stoffliche Verwertung")[102].

7.5.1.2.2 Methodological issues (5.D.1 Sludge treatment)

7.5.1.2.2.1 Digester gas

As described above, the digester gas that is produced by the digestion process in wastewater treatment plants is recovered and used for energy generation. The methane content in digester gas is nearly 65% (Schön et al., 1993).

The quantity of methane per raw gas volume is determined as follows:

$$M_{Methan} = V_{Rohgas} \times 0{,}65 \times \sigma \times 0{,}000001$$

where:

- $M_{methane}$ = Mass of the methane produced by digestion in [kt]
- $V_{raw\ gas}$= Volume of digester gas produced (m^3)
- 0.65 = Conversion factor for methane contained in the digester gas
- σ = Density of methane (0.717 kg/m^3) (Synowietz, 1974)

7.5.1.2.2.2 Digester gas losses

Operators report data on digester gas collection and sewage sludge utilisation annually to the Federal Statistical Office, on the basis of the Act on Energy Statistics. Consultations with staff at several wastewater treatment facilities with digester gas collection showed that losses in terms of the potential energy recovery of the plants can be assumed to be 5%. This confirms the relevant figures of the Federal Statistical Office (Statistisches Bundesamt, ab 2012). Losses occur during gas collection due to technical difficulties, accidents and maintenance measures. The reported losses can also be due to discrepancies between the accuracy of measurements made at gas production sites and the accuracy of measurements made at consumption sites. Gas flares are usually installed at wastewater treatment plants as emergency equipment and are therefore rarely in operation. They are therefore designed to burn all the gas produced in an emergency and are equipped with automatic ignition. Methane emissions from unburned digester gas may occur in certain circumstances due to problems with flame ignition. To prevent this, automatic ignition and flame monitoring are required by the relevant regulations, such as DWA-M 305 "Gas flares at biogas plants". The gas passing through the flare is not usually measured separately, so it is not possible to make any precise statements about the nature of the losses at this point. Relevant methane emissions from gas flares can be reduced as far as possible through appropriate maintenance and repair intervals. Methane emissions from gas flaring relevant to the sector can therefore be ruled out.

[102] This also includes delivery to drying facilities if there are no known further disposal steps.

Any losses that occur in the facilities are taken into account by the calculations described under 7.5.1.1.2, since the area of sludge treatment was included in determination of the emission factor.

7.5.1.2.2.3 Open sludge digestion

Open sludge digestion is no longer practised in Germany. The data for the years 1990-1994 were most recently reported in the 2015 NIR. An emission factor of 210 kg CH_4/t dry matter is applied for open sludge digestion in the new German federal states, based on the results of the study Schön et al. (1993).[103] The activity data for the years 1990 to 1992 were communicated personally to the German Environment Agency by the then Chief Inspector of the former GDR's water processing plants.

Given that open sludge digestion was already banned in West Germany, this type of treatment was gradually phased out in the new German federal states and completely discontinued from 1994 onwards.

7.5.1.2.3 Uncertainties and time series consistency (5.D.1 Sludge treatment)

7.5.1.2.3.1 Digester gas

The uncertainties in determining and calculating the amount of methane are estimated as follows (UBA expert assessment):

Volume of digester gas produced = ± 5%

The uncertainties originate in the measurement inaccuracies of the measuring devices used

Methane content in digester gas = ± 15%

Varies depending on the composition of the wastewater – and thus the composition of the sludge

Density of methane = ± 30%

The literature gives a range of different densities for methane (depending on temperature, etc.)

The figure for the quantity of digester gas produced is based on data of the Federal Statistical Office. The time series are thus internally consistent. The surveys are carried out annually. The results of the surveys are considered accurate.

7.5.1.2.3.2 Open sludge digestion

Since the uncertainties associated with open sludge digestion were not assessed, which is why the default values (conservative factors) of UNFCCC Decision 20/CMP.1 (UNFCCC, 2006) are used. The activity rates between 1990 and 1992 are based on personal communication from the then chief inspector of the GDR water treatment plants, while those for 1993 are based on an estimate by the German Environment Agency.

7.5.1.2.4 Category-specific QA/QC and verification (5.D.1 Sludge treatment)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

The average methane content of sewage gas of 65% (Schön et al., 1993) used to determine the methane content in sewage gas was compared with data from the Federal Statistical Office

103 The emission factor was determined by calculating the difference between the methane emissions from psychrophilic sludge stabilisation in the new German federal states and the amount of sewage sludge produced..

(Statistisches Bundesamt, ab 2012). For 2015, an average sewage gas methane content of 63.17% was obtained from data of the Federal Statistical Office. The value used is thus considered verified. A review of the values for 2023 produced an average methane content of 62.38%. The verification can therefore still be confirmed.

No comparable emissions data for Germany or other data on methane collection from wastewater treatment plants are known.

7.5.1.2.5 Category-specific recalculations (5.D.1 Sludge treatment)

Data on sewage sludge production and losses are available through 2022. The figures for 2023 were obtained by carrying forward the figures for 2022.

7.5.1.2.6 Category-specific planned improvements (5.D.1 Sludge treatment)

At present, improvements seem neither necessary nor possible, since no further activity data are available.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

7.5.1.3 Nitrous oxide emissions from municipal wastewater (5.D.1 Nitrous oxide emissions from municipal wastewater)

7.5.1.3.1 Category description (5.D.1 Nitrous oxide emissions from municipal wastewater)

Municipal wastewater contains a range of nitrogen compounds. In bacterial decomposition processes, part of the available organic nitrogen is converted back into biomass.

Direct emissions: To eliminate as much of the remaining nitrogen in wastewater as possible, almost all municipal wastewater treatment plants in Germany operate with an additional nitrification and denitrification stage to supplement biological wastewater treatment. In nitrification, the nitrogen compounds in the wastewater are converted into nitrate under aerobic conditions. In denitrification, the nitrogen bound in the nitrate is converted into molecular nitrogen and nitrogen oxides. Under unfavourable conditions (cf. also Chapter 7.5.2.2.1), nitrous oxide (N_2O) can occur as a by-product/intermediate product in both processes, with denitrification appearing to be the dominant source (IPCC (2006a): Volume 5, Chapter 6.1, Table 6.8).

Indirect emissions: The nitrogen that remains in wastewater following wastewater treatment makes its way to water bodies. Under certain circumstances, microbial degradation processes may take place there, during which nitrous oxide, among other things, can be formed and emitted.

To determine the total emissions of nitrous oxide from municipal wastewater, direct nitrous oxide emissions (N^2O_{PLANTS}) and indirect nitrous oxide emissions ($N_2O_{Effluent}$) are determined.

The total emissions are calculated as follows:

$$N_2O_{Gesamt} = N_2O_{PLANTS} + N_2O_{EFFLUENT}$$

The emissions show a strongly decreasing trend as a result of extensive additions of denitrification systems to wastewater treatment facilities in the period 1990 through about 2001. The reason for this was the implementation of the EU Urban Wastewater Treatment Directive(BML, 1991), which made nutrient removal in wastewater treatment plants state of the

art in the early 1990s. Nutrient removal technology has since reached high technological standards, and a slightly decreasing emissions trend became established in about 2005.

7.5.1.3.2 Methodological issues (5.D.1 Nitrous oxide emissions from municipal wastewater)

Direct emissions

Pursuant to the 2006 IPCC Guidelines, only countries with modern wastewater treatment facilities are required to report direct emissions. These facilities include nitrification and denitrification stages. As described above, nitrous oxide emissions occur primarily in denitrification pursuant to the IPCC (ibid.). For this reason, the degree to which German wastewater treatment plants are equipped with denitrification technologies (T_{Plant}) is used for the calculation below, rather than nitrification technologies. 99% of wastewater is treated in wastewater treatment plants with nitrification, and 97% is treated in plants with denitrification (Statistisches Bundesamt, 2024a). Calculation of the nitrous oxide emissions takes account of municipal wastewater treatment plants that are equipped with denitrification.

Pursuant to 2006 IPCC Guidelines IPCC (2006a): Vol. 5, Chapter 6.3.1.3, Equation 6.9), nitrous oxide emissions as calculated as follows:

$$N_2O_{PLANTS} = P \times T_{PLANT\ DENI} \times F_{IND-COM} \times EF_{PLANT}$$

where:

- N_2O_{PLANTS} = Total annual N_2O emissions of the facilities in [kg N_2O/a]
- P = Population
- $T_{PLANT\ DENI}$ = Degree of utilisation of modern wastewater treatment plants with denitrification, in [%/100] (i.e. related to the total wastewater load in Germany)
- $F\ I_{ND-COM}$ = Fraction of protein of industrial/commercial wastewater; adjusted country-specific value = 1.3
- EF_{PLANT} = Emission factor derived on a country-specific basis; 35 g N_2O/person x year

Based on international publications, an emission factor of 0.035 kg of nitrous oxide per year and inhabitant has now been derived (not yet published), which adequately reflects the situation in Germany according to current data. Due to the limited comparability of measurements taken at individual plants and the different sampling and detection methods used, a high degree of uncertainty is to be expected. The number of inhabitants (P = population), the degree of utilisation of modern centralised wastewater treatment plants with denitrification ($TP_{LANT\ DENI}$) and the proportion of wastewater from industrial plants (indirect discharges) and manufacturing plants ($F_{IND-COM}$) disposed of via municipal plants are values determined specifically for each country. $F_{IND-COM}$ must be taken into account, as otherwise the calculation approach would only consider the connected population (EW) and not the population equivalents (p.e.) of indirect discharges.

Due to the share of commercial and industrial wastewater (2016: 38,478,100 population equivalents; p.e. = 32.8 %) of the total organic wastewater load in municipal wastewater treatment plants (2016: 117,448,800 population equivalents in total; EW = 100%) (Statistisches Bundesamt, 2024b), amounting to about 30%, $F_{IND-COMM}$ was set at 1.3.

Indirect emissions

In accordance with the method proposed by the 2006 IPCC Guidelines, first the total annual quantity of nitrogen in wastewater effluent is determined.

This is carried out on the basis of the following formula for Germany:

$$N_{EFFLUENT} = V_{Abw} \times N_{ges} \times F_N$$

where:

- $N_{EFFLUENT}$ = Total annual quantity of nitrogen in wastewater effluent, in [kg N/year]
- $V_{Wastewater}$ = Total quantity of wastewater
- N_{total} = Average nitrogen concentration in wastewater effluent in Germany, in [mg/l]
- F_N = Conversion factor N_{total} in total N

The data on the total quantity of wastewater treated in Germany and on the nitrogen concentration were obtained from Destatis (Statistisches Bundesamt, 2024a). In the process, non-reported (but required) values were interpolated or extrapolated. For the sake of simplicity, the annual wastewater volume of the wastewater treatment plant inflow is treated as equivalent to the wastewater treatment plant outflow. Since the nitrogen concentration is reported as the standard wastewater parameter N_{total}, which only includes the sum of the inorganic nitrogen parameters, a conversion must be made here. For this purpose, a conversion factor of 1.21 was determined from the data available in (DWA, seit 1988).

The nitrous oxide emissions are determined as follows in accordance with the IPCC method:

$$N_2O = N_{EFFLUENT} \times EF_{EFFLUENT} \times \frac{44}{28}$$

where:

- N_2O = N_2O emissions in [kg N_2O/a]
- $N_{EFFLUENT}$ = Nitrogen discharged into the aquatic environment, in [kg N/year]
- $EF_{Effluent}$ = Emission factor for N_2O emissions released into wastewater, in [kg N_2O-N/kg N] (default = 0.005)
- 44/28 = Conversion factor of N_2O-N in N_2O

The total emissions of nitrous oxide from the area of municipal wastewater treatment are obtained as the sum of the relevant direct and indirect emissions described in detail.

7.5.1.3.3 Uncertainties and time series consistency (5.D.1 Nitrous oxide emissions from municipal wastewater)

The following uncertainties are used:

- P (expert estimate) = ±3%
- $T_{PLANT\ DENI}$ (expert estimate) = ±5%

- $F_{IND-COM}$ (expert estimate) = ±25%
- EF_{PLANT} (derived from fluctuation ranges from the underlying research project) = -100/+500%
- $V_{Wastewater}$ (expert estimate) = ±5%
- N_{total} (expert estimate) = ±5%
- F_N (expert estimate) = ±10%
- $EF_{EFFLUENT}$ (IPCC (2006a): Vol. 5, Table 6.11) = -90/+4900%

The activity data are based on data of the Federal Statistical Office. The population figure (P) for Germany is determined on an annual basis, while the quantity of wastewater treated in wastewater treatment facilities with denitrification (results in $T_{PLANT\ DENI}$), the total annual wastewater quantity ($V_{wastewater}$) and the average nitrogen concentration in wastewater treatment plant operations (N_{total}) is determined every three years (without any indication of uncertainties). The results of the surveys may be considered very precise, since the surveys are exhaustive. Figures for the years prior to 1998 were extrapolated and are plausible, as nitrogen elimination in wastewater treatment plants was expanded in Germany at the beginning of the 1990s.. All of the missing data are interpolated or extrapolated on a linear basis.

The uncertainty for the EF_{PLANT} results from the derivation of the new country-specific EF (not yet published), and the underlying research project.

The factor needed for the conversion of N_{total} to Total-N was determined on the basis of complementary data from (DWA, seit 1988). Approx. 87% of the annual wastewater produced in Germany is treated in facilities belonging to the DWA. There is therefore sufficient coverage to permit the deduction of an average value for the relationship between the two parameters.

The uncertainties for the EFEFFLUENT are taken from the (IPCC (2006a): Vol. 5, Table 6.11). The range is 0.005-0.25 kg N2O-N/kg N.

7.5.1.3.4 Category-specific QA/QC and verification (5.D.1 Nitrous oxide from municipal wastewater)

General and category specific quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

For the derivation of country-specific emission factors (applied from NID 2024) for direct methane and nitrous oxide emissions from wastewater treatment, a wide-ranging review of international publications on the issue was carried out, and the findings were placed in the German context and published (publication forthcoming).

In calculation of the nitrous oxide emissions, all the available data sources were used. The derivation cannot be verified due to a lack of alternative data sources.

As described above, the IPCC method for the determination of nitrous oxide emissions is only partly applicable, since it does not take account of the nitrogen load eliminated via denitrification and thus considerably overestimates the emissions. For this reason, an adjusted

method was used. The EFs in the 2006 IPCC Guidelines, which are default values, are used only for the calculation of the indirect emissions. According to the refinements to the 2019 IPCC Guidelines, which are currently not applicable, the default value used at present should only be applied to waters that are not contaminated with nutrients. In light of this recommendation, a higher emission factor should be used for water bodies with nutrient contamination. Since not all water bodies in Germany can be classified as healthy and not contaminated, this approach will have to be reviewed in future. It may be necessary to derive a specific emission factor for Germany.

A comparison of the IEF for nitrous oxide emissions in municipal wastewater treatment for the reporting year 2021 with international IEFs (GHG Locator (UNFCCC, 2023a); latest available status; according to the UNFCCC, now discontinued) is consistent with most other countries. This is attributed to the previous application of the calculation method in accordance with IPCC Guidelines. Significantly higher IEF scores can be linked to the use of a country-specific method, as demonstrated by the examples of Austria and Switzerland. The application of an adapted country-specific methodology for Germany from the NID 2024 makes an alignment of the values likely for future IEF comparisons.

The method used for Germany and the resulting emission factors were compared with the methods and factors of countries that have similar wastewater system standards. In each case, the 2024 NID was considered, although for Germany the method reported in the 2025 NID is used. The following results emerged:

- Austria (Anderl et al., 2025): The calculation is carried out in accordance with the IPCC guidelines. Measured nitrogen values can be used. To calculate emissions from central wastewater treatment, it uses a country-specific EF based on measurements. This EF, at 43g N_2O/inhabitant*a, is near to the value derived for Germany, 35g N_2O/inhabitant*a. As in Germany, the default value (0.005kg N_2O-N/kg N) is used to determine emissions from effluent.
- Switzerland (Röthlisberger et al., 2025): Calculations for emissions from wastewater treatment and effluent are carried out in accordance with IPCC Guidelines. Country-specific data for inflow and outflow can be used to take into account the removed N load. As in Germany, Switzerland uses the EF default values for emissions from effluent. The EF for direct emissions is represented using a tiered model based on the type and extent of nitrogen removal by the wastewater treatment plant using country-specific EFs.

7.5.1.3.5 Category-specific recalculations (5.D.1 Nitrous oxide from municipal wastewater)

The statistically recorded population data for the total population of Germany was adjusted for 2022 and 2023 and has risen slightly. For 2022, the previously extrapolated values for total annual wastewater volume, annual wastewater volume treated with denitrification and the concentration of N_{total} in the wastewater treatment plant effluent were replaced with statistically surveyed data. Due to adjusted interpolation and extrapolation, the figures changed from 2020 onwards, including the auxiliary variables total nitrogen and splitting factor determined from them. The total population increased slightly compared to the previously reported data. The annual wastewater volumes and the concentration of N_{total} in the effluent decreased slightly. Due to methodological differences from last year's calculation, this resulted in a reduction in indirect emissions (approx. 10% for 2023) and a slight increase in direct emissions (approx. 1% for 2023). As a result, total emissions fell very slightly (by around 0.5% for 2023).

Table 453: Recalculation of N_2O emissions

Description	Units	NID	2020	2021	2022	2023
Total inhabitants of Germany	[inhabitants] in 1,000s	2026	83,155,031	83,237,124	83,118,501	83,456,045
		2025	83,155,031	83,237,124	82,711,282	82,711,282
Total annual wastewater volume	[m³] in 1,000	2026	8,808,439.667	8,568,937.333	8,329,435.000	8,089,932.667
		2025	8,870,238.667	8,692,535.333	8,514,832.000	8,337,128.667
Annual wastewater volume (denitrification)	[m³] in 1,000	2026	8,482,148.667	8,288,413.333	8,094,678.000	7,900,942.667
		2025	8,539,662.333	8,403,440.667	8,267,219.000	8,130,997.333
Average N_{total} (N anorg.)	[mg/l]	2026	7.60	7.50	7.40	7.30
		2025	7.73	7.77	7.80	7.83
Indirect N_2O emissions	[kt]	2026	0.636	0.611	0.586	0.562
		2025	0.652	0.642	0.631	0.621
N_2O emissions Direct	[kt]	2026	3.643	3.663	3.675	3.709
		2025	3.643	3.661	3.654	3.670
Total N_2O emissions	[kt]	2026	4.280	4.274	4.261	4.270
		2025	4.295	4.303	4.285	4.291

7.5.1.3.6 Planned improvements, category-specific (5.D.1 Nitrous oxide from municipal wastewater)

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

7.5.2 Industrial wastewater handling (5.D.2)

7.5.2.1 Methane emissions from industrial wastewater treatment (5.D.2)

7.5.2.1.1 Category description (5.D.2 CH_4)

Gas	Method used	Source for the activity data	Emission factors
CH_4	Tier2/CS	NS	CS
N_2O	Tier 2/CS	NS	CS

Emissions from industrial wastewater treatment are not a key category.

In accordance with (IPCC, 2006a), the CH_4 emissions reported here relate solely to the fraction of wastewater treated in industrial wastewater treatment plants. The industrial wastewater fraction that is sent to municipal facilities is included under 5.D.1 (municipal wastewater treatment).

The foundations for calculation of CH_4 emissions from industrial wastewater treatment are described in detail in the underlying research report (Austermann-Haun & Witte, 2014).

The biological stage of industrial wastewater treatment in Germany is carried out partly aerobically and partly anaerobically. Digester gas, consisting largely of CO_2 und CH_4, occurs when organic substances in wastewater are broken down anaerobically.

In Germany today, industrial wastewater is treated anaerobically in many sectors, particularly in the food industry. Data on the plant equipment and systems used in this area are not systematically collected in Germany. However, an evaluation (Austermann-Haun & Witte, 2014) shows that there are currently 184 anaerobic plants in operation in Germany at 136 companies in 26 economic sectors, ranging from vegetable processing to sugar and paper production to the production of cleaning agents. The largest COD loads that are treated anaerobically occur in pulp and paper production, sugar production and the breweries sector.

Sludge bed reactors (upflow anaerobic sludge blanket (UASB) and expanded granular sludge bed (EGSB) reactors) are primarily used for anaerobic industrial wastewater treatment. All facilities are equipped with gas flares with automatic ignition as required by law. Only one plant, a relatively small sugar plant, treats its wastewater in anaerobic ponds.

Almost all of the resulting digester gas is recovered and combusted either to provide process heat (where it replaces town gas) or to generate electricity. Use for energy recovery is reported under CRF 1.A.1. The data published by the Federal Statistical Office on the volume of sewage gas includes both the digester gas produced in this category and that from municipal plants (telephone call between an expert from the German Environment Agency with the Federal Statistical Office, 23 August 2016).

The only CH_4 emissions that are therefore relevant for Germany are those resulting from unintended releases. These unintended releases can include:

- CH_4 present in the liquid phase effluent of methane reactors (the solubility of methane is temperature-dependent; cf. the section “Methodological issues”),
- Losses in gas storage systems,
- Losses via sludge removal from pellet storage systems (systems for storage of granulated sludge from sludge blanket reactors),
- Gas that forms in non-aerated pond systems of the sugar industry,
- Gas that forms in acidification reactors,
- Losses via leaks/disruptions/flaring losses.

Gas flares are used exclusively as emergency flares, for example, in the event that maintenance work needs to be carried out on the CHP unit. The gas flares are designed to burn all of the gas produced in an emergency. The amount of gas passing through the gas flares is not recorded. The flares are used as emergency flares, meaning that the quantities of combusted gas in this area of application are near zero. Gas flares are equipped with automatic ignition systems that assure reliable burning of collected gas during disruptions of normal system operation. During the startup and shutdown phases of digesters, the methane produced is also burned via gas flares due to low methane concentrations, i.e. at the beginning and end of the operational season. The methane emissions from high-performance gas flares are assessed by experts to be “zero”.

According to experts (Austermann-Haun & Witte, 2014), disruptions involving gas losses have occurred twice in recent decades in the area of anaerobic industrial wastewater treatment in the form of leaks from the methane reactor in the gas chamber. As a result of the odour associated with leaks, they are quickly detected, located and eliminated. In 1992, odour emissions at a wastewater treatment plant led to the discovery of a leak in a methane reactor’s glass-fibre reinforced plastic (GRP) roof. A second case of leakage occurred in 2013 in the steel roof of a methane reactor. As a result of the small number of such disruptions (2 in a total of 30 years of

operation of a pool of methane reactors that now numbers 184), the methane emissions from disruptions involving leaks are classified as negligible.

Other types of disruptions – for example, disruptions that inhibit the methane bacteria – do not result in any methane emissions.

7.5.2.1.2 Methodological issues (5.D.2 CH_4)

The calculation method selected is in accordance with Tier 2.

Annual COD loads were calculated for 20 of the 26 relevant industrial sectors using the formula below ((IPCC, 2006a): Vol. 5, Chapter 6.2.3.3, Equation 6.6). To this end, the production volume for 2013 and the specific wastewater volume from federal statistics (Statistisches Bundesamt, jährlich - FS 4, R. 3.1) were determined for each economic sector and calculated using the specific COD content of the raw wastewater specified in the research report. It should be noted that wastewater statistics are updated only once every three years. Interim years are thus interpolated, while data for subsequent years are carried forward consistently until the next update, and then recalculated when the update becomes available.[104] For 6 industrial sectors (Manufacture of grain mill products (industrial sector (Wirtschaftszweig) code WZ 10.61), Manufacture of prepared meals and dishes (WZ 10.85), Manufacture of other organic basic chemicals (WZ 20.14), Manufacture of fertilisers and nitrogen compounds (WZ 20.15), Manufacture of plastics (WZ 20.16) and Manufacture of soap, detergents and cleaning and polishing preparations (WZ 20.41)), the literature provided no data on specific wastewater production. As a result, it was not possible to calculate the annual COD load for those sectors.

Equation 100:

$$TOW_i = P_i \cdot W_i \cdot COD_i$$

where:

- TOW_i = Total organically degradable material in wastewater for industry i (annual COD load), in kg COD/year
- I = Industrial sector
- P_i = Total industrial product for industrial sector i, t/yr
- Wi = Wastewater generated in industrial sector, m^3/t product
- COD_i = Chemical oxygen demand (industrial degradable organic component in wastewater), kg COD/m^3

Since it is good practice to calculate with country-specific data and since country-specific data are available for Germany, we use our own method for calculation of total methane emissions, rather than the IPCC ((IPCC, 2006a): Vol. 5, Chapter 6.2.3.1, Equation 6.4). The total methane emissions from industrial wastewater treatment are calculated with the following formula:

[104] These changes have no impact on the reported methane emissions, because these emissions are calculated by other means as described below. In general, the Federal Statistical Office does not provide updates of wastewater statistics until after the NIR's editorial deadline.

Equation 101:

$$CH_4\ Emissions = \sum_i \left[\left(TOW_i \cdot \omega_{ANR,i} \cdot \omega_{CSB,i} \cdot EF_{CH4,gelöst,i}\right) + E_{CH4,GS,i} + E_{CH4,PS,i} + E_{CH4,AT,i}\right]$$

where:

- $CH_4\ Emissions$ = CH_4 emissions in the inventory year in kg CH_4/a
- TOW_i = Total organically degradable material in the wastewater of industrial sector i (annual COD load), in kg COD/a
- i = Industrial sector
- $\omega_{ANR,i}$ = Percentage share for anaerobic treatment for industrial sector i
- $\omega_{CSB,i}$ = Degree of COD degradation in anaerobic treatment for industrial sector i
- $EF_{CH4.aelöst.i}$ = Emission factor for CH_4 dissolved in water, in industrial sector i, in kg CH_4/kg $COD_{eliminated}$
- $E_{CH4,GS,i}$ = CH_4 emissions from gas storage systems in industrial sector i, in kg CH_4/a
- $E_{CH4,PS,i}$ = CH_4 emissions from pellet storage systems in industrial sector i, in kg CH_4/a
- $E_{CH4,AT,i}$ = CH_4 emissions from wastewater ponds in industrial sector i, in kg CH_4/a

The specific emission factors $EF_{CH4,gelöst,i}$ for methane dissolved in the water phase were calculated on the basis of Henry's law, and they are listed in the research report. A pressure of 1.043 bar is used as a basis. The temperature, which is always sector-specific, varies between 32°C and 37°C.

The emissions from gas storage systems are based on the permissible rates of leakage from storage systems. On this basis, the CH_4 emissions for each gas storage system were calculated as 20 m^3 CH_4/year.

The emissions from systems for storage of anaerobically granulated sludge were set at 0 kg CH_4/year, since the emissions from this area are considered to be negligible. Expert assessment (Austermann-Haun & Witte, 2014). Similarly, the CH_4 emissions from disruptions were set at 0 kg CH_4/year.

Due to unfavourable conditions for methane formation, methane emissions from acidification reactors are negligible and are estimated at 0 kg CH_4/a.

The emission factor for emissions from wastewater ponds was calculated according to formula 6.5 and Table 6.8 ((IPCC, 2006a): Vol. 5, Chapter 6). For Bo, the IPCC default value was used; for the MCF, 0.2 was used, for a pond depth of no more than 2 metres.

The time series for the period as of 1990 was determined on the basis of trends in anaerobic industrial wastewater treatment – especially with regard to capacities for treatment of COD loads. The entire time series for the period from 1990 to 2013 was published in the 2015 NIR. Until the data is updated again, the figures from 2014 onwards will be extrapolated at a growth rate of 2 percent per year, assuming that there will be a moderate increase in the number of anaerobic plants (expert estimate). The following table provides an overview of the time series. The percentages listed show the changes relative to the reference year 2013. The table also

shows the annual COD loads that the calculation is based on. The calculations produce an implied emission factor of 1.86 kg CH_4/t COD.

Table 454: Calculation of CH_4 emissions from industrial wastewater treatment

	Anaerobically treated annual COD loads [t/a]	CH_4 emissionscompared to 2013 [kg CH_4/a]
1990	198,477	22%
1995	332,950	37%
2000	493,357	56%
2005	744,371	84%
2010	854,374	96%
2013	888,757	100%
2014	906,532	102%
2015	924,307	104%
2016	942,083	106%
2017	959,857	108%
2018	977,632	110%
2019	995,407	112%
2020	1,013,183	114%
2021	1,030,958	116%
2022	1,048,733	118%
2023	1,066,508	120%
2024	1,084,283	122%

The TOW figures for the individually considered subsectors are shown in (Austermann-Haun & Witte, 2014)/Table 9. For the chemical industry, the food industry and the paper and pulp industry, the total TOW was determined on the basis of an average COD concentration and the absolute wastewater quantity (Table 456). Until 2016, the underlying wastewater statistics were updated every three years. There was no update in 2019 for the first time. For this reason, the data is extrapolated from 2017 onwards, assuming an annual reduction in wastewater volume of 1% for the chemical industry and 1.5% for paper and cardboard production. For the food industry, the figure is still assumed to be constant. The extrapolation (expert estimate) was carried out on the basis of the developments of the previous years. However, this total TOW is not used in the formula $TOW_i = P_i \cdot W_i \cdot COD_i$ for calculating CH_4 emissions because, as described above, these were calculated using a country-specific method based on the sub-sector-specific TOW_i. In the country-specific approach, the fraction of anaerobically treated wastewater $\omega_{ANR,i}$ in the individual sectors and sub-ectors was taken into account in accordance with the formula term $TOW_i \cdot \omega_{ANR,i} \cdot \omega_{CSB,i} \cdot EF_{CH4,gelöst,i}$specified above, and the sector-specific achievable degradation rate $\omega_{CSB,i}$ and the temperature- and sector-dependent fraction of dissolved methane $EF_{CH4,gelöst,i}$ were applied to the sector-specific TOW_i. The sector-specific parameters are listed in the following Table 455 (cf. also Table 12 in (Austermann-Haun & Witte, 2014)).

The various subsectors differ in terms of the fractions of wastewater (cf. $\omega_{ANR,i}$ in Table 455) and thus of the total TOW that they treat in anaerobic installations. Only treated quantities of TOW can result in methane emissions. However, when deriving the IEF, the total TOW quantity for the category is used as the reference value, not just the anaerobically treated TOW quantity. This leads to comparatively very low IEFs.

Table 455: Parameters used to determine emissions of dissolved methane from anaerobic treatment of industrial wastewater (for reference year 2013)

WZ code	TOW_i [t COD/a] (rounded)	$\omega_{ANR,i}$ [%]	$\omega_{CSB,i}$ [$EF_{CH4,dissolved,i}$]	[kg CH_4/kg CSB_{eli}]%]
10.20 Fish processing	12,000	9.0	77.5	0.00455
10.31 Potato processing	47,000	35.6	85	0.00244
10.32 Manufacture of fruit and vegetable juices	12,000	96.3	80	0.00838
10.39 Other processing of fruit and vegetables	80,000	8.7	85	0.00097
10.51 Milk processing	109,000	7.3	77.5	0.00615
10.52 Production of ice cream	17,000	8.2	80	0.00196
10.61 Manufacture of grain mill products	no data	no data	80	no data
10.62 Manufacture of starches and starch products:				
– potato starch	1,000	94.0	75	0.00087
– wheat starch	18,000	36.0	75	0.00087
10.71 Production of baked goods	268,000	0.2	80	0.00093
10.81 Production of sugar	64,000	95.1	95	0.00085
10.82 Confectionary production	43,000	10.1	95	0.00165
10.83 Processing of coffee and tea, production of coffee substitutes	49,000	2.1	75	0.00067
10.84 Manufacture of condiments and seasonings	12,000	0.2	80	0.00395
10.85 Manufacture of prepared meals and dishes	no data	no data	80	no data
10.89 Manufacture of other food products				
– Baking yeasts	2,000	86.2	90	0.00223
– Other yeasts	7,000	32.1	90	0.00223
10.9 Production of animal feed	24,000	3.5	70	0.00258
11.02 Manufacture of wine from grapes	18,000	1.0	90	0.00177
11.05 Production of beer	88,000	28.0	85	0.00748
11.06 Production of malt	4,000	1.1	80	0.01236
11.07 Manufacture of soft drinks; production of mineral waters	21,000	5.2	80	0.00656
17.1 Manufacture of pulp, paper and paperboard	759,000	39.1	70	0.00578
20.14 Manufacture of other organic basic chemicals	no data	no data	80	no data

WZ code	TOW_i [t COD/a] (rounded)	$\omega_{ANR,i}$ [%]	$\omega_{CSB,i}$ [$EF_{CH4,dissolved,i}$]	[kg CH_4/kg CSB_{eli}]%]
20.15 Manufacture of fertilisers and nitrogen compounds	no data	no data	80	no data
20.16 Manufacture of plastics	no data	no data	72	no data
20.41 Manufacture of soap, detergents and cleaning and polishing preparations	no data	no data	80	no data
Total (rounded)	1,653,000			

no data: No data is available.

It was not possible to determine average COD quantities for other sectors. In addition to the sectors previously included, the 2006 IPCC Guidelines also provide default values for "Organic Chemicals", "Plastic & Resins" and "Soap & Detergents". In German statistics, these sources are grouped differently: Under the heading "Chemische Erzeugnisse" ("chemical products"), wastewater statistics list products with WZ 2008 Code 20. This group includes organic chemistry (WZ 2008 Code 20.14), plastics and resins (Code 20.1) and soap and cleansers (Code 20.4). Unlike Code 20.4, which reports on precursors, Code 22 lists plastic and rubber goods (end products). The default value reported in IPCC 2006 ((IPCC, 2006a): Vol. 5, Chapter 6) relates to precursors. The reporting to date thus already includes the required additional product categories. (IPCC, 2006a) notes that the default values have to be used with caution as they are specific to the industry, process and country.

Table 456: Calculation of the TOW for 2022, direct discharges

Industrial sector	Mean CSB [kg/m³]	Wastewater quantity [m³]	TOW [t CSB/year]
Chemical industry	3 [1)]	237,112,797	711,338
Food industry	3 [2)]	59,802,282	179,407
Paper and pulp industry	2 [2)]	177,220,171	354,440
TOTAL			1,245,186

1) 2006 IPCC Guidelines, (IPCC, 2006a): Volume 5, Chapter 6, Table 6.9

2) Expert estimate by German Environment Agency

7.5.2.1.3 Uncertainties and time series consistency (5.D.2 CH_4)

Experts put the uncertainty of the total methane emissions to be ± 50% due to a lack of data for some industrial sectors, differences between operating pressures in methane reactors, differences between the membranes used in gas storage systems and the unknown number of gas storage systems in operation.

7.5.2.1.4 Category-specific QA/QC and verification (5.D.2 CH_4)

General quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

The underlying research reports were reviewed and quality assured by technical advisors from the German Environment Agency as part of the approval process.

It is not possible to compare the results obtained using the selected country-specific method with results obtained using the method described in (IPCC, 2006a), as only the selected

approach is feasible due to technical constraints (cf. "Category description") and the available data. The data cannot be cross-checked against ETS data, since the described installations are not subject to emissions trading requirements.

In addition, comparative data from inventory reports from other countries were used to verify plausibility. For this reason, various countries with similar climatic and structural/technical conditions to Germany were selected from the 2020 inventory reports to be included in the 2021 inventory report.

- In its 2020 NIR, Austria modified its methodology. It now assumes that methane emissions from industrial wastewater treatment are equivalent to 1% of the quantity of CH_4 produced in anaerobic systems.
- In the Netherlands, methane emissions are reported on the basis of the IPCC default values in conjunction with country-specific data on TOW and other specific adjustments. No current information about the COD quantities treated in industrial wastewater treatment plants is available. This means that data availability is the limiting factor here as well. The data cannot be directly compared. No methodological changes relative to previous years were made.
- In Denmark, no distinction is made between industrial and municipal installations. The method is in accordance with the IPCC Guidelines.

A comparison of the IEFs for methane with the figures published in other countries' reports (GHG Locator 2023) shows that the IEF described here is lower – in some cases, considerably – than the other countries' figures. The reasons for this are that the methane emissions were determined using a country-specific method and only the TOW treated anaerobically can lead to methane emissions as described above.

Further verification is not possible, since no additional specific data for this category are available for Germany.

7.5.2.1.5 Category-specific recalculations (5.D.2 CH_4)

No recalculations are required.

7.5.2.1.6 Category-specific planned improvements (5.D.2 CH_4)

No further improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

7.5.2.2 Nitrous oxide emissions from industrial wastewater treatment (5.D.2 N_2O)

7.5.2.2.1 Category description (5.D.2 N_2O)

Nitrous oxide emissions can occur as a by-product of biological wastewater treatment with targeted nitrogen elimination, mainly during denitrification, but presumably also during nitrification. (cf. (IPCC, 2006a), Vol. 5, Chapter 6.1, p. 6.8), It is assumed that the reduction from N_2O to N_2 is hindered by various influencing factors, such as free oxygen, high concentrations of nitrite, ammonium and/or sulphides, thereby producing N_2O.((Austermann-Haun & Carozzi, 2011): page 2-12 ff).

The majority of industrial wastewater is treated in municipal wastewater treatment plants and taken into account accordingly in 5.D.1. For this reason, only direct industrial discharges are considered under 5.D.2.

7.5.2.2.2 Methodological issues (5.D.2 N_2O industrial)

he 2006 IPCC Guidelines do not contain any provisions or requirements for calculating 5 N_2O emissions from the industrial sector ((IPCC, 2006a): Volume 5, Chapter 6.3.4). Neither a relevant decision tree nor any higher-Tier calculation methods are available. The calculation methods presented in the following are thus seen in the context of the decision tree and the Tier classification for CH_4 (industrial). The approach used here is thus in accordance with a Tier 2 calculation method.

The statistical input data for 2020 was included in the inventory report. In general, due to the extremely small significance of this category, resource limitations and the large number data sources used, the statistical input data can be updated only at irregular intervals. In all other years, therefore, the data are carried forward from the last updated year.

To determine the nitrous oxide emissions from industrial wastewater treatment, a research project collected data on product-specific wastewater production, nitrogen concentrations and COD (chemical oxygen demand) for all industrial sectors and then determined annual nitrogen loads on the basis of annual production figures. The underlying data on nitrogen loads originated from information sheets of the DWA (Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e. V.; German association of the water, wastewater and waste management industries) and reflect the current state of scientific research. The statistical data used are taken from annual publications of the Federal Statistical Office and are documented in the German Environment Agency's internal calculations. With a few exceptions, the activity data is provided directly by the Federal Statistical Office. Also, queries can be submitted on the Federal Statistical Office's "Genesis-Online" website. In addition, brewery industry statistics are used, and data on milk processing and sugar production are obtained from the Federal Agency for Agriculture and Food (BLE). Data on the processing of animal by-products are obtained from Servicegesellschaft Tierische Nebenprodukte mbH.

The process used to calculate nitrous oxide emissions is outlined in detail in (Austermann-Haun & Carozzi, 2011). A COD:N ratio < 40 served as the threshold criterion for assuming a nitrogen surplus in the wastewater of a given sector that can cause nitrous oxide emissions in subsequent biological wastewater treatment. Only when there is so much nitrogen in the wastewater that, after incorporation into the biomass, there is still some residue that must be removed by biological nitrogen elimination, can it be assumed that nitrous oxide may be emitted during biological wastewater treatment. Similar values related to the design of denitrification systems are provided in ATV-DVWK-Arbeitsblatt A 131 (worksheet A 131 of the German association of the water, wastewater and waste management industries (DWA)). For the sake of simplicity, the nitrogen load is assumed to be 2 to 2.5% of the COD concentration (2.5% is equivalent to a COD:N ratio of 40:1). Through the compilation of data, the six most relevant industrial sectors were identified, which together account for approximately 75% of the nitrogen load from industrial wastewater treatment (Austermann-Haun & Carozzi, 2011). These include:

- Slaughterhouse and meat-processing operations,
- Milk processing,
- Processing of animal by-products,
- Beer production,
- Sugar production,
- Wheat starch production.

Data for the textile industry (7.5% of the total nitrogen load) and potato processing (2.6% of the total nitrogen load) were included, since the wastewater from these areas has a COD:N ratio greater than 40 and thus, according to the findings of the research report, does not lead to formation of nitrous oxide. Production of potato starch is not considered relevant with regard to formation of nitrous oxide – that area accounts for less than 0.4% of the total nitrogen load in wastewater. The remaining approx. 15% of the total nitrogen load is spread over many individual sectors with unclear data situations (especially the ratio COD:N). Most of these sectors discharge their nitrogen loads into municipal wastewater treatment plants as indirect dischargers and are already taken into account in the emissions reporting under 5.D.1.

The annual nitrogen load discharged into raw water is determined on the basis of the average product-specific nitrogen load of the six industrial sectors mentioned and using annual production figures. It is assumed that organisational and technical measures have led to a gradual reduction to 2010 levels and that the amount of nitrogen discharged into wastewater was 30% higher in 1990 (expert estimate). For the years 1990 through 2000, annual nitrogen load reductions of 2 percentage points are assumed, while one percentage point reductions are assumed for the period 2000 through 2010 (expert estimate). As of 2010, the nitrogen load per cubic metre of wastewater is assumed to be constant (expert estimate).

The activity data calculation was carried out as follows:

Equation 102:

$$AD = \sum_B [NF_B \times PZ_B \times 10^{-6}]$$

where

- AD = Total activity data [t N/a][t N_Z/a] = average N load in the inflow = N_Z
- NF_B = Average specific N load for the relevant sector [g N per unit]
- PZ_B= Production figures for the year 2010 for the relevant sector [number of units/a]
- 10^{-6}= Factor for conversion of g into t

The N_2O emission factor was determined, in the aforementioned research project by analysing various data from the literature. From these data, a weighted mean value was formed. As a result, it was found that 1% of the nitrogen load in a wastewater treatment plant is emitted as N_2O-N (cf. also Chapter 7.5.2.2.4).

Equation 103:

$$N_2O = EF \times AD \times 44/28$$

where

- N_2O = N_2O emissions in t N_2O/a
- EF= Emission factor 0.01 t N_2O-N/t N
- 44/28 = Stochiometric conversion factor of N_2O-N in N_2O

In addition, the share of direct dischargers was determined for the individual sectors and taken into account in the calculation.

The formula above yields the IEF:

Equation 104:

$$IEF[N_2O\text{-}N]: EF \times 44/28 = 0.01 \times 44/28 \text{ kg } N_2O/\text{kg N} = 0.0157 \text{ kg } N_2O/\text{kg N}$$

The nitrous oxide formation rate in the sectors considered differs significantly from the corresponding formation rate in municipal wastewater treatment plants; the rate for industrial wastewater treatment plants is higher by a factor of 100 than that for municipal plants. This is due to the above-described COD:N ratio and the resulting better conditions, in industrial plants for N_2O formation.

7.5.2.2.3 Uncertainties and time series consistency (5.D.2 N_2O)

The uncertainties in the production figures originate from the federal statistics, and other statistics, all of which are based on exhaustive surveys. The uncertainties for the data are thus likely to be very low. The production statistics are updated annually, and the wastewater statistics are updated at three-year intervals. Wastewater statistics, with data for the current report year, do not appear until after the editorial deadline for the NIR.

In the aforementioned research project, the N_2O emission factor was estimated by experts to have a very high uncertainty of -90%/+310%.

The mean specific nitrogen loads of the various industries are subject to the following uncertainties (Table 457), which were determined by expert estimates. In a conservative estimate, the uncertainty for the total nitrogen load (activity data) is assumed to be -50%/+50% (expert estimate)

Table 457: Uncertainties in the mean specific nitrogen load of the most relevant industrial sectors

Mean spec. N load of the industrial sector	Upper bound	Lower bound
Slaughtering of swine	40	40
Slaughtering of sheep	50	50
Slaughtering of goats	50	50
Slaughtering of cattle	40	40
Slaughtering of horses	50	50
Slaughtering of poultry	40	40
Processing of meat	40	40
Processing of animal by-products	20	20
Milk processing	15	15
Manufacture of beer	30	30
Manufacture of sugar	30	30
Wheat starch production	30	30

7.5.2.2.4 Category-specific QA/QC and verification (5.D.2 N_2O)

General quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

The underlying research reports were reviewed and quality assured by technical advisors from the German Environment Agency as part of the approval process.

The activity data is mainly derived from national statistics and have been reviewed for any conspicuous changes relative to the previous year. Larger changes can be explained as the result of climatic effects (impacts on harvests) and structural changes.

A comparison of Germany's N2O-IEF (determined as part of national calculations; cf. Chapter 7.5.2.2.2) with those of other reporting countries (GHG Locator 2023 (UNFCCC, 2023a)) shows that, at 0.0157 kg N_2O/kg N, Germany's value lies clearly within the range formed by the values of the reporting countries.

The data cannot be cross-checked against ETS data, since the described installations are not subject to emissions trading requirements. The described activity data originated from the public statistics of the Federal Statistical Office with the exception of the data for processing of animal by-products; these data were taken from the report of the "Servicegesellschaft tierische Nebenprodukte" (animal by-products service company). No further activity data is available to verify plausibility.

In addition, comparative data from inventory reports from other countries were used to verify plausibility. To this end, for the 2021 inventory report, various countries with climatic conditions, and structural/technical frameworks, similar to those of Germany were selected from the 2020 inventory reports:

- In Austria, N_2O emissions from industrial wastewater treatment are now being determined for the first time using a country-specific method. A detailed comparison cannot be carried out, however, since the method is described in an unpublished report from 2019.
- In the Netherlands, N_2O emissions from industrial wastewater treatment are classified as irrelevant in comparison to N2O emissions from municipal wastewater treatment, and they are not reported, making a comparison impossible.
- In Denmark, industrial wastewater treatment is considered using a country-specific method. Denmark's method is similar to the approach used by Germany. An emission factor EF_{N20} of 0.0032 was used directly.

A review of literature on nitrous oxide emissions from wastewater treatment was conducted in (Austermann-Haun & Carozzi, 2011). The emission factors used in this context were taken from this study.

Further verification is not possible, since no additional specific data for this category are available for Germany.

The approach used differs from the IPCC default method in (IPCC, 2006a), Vol. 5, Chapter 6.3.1.2, page 6.25. The IPPC specifies a value range of 0.0005 – 0.25 kg N_2O-N/kg–N (default: 0.005 kg N_2O-N/kg–N). As a result of the research project described above, a country-specific emission factor of 0.01 kg N_2O-N/kg–N was determined and used for emission reporting. The emission factor used is therefore twice as high as the default value, but still within the specified range.

7.5.2.2.5 Category-specific recalculations (5.D.2 N_2O)

No recalculations are required.

7.5.2.2.6 Category-specific planned improvements (5.D.2 N_2O)

No further improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

7.6 Other sectors (5.E)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	Fraction [%]	2024 (kt CO_2-e.)	Fraction [%]	Trend [%] 1990-2024
-/-	5 E, Other		CH_4	0.00	0.00	2.36	0.01	0.00
-/-	5 E, Other		N_2O	0.00	0.00	25.90	0.01	0.00

The category 5.E – Other is not a key category.

At present, only emissions from mechanical-biological waste treatment are reported in category 5.E. Other.

Emissions from accidental fires in buildings and vehicles are also assigned to this category, but this is of no current relevance with regard to greenhouse gases, since such emissions from accidental fires account for less than 0.05% of the total inventory (without LULUCF). Furthermore, they account for considerably less than 500 kt UNFCCC CO_2-equivalents, and it cannot be guaranteed these emissions will be recorded annually (UNFCCC, 2013). The theoretical time series is below 100 kt CO_2-equivalents per year, assuming that less than 20% of the material burned is of fossil origin (expert estimate without suitable activity data). A description of the method for calculating emissions of particulates and other pollutants was provided in the inventory report for the Convention on Long-range Transboundary Air Pollution (CLRTAP)[105].

7.6.1 Other areas – mechanical-biological waste treatment (MBT) (5.E Other MBT)

7.6.1.1 Category description (5.E Other MBT)

Gas	Method used	Source for the activity data	Emission factors
C_H4	Tier 2	NS	CS
N_2O	Tier 2	NS	CS

In Germany, a distinction is made between biological treatment of separately collected biowaste (cf. 7.3) and biological treatment of residual waste. The purpose of biowaste treatment is to produce compost (cf. 7.3.1) or digestates (cf. 7.3.2) that can be used as fertiliser. Biological treatment of residual waste, which normally has a high organic fraction, takes place in mechanical-biological waste treatment (MBT) facilities, and serves as pretreatment prior to landfilling or energy-related uses. The emissions control requirements for the treatment of

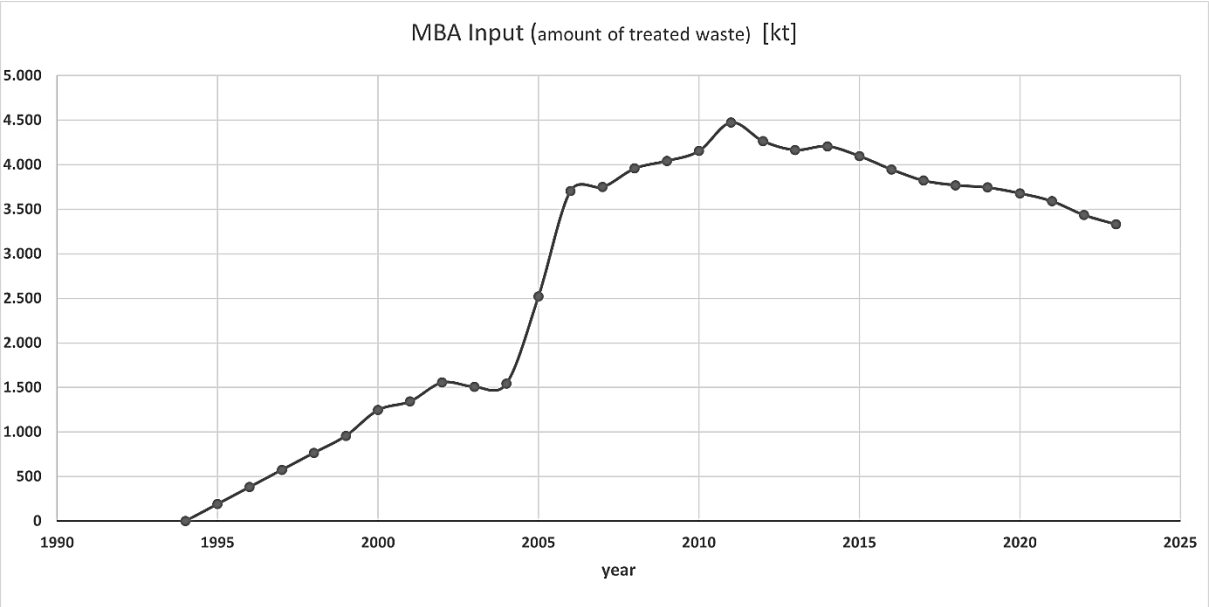
[105] Informative Inventory Report – Germany http://iir.umweltbundesamt.de

residual waste are stricter than those for biowaste treatment. For this reason, the emission factors for MBT are considerably lower than those for composting and digestion of biowaste. The respective waste streams are separately recorded in federal statistics.

Since the 1990s, mechanical-biological processes have been used on a large scale in Germany for residual waste treatment. Initially, simply designed systems without exhaust gas collection and treatment were the norm. As processes have improved, however, closed systems, with biofilters for waste gas scrubbing have gradually become prevalent. While the waste gas scrubbing processes used by these plants have significantly reduced the plants odour emissions, they have not reduced greenhouse gas emissions.

Landfilling of organic and biologically degradable waste has been prohibited in the Federal Republic of Germany since 1 June 2005. Residual municipal waste and waste of similar composition can therefore only be landfilled after pre-treatment. In addition to thermal waste treatment processes (waste incineration), mechanical-biological processes are also used, the capacities of which were significantly expanded when untreated waste disposal ended in 2005 (see Figure 111).

Figure 111: Development of input quantities for mechanical-biological waste treatment plants in Germany



Source: own illustration, German Environment Agency

The 30th Ordinance Implementing the Federal Immission Control Act (BFJ & BMJ, 2017) imposes stringent technical specifications and standards for new MBT plants as of 1 March 2001. The transitional provisions for old plants called for these plants to be retrofitted by no later than 1 March 2006. Based on current technology, the emission values specified in the 30th Ordinance on the Implementation of the Federal Immission Control Act can only be reliably complied with using thermal exhaust gas treatment processes (e.g. regenerative thermal oxidation – RTO).

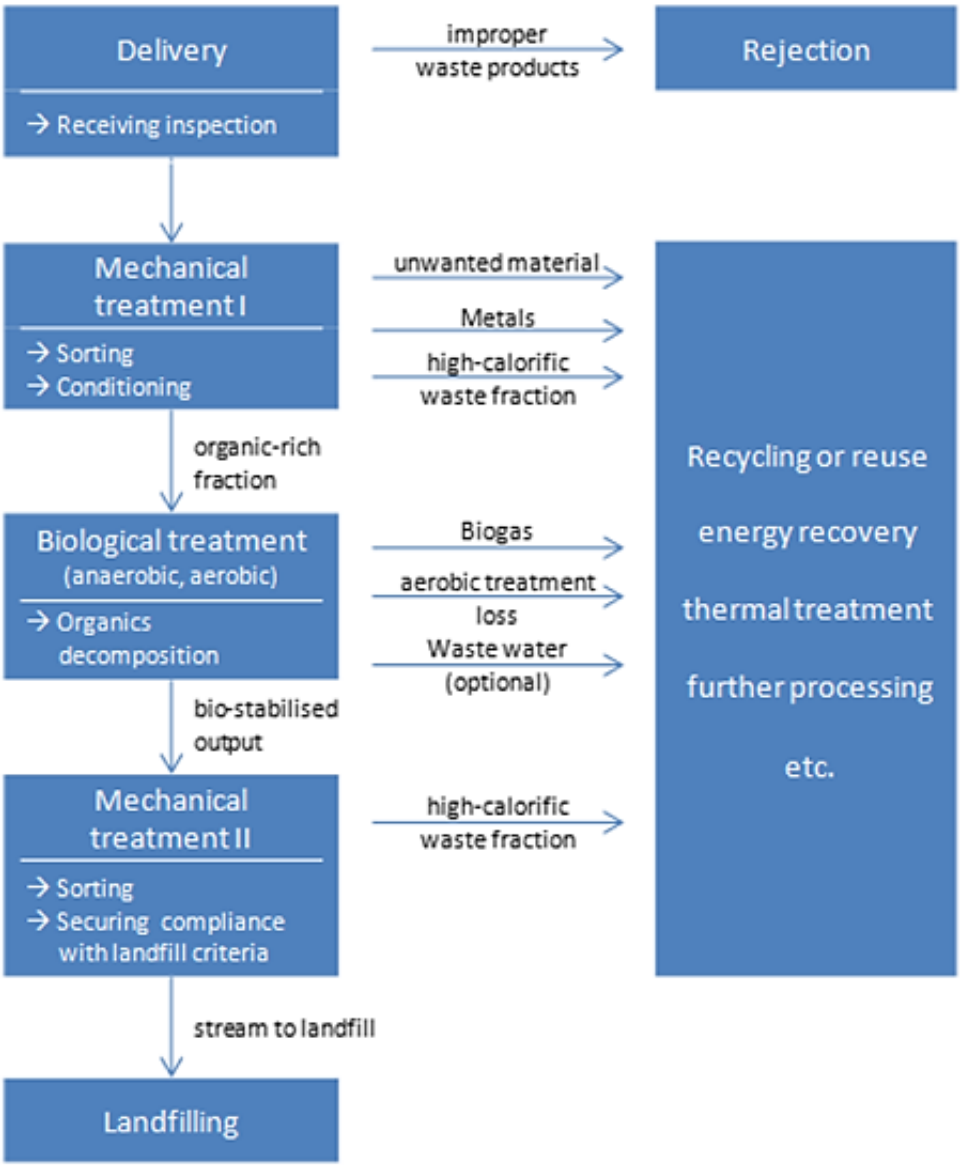
For MBT installations, the 30th Ordinance on the Implementation of the Federal Immission Control Act limits total organic carbon (TOC) emissions loads to 55 g per tonne of treated waste and N_2O loads to 100 g per tonne of treated waste. Several reviews have shown that all German installations are well within the emission limits, and in many cases are significantly below them

(cf. Table 458). The emissions limits and the emission factors relate to wet material; waste quantities are recorded accordingly when delivered to the installations.

Nearly all new facilities were commissioned sometime in 2005. Due to expansions and adjustments to the treatment technology, almost all of the old plants were already adapted to the requirements of the 30th Ordinance on the Implementation of the Federal Immission Control Act in 2005. As it was not possible to allocate waste quantities to the various plant technologies during the transition period in 2005, it was also not possible to differentiate emissions. For this reason, emissions up to and including 2005 are calculated entirely using the higher emission factors of the older waste gas scrubbing systems. Emissions as of the year 2006 are calculated with the lower emission factors for the new (or modernised) facilities.

In 2023, about 3.3 million t of waste was treated annually in mechanical-biological waste treatment plants in Germany. The treatment process generates around 2.9 million tonnes of residues, of which 0.78 million tonnes are waste for disposal (a high fraction is sent to landfill), 1.9 million tonnes are waste for re-use (largely substitute fuels) and 0.04 million tonnes are other residues (e.g. secondary raw materials and products) (all data: (Statistisches Bundesamt); GENESIS-ONLINE; Table 32111-0003). In addition, during the treatment process, a total of 0.4 million tonnes of mass is lost through the biological degradation of organic components and the evaporation or discharge (wastewater) of the water contained in the waste.

Figure 112: Substance flow scheme for mechanical-biological waste treatment (MBT)[106]



Source: own illustration, German Environment Agency

7.6.1.2 Methodological issues (5.E Other: MBT)

The calculation method is in accordance with the standard calculation method:
AD x EF = Emissions

Activity data (AD):

MBT plants have only been operated in Germany since 1995. The data from the Federal Statistical Office, which has been collecting these figures regularly since 1995, are used for reporting purposes. Up to and including 2019, these data were published by the Federal Statistical Office as "Fachserie 19, Reihe 1" (Statistisches Bundesamt, 2019). The publication was discontinued in 2020 and the Federal Statistical Office has been providing the activity data since then via GENESIS-ONLINE ((Statistisches Bundesamt), Table 32111-0003).

[106] Source: VDI 3475 Blatt 3, emissions reduction - installations for the MBT of settlement waste, 2006-12 (amended)

Emission factors (EFs)

In the 1990s, emissions from mechanical-biological waste treatment were studied in a major collaborative research project supported by the Federal Ministry of Education and Research (BMBF). In a project carried out in 2003, the Institute for Energy and Environmental Research (Detzel et al., 2003) refined the emission factors developed by the collaborative research project. A distinction was made between mechanical-biological waste treatment processes that were open (no waste gas collection and treatment) and closed (waste gas collection with treatment in a biofilter) MBA processes. For methane, the emission factors for both types of processes were considered to be the same, since biofilters achieve virtually no reductions of methane quantities. The N_2O emission factor was set higher for closed systems than for open systems, as N_2O is also formed in the biofilter through the oxidation of ammonium nitrogen.

For open mechanical-biological waste treatment facilities, the following emission factors resulted:

$EF\text{-}N_2O = 190$ g N_2O/t waste

$EF\text{-}CH_4 = 150$ g CH_4/t waste

For closed MBT facilities with biofilters and for the period prior to 2005, the same study determined the following emission factors:

$EF\text{-}N_2O = 375$ g N_2O/t waste

$EF\text{-}CH_4 = 150$ g CH_4/t waste

Since June 2005, as a result of new legal requirements(BFJ & BMJ, 2017), all MBT plants in operation are closed facilities with more effective waste gas scrubbing processes that naturally lead to lower emission factors. The 30th Ordinance on the Implementation of the Federal Immission Control Act requires continuous emissions measurements for organic substances and N_2O, and it limits the permissible emissions loads. The emissions loads are determined on the basis of the monthly average concentrations, measured as half-hour averages, and of the waste quantities treated in the corresponding monthly period.

To assess this new situation, the emission data for mechanical-biological treatment (MBT) plants determined by the German Environment Agency in cooperation with the Working Group on Material Flow-Specific Waste Treatment (ASA, association of MBT plant operators) as part of the data collection for the revision of the Best Available Techniques Reference Document "Waste Treatment" in 2013 was used (Cuhls & Kühle-Weidemeier, 2013). The emissions data for methane and N_2O were well below the permissible limits (Table 458).

Table 458: MBA emissions

Emission parameter (waste gas)	Framework conditions (normal conditions)	Emission ranges 16 plants		Emission factor (average value)	Maximum permitted levels 30th BImSchV
Total carbon ($C_{total.}$)	Monthly averages: Load in g C_{total}/t waste, calculated from half-hourly averages	Lower values	2.3-21.8		55
		Median	8.36-30.7	19.5	
		Upper values	10.6-44.0	(26.1 g CH_4/t)	
Nitrous oxide (N_2O)	Monthly averages: Load in g N_2O/t waste, calculated from half-hourly averages	Lower values	0.01-33.3		100
		Median	1.54-59.0	30.3	
		Upper values	6.23 - 108		

The emissions data reported in the survey are representative for existing German installations and take all MBT types used in Germany into account. The data requested in the survey include the ranges of the emissions loads for the respective installations. In responses from a total of 16 plants, the lower values of the emission ranges for the individual plants were between 2.3 to 21.8 g/t waste for C_{total} and from 0.01 to 33.3 g/t waste for N_2O. The upper values of the ranges were between 10.6 and 44.0 g/t waste for C_{total} and between 6.23 and 108 g/t waste for N_2O. The medians of the individual plants ranged from 8.36 to 30.7 g/t waste for C_{total} and from 1.54 to 59.0 g/t waste for N_2O.

On the basis of this survey, the emission factors for years as of 2006 have been aligned with the actual plant emissions.

For the emission factors, in each case the average values of the lower and upper emissions values were used; i.e.:
EF-N_2O = 30.3 g N_2O/t waste
EF-CH_4 = 26.1 g CH4/t waste (under stoichiometric conversion, 19.5 g C_{total} is equivalent to 26.1 g CH4; 12 g C = 16 g CH_4)

7.6.1.3 Uncertainties and time series consistency (5.E Other MBT)

The uncertainties for mechanically-biologically treated waste quantities are considered to be very small (2%), since the data were obtained in an exhaustive survey, the quality of reporting to the Federal Statistical Office is good and operators have an interest in high-quality reporting. The uncertainties for the emission factors for the period prior to 2005 depend on the type of facility/plant in question, on the type of process used at the relevant time and on the effectiveness of the biofilters used. As the data from the literature varies greatly, the results of the underlying research project (IFEU, see above) determined the uncertainties for methane to be ±60% and for nitrous oxide to be ±100% (open MBA) and ±60% (closed MBA).

As of 2006, all installations in operation are closed installations with waste air collection and treatment. Emissions of CH_4 and NO_2 are measured continuously, but they fluctuate over a wide range in all individual plants, depending on operating conditions and the composition of the waste. Due to this fact and the high quality of the database, experts at the German Environment Agency estimate the uncertainties for the period from 2006 onwards to be ±20%.

For technical reasons, it is not possible to show the resulting jump in the uncertainties, over the course of the time series, within the Central System of Emissions (CSE). For this reason, a prioritisation has been carried out whereby quantification of the uncertainties for the current values is considered to be much more important. Consequently, as of the 2022 report, the uncertainties have been adjusted to ± 20% over the entire time series. The reference value for 1990 is not affected by this adjustment, since GHG emissions of MBT have been reported only since 1995.

7.6.1.4 Category-specific QA/QC and verification (5.E Other MBT)

General quality control and a quality assurance have been carried out by category experts and the Single National Entity, in conformance with the requirements of the QSE-manual and its associated applicable documents.

A comparison with the reports of other countries was carried out in connection with the 2021 report. In the process, it emerged that a comparison is not possible, because Germany is so far the only country that reports GHG emissions of MBT in its national greenhouse-gas inventory;

consequently, no IEFs from other countries are available for a comparison. A review of this assessment in the course of the 2025 reporting showed that this remains the case.

7.6.1.5 Category-specific recalculations (5.E Other MBT)

In each case, when the inventory data for the current year are being prepared, the most recent available statistical data on treated quantities of waste are the data for the previous report year, because the Federal Statistical Office's waste quantities appear with a one-year time lag (cf. Chapter 7.6.1.2, activity data). The figures for the current report year, therefore, have been extrapolated on a linear basis from the trend of the last two previous years. This update will be replaced by the current data in the following year. For this reason, annual recalculations for the previous year are necessary.

Table 459: MBA recalculation for 2023

	Units		
Waste quantities treated	[kt]	2026 submission	3,331.0
		2025 submission	3,281.0
CH_4	[kg]	2026 submission	86,939
		2025 submission	85,634
N2O	[kg]	2026 submission	100,929
		2025 submission	99,414

7.6.1.6 Planned improvements, category-specific (5.E Other MBT)

No further improvements are planned at present.

Where improvements have been mentioned in previous reports in this chapter, these can be found in the form of an overview in the Chapter 10.4 Improvements in the inventory, Table 468. Improvements that have been completed are listed in Table 467 in the same chapter.

8 Other (CRF Sector 6)

In accordance with recommendations made by the UNFCCC Expert Team in the 2016 In-Country Review, no greenhouse gases are reported in CRF Category 6. In CRF 6, the total emissions of GHG precursors, except for NH_3 from LULUCF and agriculture, are reported.

9 Indirect CO_2 & N_2O

9.1 Category description (Indirect emissions)

The indirect emissions category reports greenhouse gas emissions (CO_2 and N_2O) that arise from the conversion of emitted gases, which themselves have no direct greenhouse effect, in the atmosphere (CO and NMVOC to CO2) or in water and soil (NO and NH3 to N2O).

Indirect emissions occur in the categories CRF 1.A, CRF 2.D.1 & 3, CRF 3 and CRF 4. The descriptions of the indirect emissions sources are presented in the respective source category chapters.

9.2 Methodological issues (indirect emissions)

Indirect CO_2 emissions from CO and NMVOC are not explicitly calculated in the inventory. However, they are indirectly taken into account as CO_2 in the following CRF via the specified/used calculation method:

- CRF 1.A: Since the emissions are calculated on the basis of a carbon mass balance, indirect CO_2 is taken into account using the calculation method. It cannot be listed separately, however.
- CRF 2.D.1 & 3: NMVOC emissions are converted and reported on the basis of the carbon content in CO_2 emissions.

Indirect N_2O emissions from NO_x and NH_3 are only reported in very few individual cases for the national inventory. These include:

- CRF 3: Indirect N_2O from atmospheric deposition and leaching/surface runoff are reported in CRF Tables 3.B(b) and 3.D.
- CRF 4: Indirect N_2O from leaching/surface runoff are reported in CRF 4(III).

On the basis of the 2018 ARR result (G.11, Table 6) and its reiteration in the 2020 ARR (G7, Table 3 2020), the indirect N_2O emissions of the agriculture and LULUCF sectors are reported using the notation key “IE.” This process was confirmed in the 2020 Review. “NE” is reported for the energy, IPPU and waste sectors.

9.3 Uncertainties and time series consistency (indirect emissions)

Uncertainties and time series consistencies are described in the respective chapters for CRF 1.A, 2.D.1, 2.D.3, 3 and 4.

9.4 Category-specific QA/QC and verification (indirect emissions)

Category-specific QA/QC and verification are described in the respective chapters for CRF 1.A, 2.D.1, 2.D.3, 3 and 4.

9.5 Category-specific recalculations (indirect emissions)

Any required recalculations are described in the respective chapters for CRF 1.A, 2.D.1, 2.D.3, 3 and 4.

9.6 Planned improvements, category-specific (indirect emissions)

Currently planned improvements are described in the respective chapters for CRF 1.A, 2.D.1, 2.D.3, 3 and 4.

10 Recalculations and improvements

10.1 Explanation and justification of the recalculations

10.1.1 General procedure

There are a number of other reasons, in addition to the need for corrections, why recalculations and improvements are necessary:

- Additional data become available that make it possible to close gaps in the inventory.
- A data source has changed.
- The method used for the source category was adapted to the requirements in the *Good Practice Guidance*.
- The source category has become a key category requiring a change in the methodology.
- New country-specific calculation methods are used.
- Comments and findings from reviews have been implemented.

10.1.2 Recalculations in the 2026 inventory, by source categories

This year's retroactive calculations are due to various methodological adjustments, some of which resulted in significant changes in the source categories concerned, as well as further improvements in detail.

The inventories contain improvements in the following areas (unless otherwise indicated, in each case the changes relate to the entire time series):

Energy

In source category 1.A, the revision of the energy balances for 2003 to 2022 and the availability of the final balance for 2023 for the various fuels will result in more or less significant retroactive calculations.

At the same time, the recalculations made compared to Submission 2025 also result from revised emission factors. This included updating, standardising and consolidating commonly used carbon dioxide emission factors.

(in addition, excerpts)

- Mobile emitters in 1.A.2.g vii, 1.A.4.a ii, b ii and c ii: revised percentages of inland sales pursuant to Energy Balance Line 67 National
- 1.A.1.b+c, 1.A.2.g viii: Revision of activity data calculation due to changes in the structure of the data sources used, from 2003
- 1.B.2.a: New findings from research projects on the storage of mineral oil products, from 1990

Industrial processes & product use

- 2.B.9.b: Implementation of current research findings on SF_6 emissions, 2014 and 2023
- 2.B.10: Implementation of results from research projects for CH_4

- 2.C.1: Implementation data for the final Energy Balance 2023
- 2.C.2: Adjustment of production volumes 2021–2023
- 2.D.2, 2.G.4 Charcoal: Adjustment of foreign trade statistics 2023
- 2.F.1: Recalculations based on publications of the Federal Statistical Office
- 2.F.2: Recalculation of previous year's domestic consumption of HFC-134a, HFC-152a, HCO-1234ze
- 2.F.3: Revision of HFC-236fa stock emissions, 2004 to 2023
- 2.F.4: Recalculation of application emissions HFC-134a And HFC-227ea 2022 and 2023
- 2.G.2.c Correction of calculation process, from 1995
- 2.G.4: Revision in accordance with new research on domestic new consumption HFC-245fa, from 2018

Agriculture

- 3.B, 3.D: New model for the spatial and temporal distribution of substrates containing nitrogen
- 3.D: Correction EF(NH3) for synthetic fertiliser from EMEP (2023)
- 3.D: Application of climate-specific EFs according to IPCC (2019) for emissions from grazing and indirect emissions from deposition
- 3.A+B, dairy cows: Change in derivation of N excretion, improved calculation method for milk yields; pigs: Breakdown of young and old sows; game in enclosures: Correction of animal numbers, from 2009
- 3.B, horses: Update of N and VS excretions
- 3.D, Manure imports: Correction of Dutch export data, from 2010 onwards; harvest residues: Update of quantity of grassland waste
- 3.J, Digestion: Change in shares of manure for digestion
- 3.D, N mineralisation mineral soils: New designation of N mineralisation in grassland
- 3.D, Cultivated organic soils: Change in total area due to data update in CRF 4

Land use, land-use change and forestry:

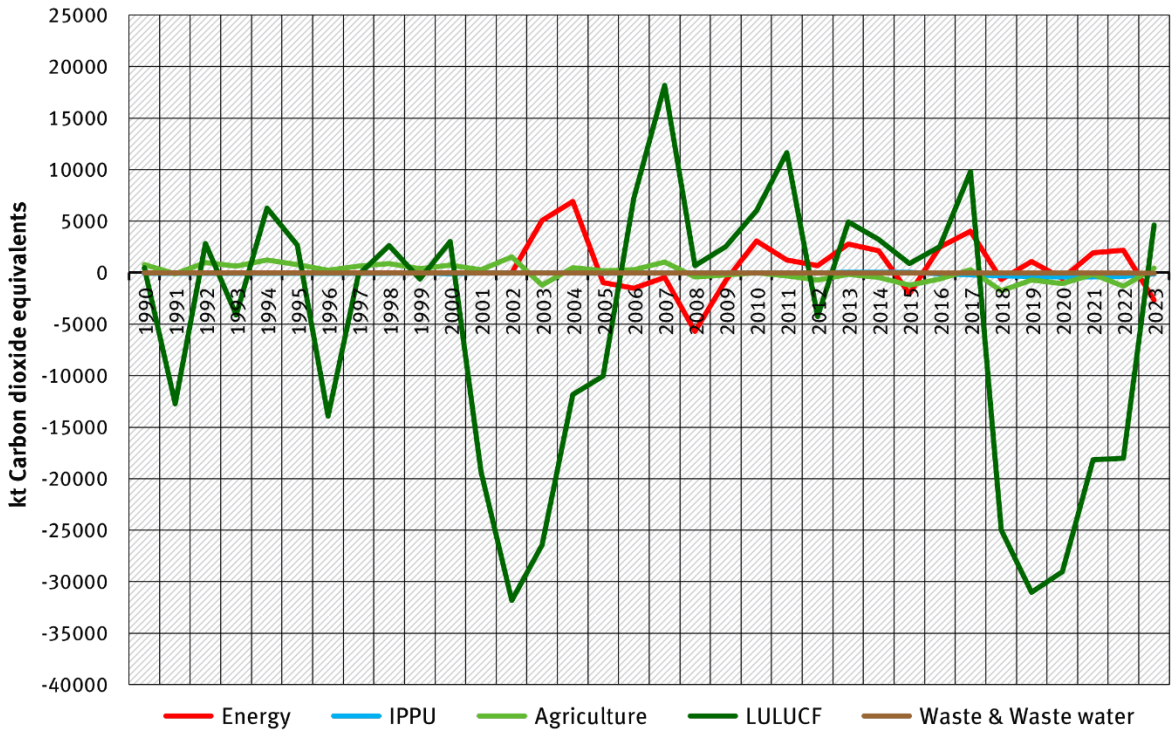
- 4.A: Modification of input data for computer-based modelling with YASSO15
- 4.A-E: Modification of hydrological model for calculating groundwater levels in organic soils; new method for determining land use prior to 2010
- 4.B: Modification of model for calculating carbon stocks in mineral soils on cropland; implementation of individual site calculation
- 4.B-E: Explicit inclusion of orchard meadows; reported under fruit growing

- 4.D: Breakdown of "natural water bodies" into the subcategories "rivers" (wetr) and "lakes" (wetl)
- 4.E: Correction of C stock by sealing factor for settlement/open areas and virtual correction of mass balance
- 4.E: New model for determining the development of perennial phytomass in settlement areas, new sealing factor and new distribution coefficients for different plant types
- 4.E: New land use category "Photovoltaic areas "under LUC Settlements

Waste and wastewater:

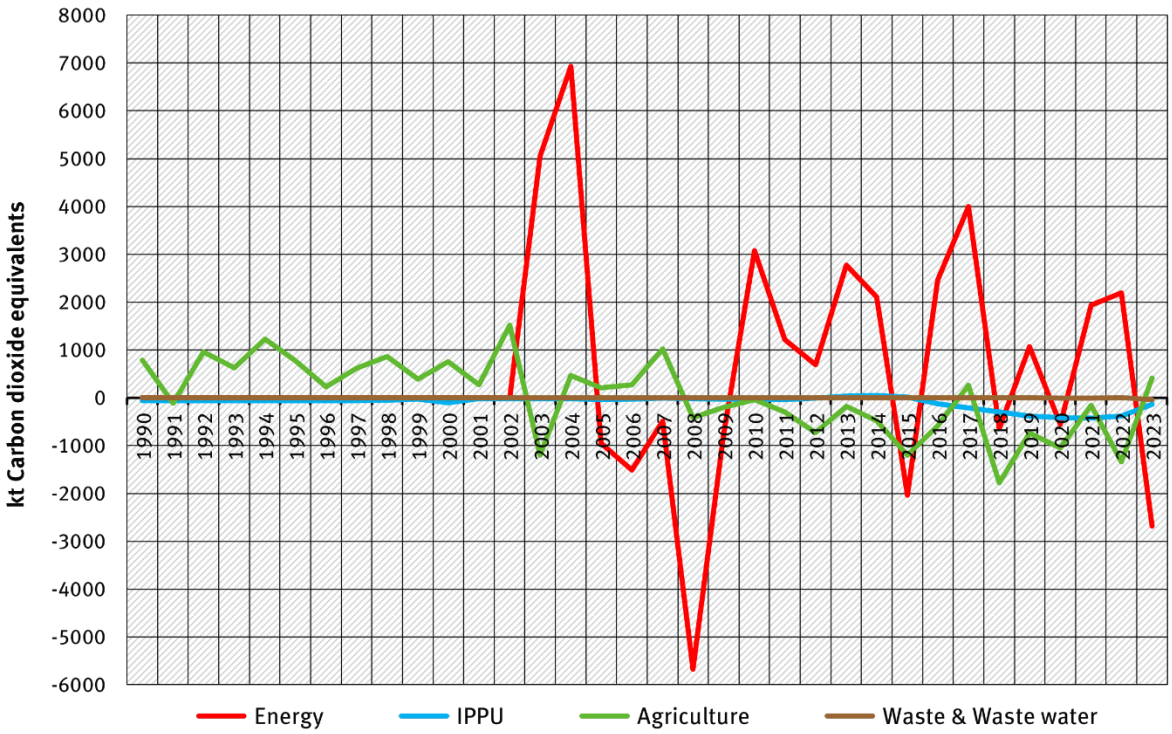
- 5.A.1, 5.B.1, 5.B.2, 5.E.1: Routine update of statistical data for the previous year
- 5.D.1, CH_4 + N_2O: Update of population figures from 2022, impact on all years from 2020

Figure 113: Change in total emissions across all categories relative to the 2025 submission



Source: own illustration, German Environment Agency

Figure 114: Change in total emissions across all categories relative to the 2025 submission, without LULUCF



Source: own illustration, German Environment Agency

10.1.3 Recalculations in the 2026 inventory, by substances

Recalculations were carried out in the following categories (cf. also specifications in 10.1.2):

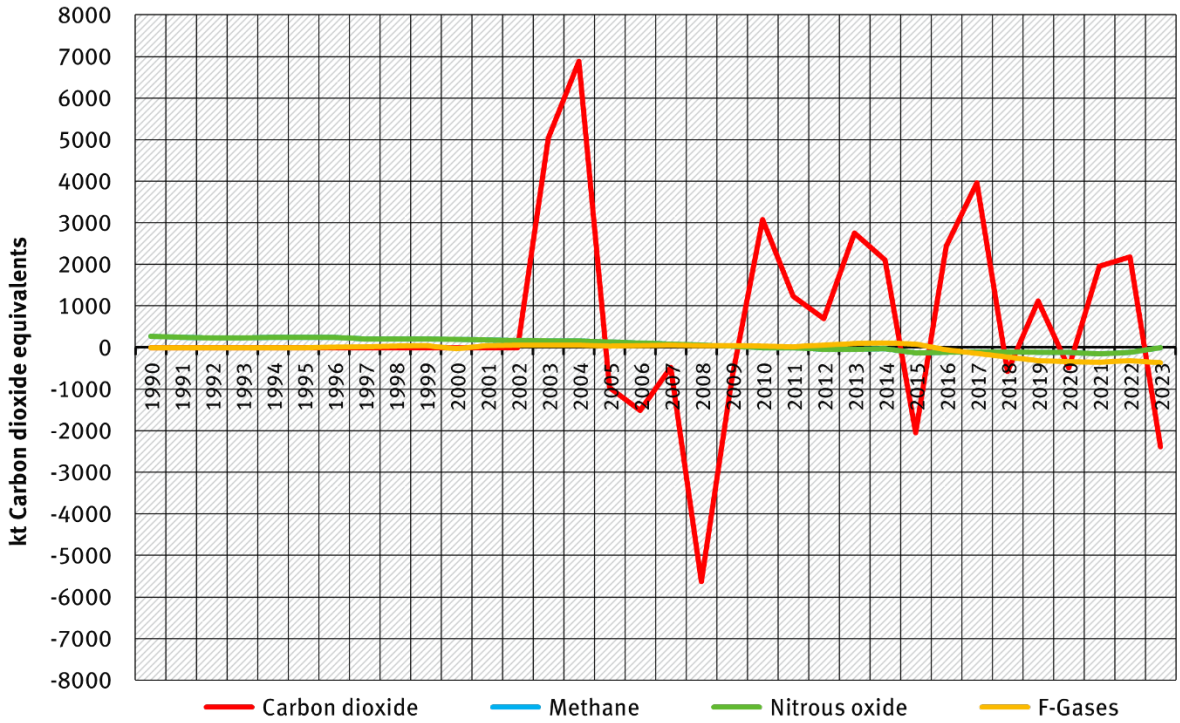
Table 460: Overview of the recalculations of the higher-level CRF categories affected

CRF	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NF_3
1 – Energy	x	x	x				
2 – Industrial processes & product use	x	x	x	x	x	x	
3 – Agriculture	x	x	x				
4 – LULUCF	x	x	x				
5 – Waste & wastewater		x	x				

Table 461: Changes (expressed as a percentage) relative to the previous year's reporting

		Base year	2005	2023
Total (CO_2-eq.)		0.06%	-0.08%	-0.36%
CO_2	1990:	0.00%	-0.11%	-0.40%
CH_4		0.20%	0.19%	-0.01%
N_2O		0.89%	0.02%	1.31%
F gases	1995:	0.01%	0.22%	-3.83%

Figure 115: Recalculation of ´the total emissions of individual greenhouse gases across all categories relative to the 2025 submission



Source: own illustration, German Environment Agency

With respect to the 2025 submission, a number of recalculations were carried out as the result of provided information or of recommendations from reviews. Details in this regard are provided in the respective chapters for the affected sectors.

10.2 Impact on emissions levels

The changes relative to the 2025 submission are similarly minor, at plus 0.06% for 1990, minus 0.08% for 2005 and minus 0.36% for 2023, as in the previous submission.

Table 464 to Table 466 show the changes in emissions as reported for 1990, 2005 and 2023 for the various CRF sectors.

The inventory has been further improved with regard to completeness and accuracy.

Table 462: Recalculation of total national GHG emissions (without LULUCF)

	2025 submission	2026 submission	Change relative to 2026 submission	
1990	1252397	1253128	731	0.06%
1995	1122691	1123404	713	0.06%
2000	1042347	1042998	651	0.06%
2005	989744	988947	-797	-0.08%
2010	930250	933250	3000	0.32%
2011	906735	907615	880	0.10%
2012	916997	916945	-51.8	-0.01%
2013	933986	936610	2624	0.28%

	2025 submission	2026 submission	Change relative to 2026 submission	
2014	893549	895232	1682	0.19%
2015	901826	898606	-3220	-0.36%
2016	897287	899030	1743	0.19%
2017	882232	886280	4048	0.46%
2018	852858	850135	-2723	-0.32%
2019	798048	798001	-47.5	-0.01%
2020	732993	730972	-2021	-0.28%
2021	761427	762773	1346	0.18%
2022	748793	749266	474	0.06%
2023	672020	669578	-2442	-0.36%

Source: Own calculations

The emissions reported as memo items have also been corrected compared to the previous report.

Of these changes, those for international civil air and maritime transports were the most pronounced.

Table 463: Recalculation of inventory data reported as memo items

	1990	2005	2023
Emissions reported as memo items:	**0.00%**	**-0.01%**	**1.10%**
From international transport	0.00%	0.00%	0.07%
of which: international civil aviation	0.00%	0.00%	-0.07%
of which: international maritime navigation	0.00%	0.00%	1.28%
From multilateral military missions	NE	NE	NE
CO_2 from combustion of biomass	0.00%	-0.02%	1.41%
Captured CO_2 (CCS)	NO	NO	NO

Source: Own calculations

10.2.1 Impacts on emissions levels of categories in 1990

Total emissions (without LULUCF) for 1990 were upwardly corrected by a total of about 0.06%, or 731 kt CO_2 equivalents (cf. Table 464).

The relevant inventory adjustment is made in the Agriculture sector (+788 kt | +1.07%).

In addition, there were far less significant corrections in the energy (+4.60 kt) and industrial processes and product use (-62 kt | +0.07%) sectors. In contrast, the most recently reported emissions for the waste and wastewater sector remain unchanged.

The net CO_2 emissions reported for the LULUCF sector have been revised sharply downwards to -1,037 kt (-3.72%). As a counteracting effect, there is a simultaneous and equally significant increase in aggregate methane and nitrous oxide emissions of 1,504 kt and 18.4%.

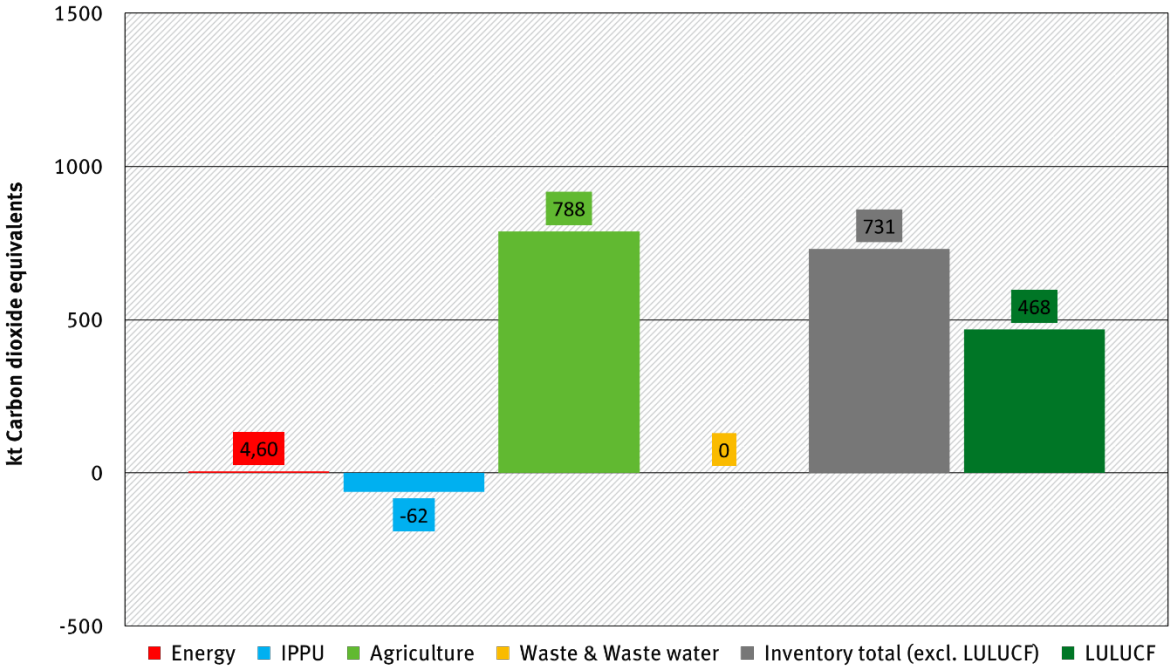
More detailed information, in addition to the data provided in the following table, is available in CRF tables 8(a)s1 to 8(a)s4.

Table 464: Recalculation of the CRF-specific total GHG emissions in 1990, in kt CO_2-eq.

	2025 submission	2026 submission	Change relative to 2025	
Total national emissions (without LULUCF)	1252397	1253128	731	0.06%
1. Energy	1044279	1044283	4.60	0.00%
2. IPPU	93278	93216	-61.7	-0.07%
3. Agriculture	73290	74078	788	1.07%
4. Land-use change and forestry	36027	36495	468	-1.30%
CO_2 (net emissions/removals)	*27859*	*26822*	*-1037*	*-3.72%*
N_2O + CH_4 (emissions)	*8168*	*9673*	*1504*	*18.4%*
5. Waste & wastewater	41550	41550	0.00	0.00%

Source: Own calculations

Figure 116: Absolute changes in CRF key categories and the total inventory, for 1990



Source: own illustration, German Environment Agency

10.2.2 Impacts on emissions levels of categories in 2005

In comparison with the 2025 submission, the total emissions (without LULUCF) reported for 2005 were corrected downwards by 797 kt CO_2 equivalents or 0.08 % (cf. Table 466).

The most significant corrections are in the energy (-957 kt | -0.11%) and agriculture (+203 kt | +0.34%) sectors.

In addition, there was a much less significant correction in the industrial processes and product use sector (-42.5 kt | -0.06%). The emissions reported for the waste and wastewater sector remain unchanged for 2005.

In the LULUCF sector, there was an extreme reduction in the CO_2 emissions for 2005 of 11,000 kt (-84%). In contrast, combined methane and nitrous oxide emissions rose significantly (+1,121 kt | +14%).

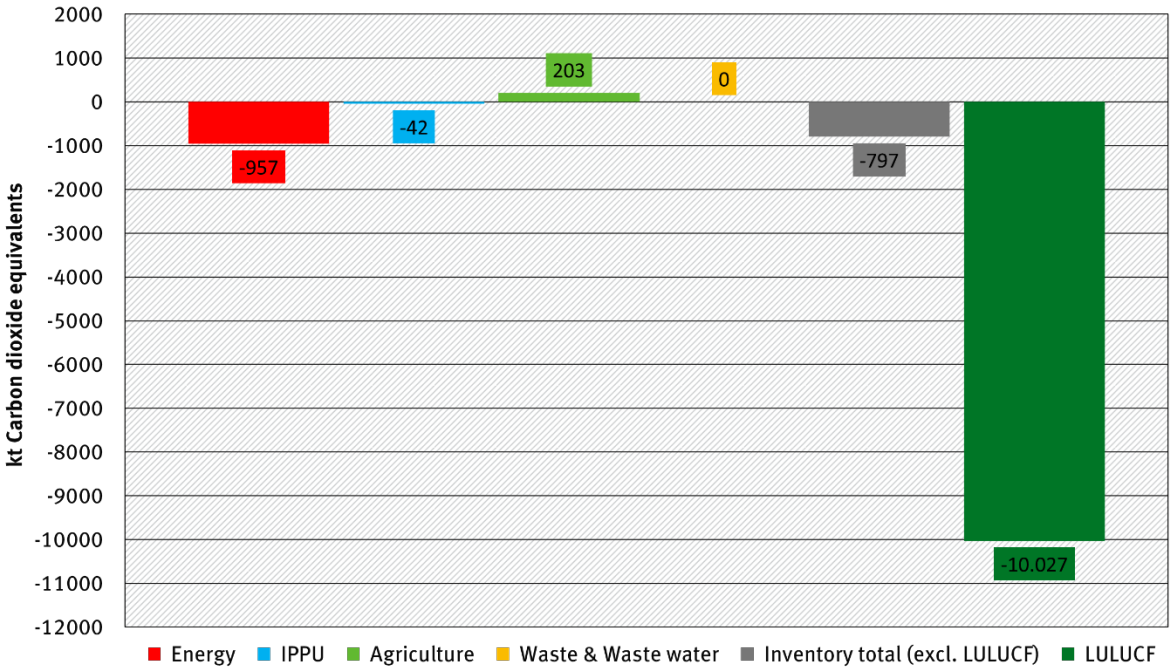
More detailed information, in addition to the data provided in the following table, is available in CRF tables 8(a)s1 to 8(a)s4.

Table 465: Recalculation of the CRF-specific total GHG emissions in 2005, in kt CO_2-eq.

	2025 submission	2026 submission	Change relative to 2026	
Total national emissions (without LULUCF)	989744	988947	-797	-0.08%
1. Energy	836715	835758	-957	-0.11%
2. IPPU	72795	72752	-42.5	-0.06%
3. Agriculture	60403	60606	203	0.34%
4. Land-use changes and forestry	21317	11290	-10027	47.0%
CO_2 (net emissions/removals)	*13303*	*2155*	*-11148*	*-83.8%*
N_2O + CH_4 (emissions)	*8014*	*9136*	*1121*	*14.0%*
5. Waste & wastewater	19831	19831	0.00	0.00%

Source: Own calculations

Figure 117: Absolute changes in CRF key categories and the total inventory, for 2005



Source: own illustration, German Environment Agency

10.2.3 Impacts on emissions levels of categories in 2023

In comparison with the 2025 submission, the total emissions (without LULUCF) reported for year 2023 were corrected downwards by 2,442 kt CO_2 equivalents or 0.36% (cf. Table 466).

The significant but opposite corrections can again be attributed to the energy (-2,680 kt | -0.47%) and agriculture (+411 kt | +0.75%) sectors.

In addition, minor changes were also made in the sectors Industrial processes and product use (-132 kt | -0.28%) and waste & wastewater (-40.7 kt | -0.74%).

In the LULUCF sector, there was an extreme increase in the CO_2 emissions for 2023 (+2,738| +4.57%). The combined methane and nitrous oxide emissions, which decreased by 1,880 kt (+21.5 %), are somewhat lower than reported in the 2025 submission.

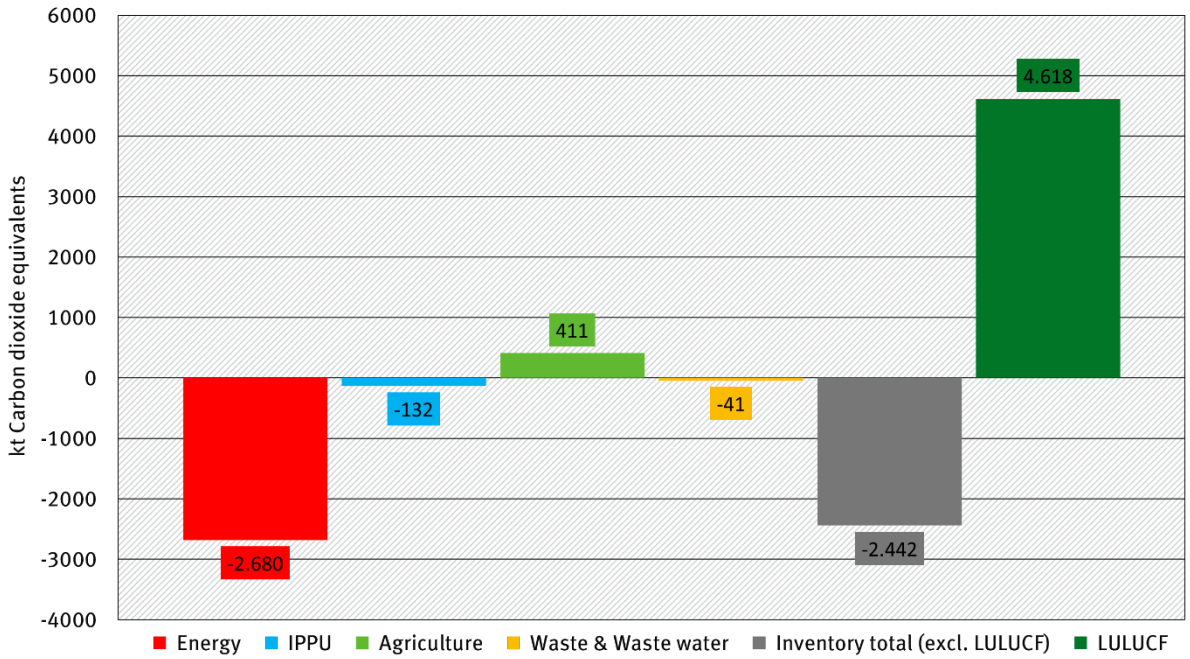
More detailed information, in addition to the data provided in the following table, is available in CRF tables 8(a)s1 to 8(a)s4.

Table 466: Recalculation of the CRF-specific total GHG emissions in 2023, in kt CO_2-eq.

	2025 submission	2026 submission	Change relative to 2025	
Total national emissions (without LULUCF)	672020	669578	-2442	-0.36%
1. Energy	564584	561904	-2680	-0.47%
2. IPPU	47154	47022	-132	-0.28%
3. Agriculture	54792	55203	411	0.75%
4. Land-use changes and forestry	68653	73271	4618	6.73%
CO_2 (net emissions/removals)	*59895*	*62632*	*2738*	*4.57%*
N_2O + CH_4 (emissions)	*8758*	*10638*	*1880*	*21.5%*
5. Waste & wastewater	5490	5449	-40.7	-0.74%

Source: Own calculations

Figure 118: Absolute changes in CRF key categories and the total inventory, for 2023



Source: own illustration, German Environment Agency

10.3 Impacts on emissions trends and time series consistency

The time series consistency improved as a result of the recalculations.

As a result, the trend for total national emissions (without LULUCF) shows a reduction of about 48% relative to the current base year. (for comparison: for 2020, which was more severely affected by the pandemic, the reduction is around 42%.

Pure CO_2 emissions in 2024 are well below the figures for 2023 due to the reduction of more than 3%. At minus 1.8% and minus 5.7%, emissions of methane and nitrous oxide also continued to decrease year-on-year.

Emissions of F gases overall decreased by nearly 2%, although trends for individual F gases continue to vary.

10.4 Inventory improvements

The following table summarises the improvements made in GHG emissions reporting on the basis of the ERT's references and remarks in past reviews under the UNFCCC. The table lists only aspects that were not already resolved during the review.

Table 467: Overview of review recommendations completed with the current reporting

CRT	Review recommendation	Improvement	Report [year]	Reference	Reference of reitteration	Resolved in … (NIR, CRF-table, …)
0.	The ERT recommends that the Party include the NCVs for all fuels included in the reference approach.	Resolved.	2022	E.7, Table 5	-	see NID 2026, Annex 3.1, Table 474
1.	The ERT **encourages** Germany to improve the transparency of the NIR by providing explicit information on the differences between the reporting to IEA and the reporting under the Convention, referencing, as appropriate, inconsistencies resulting from the use of preliminary versus final data and other differences owing to the timing of the availability of data, and, if possible, quantify the various contributions to the differences.	Resolved. Chapter 3.2.1.2 in NID contains more information on the IEA data vs the national energy balances, compared to submission 2016.	2015, 2016	E.14, Table 5	-	see NID chap. 3.2.1.2
1.A.1.a	The ERT recommends that the Party describe in more detail in the NIR the methodology, data and assumptions used to report emissions from biomass consumed under subcategory 1.A.1.a (public electricity and heat production), including the sources used for the EFs for the combustion plants regulated by the EU directive on medium combustion plants and small-sized combustion plants. The ERT also recommends that the Party adequately explain relevant recalculations made in the NIR to ensure that sufficient information is provided to show whether or not the recalculations were made in accordance with the 2006 IPCC Guidelines.	Resolved. For CH4 emissions from biomass under 1A1a the latest NID submission provides info on the relevance of firing technique (in this case biogas use in combustion engines) in Chapter 3.2.4.1. In Chapter 3.2.4.2. further explanation for the CH4 emissions factors can be found. There have also been updates to the methods of the national energy balance since submission 2022. Since the energy balance is the main source for the activity data in 1A1a, changes have an effect on the IEFs, depending on the revisions. These energy balance revisions now take place every two years. The calculation algorithms in our databank are also updated and refined, depending on data availability. Consequently, recalculations take place in recent as well as in previous years. Overall, along with the values, reasons for any recalculation are provided each year in NID under the dedicated chapters for the subcategories, as well as in Chapter 10 "Recalculation and Improvements".	2022	E.8, Table 5	-	see NID chaps. 3.2.4.1. & 3.2.4.2

All measures are aimed at achieving complete consistency with the UNFCCC report guidelines and the IPCC Guidelines.

The following table summarises the information provided in the various category chapters of the inventory reports (since 2011) regarding the planned improvements. The information is supplemented with details on the resulting required action, the planned deadlines for completing the measures and the current processing status in each case.

Table 468: Overview of improvements completed with the current reporting and planned improvements mentioned in the NIR category chapters

CRT	Planned improvement	Data quality objective	Deadline	STATUS	Comment	Report [year]	Reference NIR/NID-Chapter	Resolved in … (NID-Chapter, CRF/CRT-Table Nr.)
1.A.3.d	With regard to inland waterway transport, in cooperation with the responsible modellers (ifeu) and national experts (ZKR: Zentralkommission für die Rheinschifffahrt / CCNR: Central Commission for the Navigation of the Rhine), ways are sought for the exact separate collection of national and international vessels.	National and international ships are to be recorded exactly and separately. The procedure should be developed with ifeu and the ZKR and documented in the NIR and the IB. If needed, the inventory has to be updated.	[2020]	overdue	Germany is continuing to work on that issue.	2017	3.2.10.4.6	
1.A.3.e	Thought is being given to using the methane emission figures from the operators' data pursuant to the EU Methane Regulation 2024/1787.	If possible the Emissions reporting is to be improved by using the methane emission figures from the operators' data pursuant to the EU Methane Regulation 2024/1787.	[2026]	overdue	Germany is continuing to work on that issue.	2025	3.2.8.5.6	
2.B.10	Currently, a research project is being carried out in cooperation with the Hamburg-based Ökopol Institute for Environmental Strategies. It is focused on verification of emissions from cleaning. It comprises analysis of current VOC emissions from cleaning of the interiors of transport equipment and tanks, such as storage facilities at refineries, and non-refinery tank-storage facilities and tank containers. The results of these efforts will feed into the reporting.	The results of the research project with Ökopol Institute for Environmental Strategies shall be fed into the reporting.	[2026]	done	Project results have been intergrated into the emission reporting.	2025	4.3.10.6	see NID chap. 4.3.10.
2.B.10.(i)	It is planned to exchange further information with the manufacturer of 1,12-Dodecandiacid in order to ensure consistency of the data over the entire time series and to enable a better assessment of the quality of the reported data.	Further information must be exchanged with the manufacturer of 1,12-Dodecandiacid in order to ensure consistency of the data over the entire time series and to enable a better assessment of the quality of the reported data.	[2025]	closed	Information from the data provider have been requested, but were not provided because data submission is voluntary.	2024	4.3.10.6	-
2.D.3.(b)	Relevant findings currently available from a research project are to be used for specific evaluation of emission factors.	The emission factors need to be evaluated on the basis of the existing project report.	[2012]	overdue	Germany is continuing to work on that issue.	2012	4.2.6.6	
2.H.2.	Based on an ongoing project, emission factors shall be updated.	Based on the results of the recently launched project, the emission factors used so far need to be updated.	[2023]	overdue	Germany is continuing to work on that issue.	2021	4.9.2.6	
4.	The planned improvements for the coming years include the following: Introduction of models for calculation of carbon and nitrogen stocks in mineral soils in the land-use category Cropland. This will have to be preceded by the development of a model for derivation of complete-coverage, regionalised cultivation data from the database of the EU's Integrated Administration and Control System (IACS) (in progress).	Introduction of models for calculation of carbon and nitrogen stocks in mineral soils in the land-use category Cropland. This will have to be preceded by the development of a model for derivation of complete-coverage, regionalised cultivation data from the database of the EU's Integrated Administration and Control System (IACS) (in progress).	[2026]	done	Implemented with 2026 submission	2023	6.1.2.1.9	NID 2026 Chapter 6.1.2.1.1, Subsection: Calculation of the changes in carbon stocks in mineral soils beneath Cropland and Grassland using the RothC process model

CRT	Planned improvement	Data quality objective	Deadline	STATUS	Comment	Report [year]	Reference NIR/NID-Chapter	Resolved in … (NID-Chapter, CRF/CRT-Table Nr.)
4.	The planned improvements for the coming years include the following: Introduction of model-based calculation of carbon and nitrogen stocks in mineral soils in the land-use category Grassland. No truly reliable data sets are available for validation of models in the area of Grassland. Development of such calculation, therefore, will depend on the availability of results of repeat soil-inventory sampling (this commenced in 2022).	Introduction of model-based calculation of carbon and nitrogen stocks in mineral soils in the land-use category Grassland. No truly reliable data sets are available for validation of models in the area of Grassland. Development of such calculation, therefore, will depend on the availability of results of repeat soil-inventory sampling (this commenced in 2022).	[2028]	done	A model for mineral soils covered with grassland has been implemented; however, it is not accurate at the hectare level or site-specific. Germany is working on that issue.	2023	6.1.2.1.9	NID 2026 Chapter 6.1.2.1.1, Subsection: Estimation of carbon stock change in mineral soils under grassland
4.	Chapter 6.1.4 1. Improvement of the model for calculation of carbon and nitrogen stock changes in mineral soils in the remaining categories of the land-use category Cropland and Grassland (cf. also Chapter 6.1.2.1.9). - Development of a model for derivation of complete-coverage, regionalised cultivation data from the database of the EU's Integrated Administration and Control System (IACS) (in progress, planned for 2026 submission). - Further development of the model in order to be able to calculate the carbon and nitrogen stock changes in mineral soils of the land-use categories Cropland and Grassland on a regionalised basis at hectare level and over time (in progress, planned for 2026 submission). Chapter 6.1.2.1.9 The planned improvements for the coming years include the following: - Recalculation of the models for calculation of carbon and nitrogen stock changes in mineral soils in the land-use category Cropland. This will have to be preceded by the ongoing collection of regionalised cultivation data from the database of the EU's Integrated Administration and Control System (IACS) (in progress, planned for 2026 submission). This will then enable the model to be applied to the grid of the inventory (100 x 100 m), and a varying trend over time to be derived.	The models for calculation of carbon and nitrogen stock changes in mineral soils in the land-use category Cropland are to be recalculated.	[2026]	done	Implemented with 2026 submission	2025	6.1.4 + 6.1.2.1.9	NID 2026 Chapter 6.1.2.1.1, Subsection: Calculation of the changes in carbon stocks in mineral soils beneath Cropland and Grassland using the RothC process model

CRT	Planned improvement	Data quality objective	Deadline	STATUS	Comment	Report [year]	Reference NIR/NID-Chapter	Resolved in … (NID-Chapter, CRF/CRT-Table Nr.)
4.	Chapter 6.1.4 1. Improvement of the model for calculation of carbon and nitrogen stock changes in mineral soils in the remaining categories of the land-use category Cropland and Grassland (cf. also Chapter 6.1.2.1.9). - Development of a model for derivation of complete-coverage, regionalised cultivation data from the database of the EU's Integrated Administration and Control System (IACS) (in progress, planned for 2026 submission). - Further development of the model in order to be able to calculate the carbon and nitrogen stock changes in mineral soils of the land-use categories Cropland and Grassland on a regionalised basis at hectare level and over time (in progress, planned for 2026 submission). Chapter 6.1.2.1.9 The planned improvements for the coming years include the following: - Recalculation of the model-based calculation of carbon and nitrogen stocks in mineral soils in the land-use category Grassland on the grid of the inventory (100 x 100 m), and derivation of a varying trend over time.	The model-based calculation of carbon and nitrogen stocks in mineral soils in the land-use category Grassland are to be recalculated.	[2026]	done	A model for mineral soils covered with grassland has been implemented.	2025	6.1.4 + 6.1.2.1.9	NID 2026 Chapter 6.1.2.1.1, Subsection: Estimation of carbon stock change in mineral soils under grassland
4.	2. Improvement of the methodology to record GHG emissions from inland water bodies (planned for 2028 submission). - Recording of all inland water bodies (especially man-made water bodies) and their trophic state as completely as possible and georeferenced. - Determination of Länder-specific emission factors	The methodology to record GHG emissions from inland water bodies has to be improved. For this, all inland water bodies (especially man-made water bodies) and their trophic state shall be recorded as completely as possible and georeferenced, moreover country specific emission factors shall be determined.	[2028]	open	Germany is working on that issue.	2025	6.1.4	
4.	3. Development of methods to record GHG emissions from coastal wetlands (planned for 2030 submission). - Definition of the boundaries of the land-use category and its subcategories - Recording of the relevant activity data - Determination of Länder-specific emission factors	A methodology for recording of GHG emissions from coastal wetlands shall be developed. For this (a) a definition of the boundaries of the land-use category and its subcategories, (b) the recording of the relevant activity data, (c) the determination of Länder-specific emission factors is required.	[2030]	open	Germany is working on that issue.	2025	6.1.4	
4.	Planned improvements for the coming years include: 1. (Section 6.1.2.1.9): Improving the model-based calculation of changes in carbon stocks on cropland. Improving the data available regarding land management and data inputs. as well as 1.a. (Section 6.1.4): Further development of the model for hectare-precise calculation on cropland, particularly with regard to input data	The model-based calculation of changes in carbon stocks on cropland needs to be improved in terms of the data available regarding land management and data inputs.	[2028]	open	Germany is working on that issue.	2026	6.1.2.1.9, 6.1.4	

CRT	Planned improvement	Data quality objective	Deadline	STATUS	Comment	Report [year]	Reference NIR/NID-Chapter	Resolved in … (NID-Chapter, CRF/CRT-Table Nr.)
4.	Planned improvements for the coming years include: 2. (Section 6.1.2.1.9): Introduction of model-based calculations of changes in carbon and nitrogen stocks in mineral soils of the land use category Grassland for each individual point of the sampling grid (100 x 100 m). as well as 1.b. (Section 6.1.4): Further development of the model to enable the calculation of changes in carbon and nitrogen stocks in mineral soils of the land use category Grassland on a regionalized, hectare-precise, and temporally dynamic basis	The model-based calculation of changes of carbon and nitrogen stocks in mineral soils classified as grassland is to be implemented for each individual point in the sampling grid (100 x 100 m).	[2030]	open	Germany is working on that issue.	2026	6.1.2.1.9, 6.1.4	
4.	Planned improvements for the coming years include: 3. (Section 6.1.2.1.9): Development of a method to determine trends in carbon stock changes in mineral soils in Settlements a. the remaining category Buildings and open areas as well as 2.a. (Section 6.1.4): Implementation of a method for recording changes in carbon and nitrogen stocks in mineral soils of the remaining category of Settlements, particularly the subcategory of Buildings and open areas	The methodology for determining changes of carbon and nitrogen stocks in mineral soils classified as settlements needs to be further developed for the “Buildings and Open Spaces” land use category.	[2028]	open	Germany is working on that issue.	2026	6.1.2.1.9, 6.1.4	
4.	Planned improvements for the coming years: 3. (Section 6.1.2.1.9): Method development to determine trends in carbon stock changes in mineral soils in Settlements b. Introduction of soil sealing and emission factors for mineral soils in the subcategories Roads and Railway tracks as well as 2.c. (Section 6.1.4): Recording of emissions from the subcategories Roads and Railway facilities: Derivation and implementation of EFs for mineral soils	The methodology for determining changes of carbon stocks in mineral soils classified as settlements is to be completed when sealing- and emission factors for mineral soils in the “roads” and “railway embankments” subcategories are introduced.	[2028]	open	Germany is working on that issue.	2026	6.1.2.1.9, 6.1.4	
4.	2.b.: Dynamic management of the subcategories Roads and Rail infrastructure	Development and implementation of a method for the model-based determination and dynamization of the areas of the subcategories “roads” and “railway embankments”.	[2028]	open	Germany is working on that issue.	2026	6.1.4	
4.	2.c. Reporting emissions from the subcategories Roads and Rail infrastructure: Derivation and implementation of EFs for biomass	The methodology for determining changes of carbon stocks in biomass is to be completed when emission factors for biomass in the “roads” and “railway tracks” subcategories are introduced.	[2028]	open	Germany is working on that issue.	2026	6.1.4	

CRT	Planned improvement	Data quality objective	Deadline	STATUS	Comment	Report [year]	Reference NIR/NID-Chapter	Resolved in … (NID-Chapter, CRF/CRT-Table Nr.)
4.	Improvement of the methodology for reporting GHG emissions from inland waters: 3.a.: As complete as possible, georeferenced inventory of all inland waters (especially artificial waters) and their trophic status	Development and implementation of a method for the model-based determination of the surface areas of inland waters and their trophic levels.	[2028]	open	Germany is working on that issue.	2026	6.1.4	
4.	Improvement of the methodology for capturing GHG emissions from inland waters: 3.b.: Derivation of country-specific emission factors	Derivation and implementation of country specific EF for inland waters.	[2030]	open	Germany is working on that issue.	2026	6.1.4	
4.	Development of methods for capturing GHG emissions from coastal wetlands: 4.a: Definition of the boundaries of the land use category and its subcategories	The boundaries of the land-use category “coastal wetlands” and any subcategories must be defined, and their boundaries must be established in the system.	[2030]	open	Germany is working on that issue.	2026	6.1.4	
4.	Development of methods for recording GHG emissions from coastal wetlands: 4.b.: Recording of activity data	Development and implementation of a method for the computer-aided determination of the areas of coastal wetlands and their site conditions.	[2030]	open	Germany is working on that issue.	2026	6.1.4	
4.	Development of methods for recording GHG emissions from coastal wetlands: 4.c.: Derivation of country-specific emission factors	Derivation and implementation of country specific EF for Coastal wetlands and their subcategories.	[2030]	open	Germany is working on that issue.	2026	6.1.4	
4.G	In 2024, the Council of Experts on Climate Change examined the CRF category 4A. Forest Land in the LULUCF sector, and also touched on the CRF HWP category (4.G). It found that the Thünen-Institute of Wood Research “due to legal requirements regarding the confidentiality of individual reporting numbers of the production statistics in accordance with section 16 of the Federal Statistics Act has no access to existing data on wood products of the Federal Statistical Office” which could be used in place of the FAO data. This results in great uncertainties (cf. Chapter 6.10.5). “A calculation using more specific national activity data, as envisaged by the IPCC (IPCC et al., 2014a), and with related conversion factors already available [at the Thünen-Institute of Wood Research] is therefore not possible.” (Council of Experts on Climate Change, 2024). The “general review of the legal basis for data access and flows” recommended by the Council of Experts, which should “[therefore] be considered by the legislature, with a view to “[granting] access to relevant data for all federal authorities involved in emission calculations” has yet to be undertaken. Nevertheless, efforts continue to be made to improve the calculation of the underlying data basis. This is particularly true of the recording of the dynamism over time of the use of raw wood which is lost due to calamities (e.g. in 1990) but has not, or not yet, been used for further processing into a wood product used as a material (cf. notes in the context of the ESD review in 02/2024	The database on which the calculation is based must be improved. This applies in particular to the recording of the temporal dynamics of the use of damaged timber that has been lost due to calamities (e.g. in 1990) but has not or not yet been used for further processing into a materially used wood product (for details see “Specific objectives”).	[2026]	done	Implemented with 2026 submission.	2025	6.10.6	NID 2026 Chapter 6.10.2.1, esp. Figures 105 and 106 incl. correstponding explanation.

CRT	Planned improvement	Data quality objective	Deadline	STATUS	Comment	Report [year]	Reference NIR/NID-Chapter	Resolved in … (NID-Chapter, CRF/CRT-Table Nr.)
	and (Rüter & Stümer, 2024). The recent evaluation of the latest forest inventory data, which was only completed just before the compilation of this report (09/2024), made it possible initially to continue to differentiate the loss of raw wood by tree type group into a) those quantities of raw wood which enter deadwood storage and b) those which are mainly used for energy purposes or are available for material further processing into HWPs. In order to maintain the consistency of the time series, in a further step the current raw wood loss, which is extrapolated for the period after the last forest inventory in line with the procedure described above, has to be differentiated on the basis of information about the nature of the calamity, since suddenly accruing damaged timber cannot always be processed and used, or only in exceptional circumstances (cf. 1990) (cf. Figure 95). At the same time, it is necessary to note that Germany uses the corresponding chapters of the 2013 IPCC KP Supplement (IPCC et al., 2014a) and the 2019 Refinement (IPCC et al., 2014a) as a methodological basis for the calculation of the category in order to comply with the legal requirements for the balancing of HWPs in the inventory (i.e. EU Regulation 2018/841 and EU Regulation 2023/839). As a basic prerequisite for a corresponding calculation, the availability of transparent data is cited here, not least in order to comply with one of the core principles for the handling of measures in the LULUCF source group: not to overestimate the carbon sequestration of the storage, and not to underestimate emissions							

10.4.1 Implementing Regulation Article 9: Reporting on implementation of recommendations and adjustments

Table 469: Implementing Regulation Article 9: Reporting on implementation of recommendations and adjustments, Article 9.1

Member State: Germany						
Reporting year: UNFCCC Annual Review Report 2022						
CRF/CRT	**Review recommendation**	**MS response/status of implementation**	**Report [year]**	**Paragraph / reference**	**Reference of reiteration**	**Resolved in (NIR, CRF-table, ...)**
0.	ARR 2022: The ERT concludes that this potential problem of a mandatory nature does not influence the Party's ability to fulfil its commitments for the second commitment period of the Kyoto Protocol and therefore this issue was not included in the list of potential problems and further questions raised. The ERT recommends that the Party annually review, and if necessary, update the information in the NIR with respect to the calculation of the commitment period reserve, ensuring that it is calculated based on the most recent information	Closed, due to the ending of Kyoto commitment period.	2015, 2016	G.5, Table 5	G.6, 2015; G.5, 2018; G.3, Table 3, 2020 G.1, Table 3, 2022	-
0.	The ERT recommends that the Party archive all documentation related to expert judgment, ensuring easy accessibility for review on request by the ERT. (For specific recommendations related to the documentation of expert judgment in the NIR refer to ID#s E.10, E.13, I.11, I.12 and I.14 below.)	Resolved. Within the QAQC-Checklists of the Quality-System a new and general Task has been icluded to make it possible to document the relevant information related to expert judgment in the future. This Task has to be carried out within a special documentation form of the Central System on Emissions (CSE; Database). The Form is based on and in compliance with the 2006 IPCC-GL, Vol 1, Chap 2 DataCollection, Annex 2A1, Table 2.A.1, as requested in ARR 2022, E.10, E.13 and I.14 (table 5).	2022	G.4, Table 5		CSE
0.	The ERT encourages the Party to reduce the number of cross-references to external documents and summarize the key elements of the methodologies and justifications for country-specific EFs for the key categories (in particular where they are lower than the default EFs) within the main body of the NIR.	Open	2022	G.5, Table 5		-
0.	The ERT recommends that the Party include the NCVs for all fuels included in the reference approach.	Resolved.	2022	E.7, Table 5	-	see NID 2026, Annex 3.1, Table 474
1.	The ERT encourages the Party to continue to facilitate collaboration between inventory compilers, the Working Group on Energy Balances and the German Federal Statistical Office to ensure that the final energy balance for the most recent inventory year is made available in time for the preparation of that inventory, and to include the final energy balance in annex 4 to the NIR. The ERT also encourages the Party to include in its NIR an update on the project for improving the timely provision of energy statistics, if the project has not yet been finalized at the time of the next submission.	Resolved. The description of undertaken QC/QA measures to obtain more timely access to the final energy balance for the most recent year is correct. As described, from 2022 onward, the improved statistical data on energy has been used to compile the preliminary energy balance that is delivered to the inventory compilers for further inventory work in September. Thus, the collaboration between inventory compilers, the Working Group on Energy Balances and the German Federal Statistical Office ensures that the best possible energy balance for the most recent	2022	E.5, Table 5		https://ag-energiebilanzen.de/daten-und-fakten/bilanzen-1990-bis-2030/?wpv-jahresbereich-bilanz=2021-2030

Member State: Germany **Reporting year: UNFCCC Annual Review Report 2022**						
		inventory year is made available in time for the preparation of that inventory. The final Energy balace is to be published by AGEB by February/March of the reporting year and can be investigated under the following link: https://ag-energiebilanzen.de/daten-und-fakten/bilanzen-1990-bis-2030/?wpv-jahresbereich-bilanz=2021-2030. If the ERT wishes, the link can be referred to in Annex 4 to the NID.				
1.	The ERT also encourages the Party to include in its NIR an update on the project for improving the timely provision of energy statistics, if the project has not yet been finalized at the time of the next submission.	Resolved. The project for improving the timely provision of energy statistics has been finalized. An update on the description of the ending of the project can be found in the NIR in chapter 16.1.	2022	E.5, Table 5		NID 2024, chap. 16.1
1.A.	ARR 2022: The ERT considers that the recommendation has not yet been fully addressed because the Party has not provided a clear list of the primary assumptions used to estimate the preliminary national energy balance in the most recent inventory. The ERT recommends that Germany include in its NIR the main assumptions used to establish the provisional energy balance.	Resolved. Information on the main differences between the provisional and the final energy balance result from provisional results of the statistical offices. In NID in chapter 16.1 and 16.4 we describe the data flow from the statistical offices of the Länder to the federal statistical office and from there to AGEB as the data delivery source for UBA: Missing data at the early date of delivery has been replaced by a procedure of imputation in the federal Statistical office.	2018	E.7, Table 5	E.2, Table 3, 2020; E.2, Table 3, 2022	NID 2024, chap. 16.1 and 16.4
1.A.1.a	The ERT recommends that the Party describe in more detail in the NIR the methodology, data and assumptions used to report emissions from biomass consumed under subcategory 1.A.1.a (public electricity and heat production), including the sources used for the EFs for the combustion plants regulated by the EU directive on medium combustion plants and small-sized combustion plants. The ERT also recommends that the Party adequately explain relevant recalculations made in the NIR to ensure that sufficient information is provided to show whether or not the recalculations were made in accordance with the 2006 IPCC Guidelines.	Resolved. For CH4 emissions from biomass under 1A1a the latest NID submission provides info on the relevance of firing technique (in this case biogas use in combustion engines) in Chapter 3.2.4.1. In Chapter 3.2.4.2. further explanation for the CH4 emissions factors can be found. There have also been updates to the methods of the national energy balance since submission 2022. Since the energy balance is the main source for the activity data in 1A1a, changes have an effect on the IEFs, depending on the revisions. These energy balance revisions now take place every two years. The calculation algorithms in our databank are also updated and refined, depending on data availability. Consequently, recalculations take place in recent as well as in previous years. Overall, along with the values, reasons for any recalculation are provided each year in NID under the dedicated chapters for the subcategories, as well as in Chapter 10 "Recalculation and Improvements".	2022	E.8, Table 5	-	see NID 2026, Annex 3.1, Table 474
1.A.3.b.	ARR 2022: The ERT considers that the recommendation has not yet been addressed because the Party has not justified in its NIR the use of a CO2 EF that is higher than the upper value of the default range in the 2006 IPCC Guidelines. The ERT encourages that Germany improve the transparency of future NIRs by including an explanation of the adjustment made to the CO2 EF for gasoline, which resulted in a CO2 EF that is	Resolved	2020	E.5, Table 5	-	see NID chaps. 3.2.4.1. & 3.2.4.2

Member State: Germany						
Reporting year: UNFCCC Annual Review Report 2022						
	higher than the IPCC default value and among the highest IEFs reported by Parties for all categories in which gasoline is used.					
1.A.3.b.i	The ERT recommends that the Party provide in the NIR the NCVs used for gasoline for subcategory 1.A.3.b.i (cars) across the time series, providing references for the sources of the NCV values and an explanation of their impact on the CO2 IEF trend..	Issue has been closed. Firstly and most importantly, since gasoline is not only used in passenger cars (CRF 1.A.3.b i), fuel-specific data such as (annual) NCVs need to be provided at a super-ordinate level. Here, the German NID already includes very specific information on the individual fuels in appendix chapter 16.8 - CO2 emission factors, also providing reference to underlying studies or analyses especially with regard to gasoline fuels.	2022	E.9, Table 5		see NID 2025, appendix chapter 16.8
1.A.3.b.i	The ERT encourages the Party to include either the results of the 2021 measurement study for recalculating gasoline NCVs from the 2020 inventory year or a description of progress in implementing the 2021 measurement study in the planned improvement sections of the NIR.	Encouragement is resolved. The study was completed in 2021, with the measurement results for the gasoline fuels sampled in 2020 being included in the 2022 GHG reporting. Since no final report was published after the study was completed, relevant information is available in NID chapter 16.7.1.	2022	E.9, Table 5		see NID 2025, chapter 16.7.1
1.AD	ARR 2022: The Party did not explain in its NIR the use of “NE” in CRF table 1.A(d) for other bituminous coal, coke oven/gas coke and lignite, although for coke oven/gas coke the category in which the emissions are reported is specified in the table. Further, it did not include in its NIR information about any planned improvements to its reporting in CRF table 1.A(d). ARR 2020: The ERT recommends that Germany, when completing CRF table 1.A(d) in future submissions, report estimates of emissions from non-energy uses of fuels and/or use the appropriate notation keys in line with paragraph 37 of the UNFCCC Annex I inventory reporting guidelines (e.g. “NA” instead of “NE” when no emissions are expected from the non-energy use of a fuel).	The recommendation has been implemented. With the current submission, data from the Joint Annual Questionnairre are applied that also include specific information on the named fuels formerly reported as "NE".	2020	E.4, Table 5	E.1, Table 3, 2022	see NID 2025, chapter 13
1.AD	The ERT recommends that the Party (a) review the time series for the NEU of gasoline and recalculate it, if necessary, (b) explain in which year emissions from this source began in the time series, and (c) clarify whether emissions from the NEU of gasoline are reported elsewhere in the inventory. The ERT also recommends that the Party explain the underlying drivers if further recalculations take place for the NEU of gasoline.	Open	2022	E.6, Table 5		-
1.B.2.	The ERT recommends that, in line with the requirements under the 2006 IPCC Guidelines (vol. 1, chap. 2, annex 2A.1), the Party document the use of expert judgment that underpins the estimates for category 1.B, namely (a) country-specific EFs used to estimate CH4 emissions for subcategory 1.B.2.a.2 (oil production), (b) CH4 emissions for subcategory 1.B.2.a.4 (oil refining/storage (anode production, tank storage facilities in refineries, and tank storage facilities outside refineries)), and (c) the split factor of 40 per cent sour gas to 60 per cent sweet gas for estimating CO2 and CH4 emissions for subcategory 1.B.2.b.3 (natural gas processing), and hold the relevant documentation at the German Environment Agency (the single national entity of Germany), to be provided for review upon request by the ERT.	Resolved. The Party documented the expert judgment.	2022	E.10, Table 5		CSE

Member State: Germany						
Reporting year: UNFCCC Annual Review Report 2022						
1.B.2.	The ERT encourages the Party to update the information in the NIR and CRF tables to improve clarity on the source of the EFs and methodologies used for each subcategory under category 1.B.2 (oil, natural gas and other emissions from energy production).	Closed. With regard to the encouragement: In the CRF the requested information is given for each year (Summary 3). Further disaggregation is not possible within the CRF-Reporter. The overviewtables of each sector can only be prepared for the respective year of the NID.	2022	E.10, Table 5		-
1.B.2.a	The ERT recommends that the Party ensure consistency between the information in the NIR and CRF tables by updating the input to CRF summary 3 in terms of methods and EFs used to estimate CO2 and CH4 emissions for category 1.B.2.a.1 (oil exploration), namely a tier 1 method and default EF for CO2 and CH4 for all years.	Closed. In the CRF the requested information is given for each year (Summary 3). Further disaggregation is not possible within the CRF-Reporter. The the requested information is given in the overviewtables of each sector - these tables can only be prepared for the respective year of the NID.	2022	E.11, Table 5		-
1.B.2.a	The ERT recommends that the Party correct the description in NIR section 3.3.2.1.3.2 to reflect the CH4 methods and EFs used, and ensure consistency between the NIR and the CRF regarding the information on methods and EFs used, namely tier 1 and 2 methods and default and country-specific EFs for CH4 for all years.	Resolved. Description has been corrected	2022	E.12, Table 5		NID 2024, chap. 3.3.2.1.3.2
1.B.2.a	The ERT recommends that the Party (a) estimate CO2 emissions for subcategory 1.B.2.a.3 (oil – transport) and report them in CRF table 1.B.2 in line with the 2006 IPCC Guidelines (vol. 2, chap. 4, table 4.2.4); (b) report CO2 emissions for this category as "NE" and document the notation key in accordance with paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines, including the approximate default emissions of 0.04 kt CO2 provided during the review, in the assessment of completeness in the NIR (annex 5); or (c) continue to report the CO2 emissions in table 1.B.2 as "NA" and include in the NIR a relevant justification in line with annex 2A.1 of the 2006 IPCC Guidelines (vol. 1, chap. 2).	Closed. The Party cannot implement the issue. Reason is given in NID 2024, chap. 3.3.2.1.3.4	2022	E.13, Table 5		NID 2024, chap. 3.3.2.1.3.4
1.B.2.a	The ERT recommends that the Party describe in more detail in the NIR the assumptions, data and references used to disaggregate liquid petroleum products emissions between subcategory 1.B.2.a.4 (oil refining/storage) and category 2.B.10 (chemical industry – other), including the logical basis and split factors used across the time series. The ERT further recommends that the Party explain in the NIR that the data available do not allow for a split between gaseous fuels associated with subcategory 1.B.2.a.4 (oil refining/storage) and category 2.B.10 (chemical industry – other) and that the aggregate of emissions for both categories are reported together under category 2.B.10.	Resolved. The requested information is given in CRF 2.B.10.	2022	E.14, Table 5		NID 2024, chap. for 2.B.10.
1.B.2.b	The ERT recommends that the Party review the methodologies used for estimating CO2 and CH4 emissions from natural gas production, ensuring that, where two different methods are used (i.e. tier 1 for 1990–1998 and tier 2 for 1999–2020), there is adherence to the splicing techniques for maintaining time-series consistency described in the 2006 IPCC Guidelines (vol. 1, chap. 5.3.3). The methods and any splicing techniques used should be included in the NIR with adequate information to demonstrate compliance with the 2006 IPCC Guidelines and the UNFCCC Annex I inventory reporting guidelines. The ERT also recommends that the Party update the methodological information on subcategory 1.B.2.b.2 (natural gas production) reported in CRF Reporter as input to CRF summary 3 to reflect the actual methods and EFs used (i.e. a tier 1 method and default EFs for CO2 and CH4 for 1990–1998 and a tier 2 method and country-specific EFs for 1999–2020), and to	Resolved. A report on this issue has been published and several references have entered the NID.	2022	E.15, Table 5		https://www.umweltbundesamt.de/publikationen/aktualisierung-der-emissionsfaktoren-fuer-methan

Member State: Germany						
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	describe in the NIR the country-specific EFs used and how they were developed in line with the 2006 IPCC Guidelines.					
1.B.2.b	The ERT recommends that the Party describe in the NIR the causes for the sharp decline in natural gas produced in Germany since 2003 (75.5 per cent for 2003–2020).	Resolved. Desciption of the reasons for the sharp decline has been given.	2022	E.16, Table 5		NID 2024, chap. 3.3.2.2.2.1 and 3.3.2.2.3.1
1.B.2.c	The ERT recommends that the Party report AD used for the N2O estimates (natural gas production) in the NIR in a similar manner to the way that the AD used for the CO2 estimates is reported in the NIR (table 160). The ERT further recommends that NIR table 160 is updated to indicate that the AD currently reported in the table relate to the CO2 estimates only. The ERT also recommends that the Party include in the NIR an explanation for reporting the AD on gas flared with a notation key ("IE") in CRF table 1.B.2 when emission values are reported for CO2 and N2O for the subcategory.	Closed. Recommendation cannot be solved because only one AD can be entered in the CRF description has been given in chap. 3.3.2.3.1.2	2022	E.17, Table 5		NID 2024, chap. 3.3.2.3.1.2
1.D.1 + 1.D.2	The ERT recommends that the Party explain in the NIR the data and assumptions used to split the aviation gasoline AD between international and domestic flights, and landing/take-off and cruise.	Recommendation has been closed. The distribution of domestic fuel deliveries between domestic flights and flights abroad and between L/TO and cruise is generally carried out in the TREMOD AV (TREMOD Aviation) model named at the appropriate point in the NIR (NID).	2022	E.18, Table 5		-
1.D.1 + 1.D.2	The ERT encourages the Party to describe in the NIR the category-specific planned improvements for refinement of the disaggregation of aviation gasoline.	Open	2022	E.18, Table 5		-
2.A.4.b.	ARR 2022: The ERT considers that the recommendation has not yet been fully addressed because the Party was still working on the accuracy of the AD time series at the time of submitting its inventory. The ERT recommends that Germany either verify the decreasing emission trend and large inter-annual variation in emissions for 2016–2018 for subcategory 2.A.4.b (other uses of soda ash) and justify it in the NIR or recalculate the reported emissions to ensure time-series consistency.	Resolved. With data of 2022 the decreasing emission trend was stoped. The large inter-annual variation in emissions for 2016–2018 was recalculated. But to ensure time-series consistency we have to interpolate furthermore for this years. Former statistical data couldn't be changed.	2020	I.16, Table 5	I.2, Table 3, 2022	NID 2024, chap. 4.2.4.2.2
2.B.3.	ARR 2022: The ERT considers that the recommendation has not yet been fully addressed because the Party reported tier 3 as the method used for 1990–2020 in the CRF tables but stated in the NIR that a tier 2 approach was used for 1990–2012, and did not explain how the applied methods across the time series can be considered to be consistent. ARR 2020: The ERT considers that the recommendation has not yet been fully addressed because the Party did not include this information in the correct NIR section on time-series consistency (section 4.3.3.3). The ERT recommends that, for the third plant, which started operation in 2002 but began conducting measurements only in 2013, Germany report on how the N2O emissions were estimated for the period 2002–2012. The ERT further recommends that Germany report on how time-series consistency was ensured, given the use of different methods in the time series	Resolved. This issue has been adressed and the change of method has been carried out since submission 2023	2015, 2016	I.9, Table 5	I.4, 2018; I.8, Table 3, 2020; I.4, Table 3, 2022	CRF-Table summary3s1
2.B.9.	The ERT recommends that the Party include in the NIR a detailed explanation of the estimation of the production quantities of HCFC-22 and HFC-23 emissions under subcategory 2.B.9.a (fluorochemical production – by-product emissions) and hold the relevant background documents (details from the review of assumptions by industry representatives, including its outcomes) at the German Environment Agency to be provided for review upon request by the ERT.	Resolved. The reporting company was persuaded to provide data directly to the UBA and has transmitted the data (also retroactively to 2020) confidentially. The data is available for inspection in a confidential folder. They can be made available by reviewers on request.	2022	I.11, Table 5		NID 2024, Chemical industry: Production of halogenated

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						hydrocarbons and SF6 (2.B.9)
2.B.9.	The ERT recommends that the Party include in the NIR an explanation of the review of the EFs of the fugitive emissions for category 2.B.9.b (fluorochemical production – fugitive emissions) by industry representatives and hold the relevant documentation at the German Environment Agency to be provided for review upon request by the ERT.	Resolved. The text passages in the NID were changed accordingly: From 2011 to 2019, the production volumes for HCFC-22 and HFC-23 were estimated by experts. Due to the higher uncertainty resulting from the estimate, a forced HFC-23 production of 3 % was still assumed. The data available for 2020-2022 show that the forced production is less than 2 %, so that a recalculation for the years 2011 to 2021 was carried out this year.	2022	I.12, Table 5		NID 2024, chap. 4.3.9.2.2
2.C.2.	The ERT recommends that the Party collect AD on the quantities of reducing agent consumed in ferroalloys production and reallocate the CO2 emissions related to the consumption of the reducing agent from category 1.A.2 (manufacturing industries and construction) to category 2.C.2 (ferroalloys production) in line with the 2006 IPCC Guidelines (vol. 3, chap. 4.3.2.1), while ensuring that no double counting of these emissions occurs; alternatively, the ERT recommends that the Party include information explaining the low CO2 IEF (0.11 t/t in 2020) in category 2.C.2 (ferroalloys production) in the NIR, if the reallocation is not done.	Resolved. With the exact production figures from 2020 onwards, the emission factor is set to 0.004 %. This corresponds to the 2019-Refinements, Vol.3, page 3.19: "If the exhaust gas is captured for treatment, thermal oxidation has been shown to reduce HFC-23 emissions by 99.996 per cent (Irving, 2000)."	2022	I.13, Table 5		NID 2024, chap. 4.4.2.2
2.C.3.a.	ARR 2020: The ERT considers that the recommendation has not yet been fully addressed because the Party did not include the information on the validation of the EF used from 2009 in the NIR. The ERT recommends that Germany include in the NIR the explanation that the aluminium plant was redesigned, resulting in a reduction in the SF6 EF for secondary aluminium. The ERT also recommends that the Party explain in detail how the change in the EF was justified, whether by confidential measurement results and/or by a measurement protocol, and that the measurement protocol was checked and verified by a third party.	Resolved	2018	I.20, Table 6	I.11, Table 3, 2020; I.6, Table 3, 2022	NIR 2022, chap. 4.4.3.2, p.344
2.E.3.	ARR 2022: The ERT considers that the recommendation has not yet been fully addressed because the Party did not use the appropriate notation key, "NO", for years where SF6 emissions from photovoltaics did not occur. The ERT recommends that Germany update CRF table 2(II).B-Hs1 such that the appropriate notation key is reported for all years where SF6 emissions from photovoltaics are not occurring (i.e. 1990–2002 and 2014 onward).	Resolved. Since submission 2024, Germany updated CRF table 2(II).B-Hs1 such that the appropriate notation key is reported for all years where SF6 emissions from photovoltaics are not occurring (i.e. 1990-2002 and 2014 onward). Alte Response aus 2022: The value was replaced by the notation key.	2020	I.20, Table 5	I.9, Table 3, 2022	CRF table 2(II)B-Hs1 - 2024
2.F.1.	The ERT recommends that the Party include in the NIR an explanation of the trend of the product life factors of HFC-134a (range of 6.28–14.09 per cent) for category 2.F.1.d (transport refrigeration), which are lower than the default values of the 2006 IPCC Guidelines (vol. 3, chap. 7, table 7.9), along with relevant documentation of the expert judgment used in line with annex 2A.1 of the 2006 IPCC Guidelines (vol. 1, chap. 2).	Resolved. Germany has included the relevant information in the NID	2022	I.14, Table 5		NID 2024, chapter 4.7.1.2.4
2.F.2.	The ERT encourages the Party to include an explanation for the use of "C" for AD and "IE" for emissions from closed-cell foam products in category 2.F.2 (foam blowing agents) in the NIR.	Resolved. Germany has included the relevant information in the NID	2022	I.15, Table 5		NID 2024, chapter 4.7.2
3.B.1.	The ERT recommends the Party elaborate in the NIR fully on the basis for the updated estimates for the typical animal mass (also explaining the initial, final and average mass) and Nex rate for dairy and	Resolved. Detailed methods are described in Vos et al. 2024	2022	A.7, Table 5		NID 2024, chap. 5.1.3.3 (Table 25) and chap.

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	non-dairy cattle and explain how the new methodology is more in line with the German feeding standards, including clear references to those standards.					2.4.1 in Vos et al. 2024
3.D.a	The ERT recommends that the Party include in the NIR further information on the development of EFs for N2O emissions from application of inorganic and organic N fertilizers, along with a detailed comparison with the default values from the 2006 IPCC Guidelines (vol. 4, chap. 11, table 11.1).	Resolved. Detailed information and comparison with IPCC EF has been added to the NID	2022	A.8, Table 5		NID 2024, chap. 5.5.2.1.1
3.D.a.2.b	The ERT recommends that the Party work with data suppliers to establish the underlying reasons for the high inter-annual variations of N input from sewage sludge applied to soils and include explanatory information in its NIR.	Resolved. Explanation for variations has been given by the data supplier	2022	A.9, Table 5		NID 2024, chap. 5.1.5.1.2
3.D.a.2.c + 3.D.b	ARR 2022: The ERT considers that the recommendation has not been fully addressed, as the country-specific EF has not been compared with the default EFs for N2O emissions from agricultural soil in the 2006 IPCC Guidelines (vol. 4, chap. 11, tables 11.1 and 11.3). It is also not clear in the NIR whether indirect N2O emissions from the application of biowaste (from volatilization of ammonia and NOX or leaching and run-off) are included in the N2O EFs provided. The ERT recommends that Germany increase the transparency of its reporting by providing detailed information in the next NIR or in supplementary material on how direct and indirect N2O emissions resulting from the application of biowaste onto managed soils are included in the country-specific N2O EF used by the Party and how this EF compares with the default EFs from the 2006 IPCC Guidelines (vol. 3, chap. 11). ARR 2022:Resolved: The ERT also recommends that the Party remove the statement “they can be neglected, since the nitrogen they include is organically bound and mineralizes very slowly” from the NIR (p.709)	Resolved. Information on the inclusion of biowaste application in country-specific EF for N2O emissions has been added. Comparison with the default EF is provided. Alte Response aus 2022: Detailed information on the composition of the used EFs for N2O, regarding treatment, application and minerlisation have been added to the NIR, including a comparison with the default factor from IPCC. Addiotionally the questioned statement has been deleted and the sentence adjusted accordingly.	2020	A.8, Table 5	A.5, Table 3, 2022; A.6, Table 3, 2022	NID 2024, chap. 5.5.2.1
4(V)	ARR 2022: The ERT recommends that Germany use available data on DOM stocks to include them as fuel when calculating CH4 and N2O emissions from biomass burning.	Resolved. For forest fire, biomass from the deadwood and litter pools will also be considered for burning as of this submission.	2020	L.16, Table 5	L.12, Table 3, 2022	see NIR chapter 6.4.5, 6.4.2.7.5 and 6.4.2.7.2, Tab 369,
4.	ARR 2022: The ERT considers that the recommendation has not yet been addressed because the Party did not report SOC changes associated with changes in the use and management of land with different soil types and climate conditions at a minimum in its 2022 submission. ARR 2022: The ERT considers that the recommendation has not been addressed because the Party did not report SOC changes consistently with the 2006 IPCC Guidelines in terms of stratification by climate zone and soil type. The ERT recommends that Germany ensure that the new reporting system is capable of detecting and reporting SOC changes associated with changes in the use and management of land with different soil types and climate conditions at a minimum. Until the new reporting system is fully implemented, the ERT recommends that the Party apply a method consistent with good practice, as defined by the 2006 IPCC Guidelines (vol. 4, section 2.3.3.1), for estimating SOC changes. For instance, a set of SOCREF values stratified by climate zone and soil type using SOC measurements taken in forest land, and grassland under natural conditions, if any, could be calculated. Thus, if the SOCREF values calculated are within the uncertainty range of the IPCC default values, the IPCC default stock change factors could be applied. Then, the SOC for each combination of land use and management system, as stratified by climate and soil type, could be calculated and formulation B of	Resolved. "With this submission, Germany implemented the ERT recommendation from the 2020 review process (ARR 2020: L.8, Table 5) and regionalized the carbon and nitrogen stocks of mineral soils. "	2020	L.8, Table 5	L.1, Table 3, 2022; L.2, Table 3, 2022	see NIR chapter 6.4.2.5, 6.1.2.1.9

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	equation 2.25 from the 2006 IPCC Guidelines (vol. 4, box 2.1) could be applied to estimate the annual net SOC change associated with each change in the use and/or management of land.					
4.A .	ARR 2022: The ERT considers that the recommendation has not been addressed because the Party did not report complete, transparent information in the NIR, including, where practicable, a flow chart that clearly presents in a visual format all steps and data used in the calculation of the SOC change, in order to demonstrate that the calculated SOC change is not biased by changes in forest area over time. The ERT recommends that Germany report complete information, including, where practicable, a flow chart that clearly presents in a visual format all steps and data used in the calculation of the SOC change, in order to demonstrate that the calculated SOC change is not biased by changes in forest area over time.	Resolved. Detailed description of SOC change calculation added	2020	L.9, Table 5	L.3, Table 3, 2022	NID 2024, chap. 6.4.2.5.3
4.B.1. + 4.C.1.	ARR 2022: The ERT considers that the recommendation has not been addressed because the Party has not reported the verification of estimates by applying the default methodology in the 2006 IPCC Guidelines (vol. 4, chaps. 2, 5 and 6, and equation 2.25) to estimate SOC changes in cropland remaining cropland and grassland remaining grassland associated with changes in land management in its 2022 submission. The ERT recommends that Germany provide verification of reported estimates by applying the default methodology in the 2006 IPCC Guidelines (vol. 4, chaps. 2, 5 and 6, and equation 2.25) to estimate SOC changes in cropland remaining cropland and grassland remaining grassland associated with changes in land management.	Resolved. Already resolved in 2023!	2020	L.14, Table 5	L.10, Table 3, 2022	NID 2024, chap. 6.5.2.3.2 and 6.6.2.3
5.A.1.	ARR 2022: The ERT notes that the calculation of emissions using the currently applied national k-value, namely 0.173 for food waste and sewage sludge derived from the default half-life value of four years, is in line with 2006 IPCC Guidelines (vol. 5, chap. 3, table 3.4). However, the recommendation has not yet been fully addressed because the Party has not yet used the updated national k-value for the calculation of emissions or reported the results or status of the research project in its NIR. ARR 2020: Germany indicated during the review that the results of the ongoing research projects to determine country-specific k-values were not available in time to implement them in the 2020 annual submission (NIR, section 7.2.1.6, p.707). While the latest results of the research have been published, they can only be incorporated into the emission inventory report after clarification of review questions with the contractors, QA through peer review and public validation by national experts. These processes are planned for completion in 2020. The Party expects the results from the research projects to be applied in the 2021 submission. The ERT recommends that Germany update the k-values used in the emission estimation as soon as the data from the research projects that will determine national k-values are available. If the results are not available in time for the 2019 annual submission, the ERT recommends that the Party include the status of these projects in the NIR, including a timeline for the implementation of their results in the inventory.	Resolved. The k-Values have been updated with emission reporting 2023.	2018	W.11, Table 6	W.2, Table 3, 2020; W.1, Table 3, 2022	see NIR 2023 chapter 7.2.1.2.7
5.B.1.	The ERT recommends that the Party provide in the NIR detailed information on the types of compost and anaerobic digestion plants with their corresponding CH4 and N2O EFs, and respective shares of biowaste treated, used to derive country-specific CH4 and N2O EFs.	Resolved. Detailed information on the types of compost and anaerobic digestion plants have been added to the NID.	2022	W.5, Table 5		NID 2024, chap. 7.3.1.2 + 7.3.2.2

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5.B.2.	ARR 2022: The ERT considers that the reporting does not raise an accuracy issue, but the recommendation has not yet been fully addressed because the Party has not reported the emissions from livestock manure co-digested anaerobically with biowaste at biogas facilities in accordance with the 2006 IPCC Guidelines (vol. 5, chap. 4.1.1, p.4.5) or clearly explained allocation of the emissions (both CH4 and N2O), including from flaring and recovery, to the energy, waste and agriculture sectors. ARR 2020: The ERT recommends that Germany report in future submissions the amount of livestock manure co-digested anaerobically with biowaste at biogas facilities (i.e. the AD) in CRF table 5.B, column B, and report the associated CH4 and N2O emissions in CRF table 5.B as "IE" while indicating in the documentation box to that table that they are reported under the agriculture sector in CRF table 3.B(a) to avoid double counting.	The recommendation has been implemented. The allocation of the emissions (Notation Keys IE) has been explained thoroughly and can be found in the appropriate explanation cells of CRT-Table 5B2b-Livestock manure co-digested. Additionally, they should be also entered by the CRT-Reporter into Table 9 "Information on notation keys" and can be found there.	2020	W.10, Table 5	W.2, Table 3, 2022	CRT-Table 5B2b-Livestock manure co-digested. And/or Table 9.
5.D.1.	ARR 2022: The German Environment Agency is currently working on a review paper covering about 40 publications, including the ongoing study, as the basis for representative country-specific EFs. Germany will also consider a new CH4 EF for septic tanks derived from a literature review and expert opinions.Anmerkung StS: hier hat das ERT jetzt zwei HBs zusammengeworfen - EF für CH4+N2O (Original) und Anpassung MCF The ERT recommends that Germany implement the results of the study that will produce better documented EFs as soon as the data are available. If the results are not available in time for the 2019 submission, the ERT recommends that the Party include the status of this study in the NIR, including a timeline for the implementation of its results in the inventory.	Resolved. The inventory has been improved in keeping with the results of a review paper by the federal environment agency itself, that has just been finalised. This review incorporates the results of the R&D project on "fugitive emissions" and a variety of other studies related to Emissions of CH4 and N2O in wastewater treatment.	2018	W.14, Table 6	W.5, Table 3, 2020; W.3, Table 3, 2022	NID 2024, chap. 7.5.1
5.D.1.	The ERT recommends that the Party update in the NIR the information on the underlying reason for the decrease in the CH4 EF for wastewater treatment plants and provide an explanation of the trend before and after 2020. The ERT also recommends that the Party provide details on the contribution of various sources in the estimated emissions and the improvement measures performed in the sludge treatment units that led to the decrease in CH4 emissions in domestic wastewater sector during 1990–2020.	Resolved. Description has been improved.	2022	W.6, Table 5		NID 2024, chap. 7.5.1.1.2
5.D.1.	The ERT recommends that the Party apply updated MCF values based on actual temperatures in Germany in the estimation of emissions when the ongoing research has been completed (or provide in the NIR information on the status of the research if not yet completed) and provide information on actual temperature conditions in Germany to justify the use of the selected MCF values.	The recommendation has been implemented - the MCF has been updated.	2022	W.7, Table 5		see NID 2025, chapter 7.5.1.1.2
KP-CM	The ERT recommends that Germany consider the issues listed in ID#s L.9;, L.10; and L.12; under the LULUCF sector (CM) above as also being relevant to KP-LULUCF activities.	Closed - as KP-Inventory-Reporting is no longer carried out.	2020	KL.18, Table 5	KL.11, Table 3, 2022	-
KP-CM - GM	The ERT recommends that Germany consider the issue listed in ID# L.14 under the LULUCF sector (CM and GM) above as also being relevant to KP-LULUCF activities.	Closed - as KP-Inventory-Reporting is no longer carried out.	2020	KL.19, Table 5	KL.12, Table 3, 2022	-
KP-FM	ARR 2022: Keine zusätzliche Anleitung - recommendation aus ARR 2020 gilt unverändert. The ERT recommends that Germany provide in future submissions information demonstrating that model-based calculations reproduce the data for FM or forest land remaining forest land for the historical period reported in the inventory.	Closed - as KP-Inventory-Reporting is no longer carried out.	2020	KL.13, Table 5	KL.4, Table 3, 2022	-
KP-FM	ARR 2022: The ERT recommends that Germany provide in its next submission information on the main factors generating the accounted quantity under FM (i.e. the difference in net emissions	Closed - as KP-Inventory-Reporting is no longer carried out.	2020	KL.14, Table 5	KL.5, Table 3, 2022	-

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	between reporting of FM during the second commitment period and the FMRL) and on the difference between the projected harvest rate and the actual harvest rate.					
KP-FM	The ERT recommends that Germany consider the issue listed in ID# L.9 under the LULUCF sector (FM) above as also being relevant to KP-LULUCF activities.	Closed - as KP-Inventory-Reporting is no longer carried out.	2020	KL.16, Table 5	KL.7, Table 3, 2022	-
KP-LULUCF	ARR 2022: On the basis of information provided during the review to show the conservative nature of the Party's approach, the ERT concluded that this potential problem of a mandatory nature does not influence the Party's ability to fulfil its commitments for the second commitment period of the Kyoto Protocol and therefore the accuracy issue was not included in the list of potential problems and further questions raised. The ERT recommends that Germany consider the issue listed in ID# L.8 under the LULUCF sector above as also being relevant to KP-LULUCF activities.	Closed - as KP-Inventory-Reporting is no longer carried out.	2020	KL.10, Table 5	KL.2, Table 3, 2022	-

10.5 Areas of improvement and/or capacity-building related to the flexibility provisions applied with self-determined estimated timeframes for improvements (related to non-mandatory provisions as per para. 7(c–d) of the MPGs)

Germany makes no use of flexibilities.

Annex 1 Key categories

Pursuant to the *2006 IPCC Guidelines*, the parties to the UN Framework Convention on Climate Change and Kyoto Protocol are required to calculate and publish emissions data annually.

These emissions inventories must be clear for everyone (transparency), calculated consistently in the time series since 1990 (consistency), assessed uniformly at the international level using the prescribed calculation methods (comparability), include all the relevant emission sources and sinks in the reporting country (completeness), be evaluated for errors and be subject to ongoing internal and external quality management (accuracy).

To focus the many and detailed activities and resources required for this purpose on the inventory's principal categories, the IPCC has introduced the term "key category". Key categories are categories that are highlighted in the national inventory system because their emissions have a significant influence on total emissions of direct greenhouse gases, either in terms of absolute emissions or as a contribution to the emissions trend over time or in both ways.

Chapter 4 of the 2006 IPCC Guidelines describes the methods to be applied for identifying key categories. These methods include inventory analysis for one year (Approach 1, Level Assessment), time series analysis of inventory data (Approach 1, Trend Assessment), detailed analysis of inventory data with error evaluation (Approach 2, Trend Assessment including uncertainties) and assessment of qualitative criteria (pursuant to Chapter 4.3.3 of (IPCC, 2006b), Vol. 4, Ch. 1).

Approach 1 analyses must always be carried out using two procedures. In a first procedure, only emissions from sources are assessed – sequestration in sinks is not taken into account here. In a second procedure, emissions sequestration in sinks is then included (regardless of whether it is positive or negative). As would be expected, the two results differ. Pursuant to the 2006 IPCC GL, both results must be taken into account in the identification of key categories.

For identified key categories, the Parties are then required to use highly detailed calculation methods (Approach 2 or higher; the relevant methods are also specified in the (IPCC, 2006a)). Should direct use of such methods prove impossible, for whatever reason (e.g. data are not available for the required input variables, etc.), Parties are required to prove that the methods applied nationally achieve at least a comparable degree of accuracy in the calculation result. This proof, as well as the key category analysis performed overall, must be outlined in the national inventory report to be prepared annually.

Annex 1.1 Description of the methods for identifying key categories

The results of key category analysis using the two Approach 1 methodologies (level and trend), the Approach 2 methodology and assessment in terms of qualitative criteria are presented in Table 8, Chapter 1.4. For a description of the methodologies used, please refer to the *2006 IPCC Guidelines* IPCC (2006a): Vol. 1).

Annex 1.1.1 Approach 1 method

The level analysis identifies the source categories responsible for 95% of total national emissions (as CO2-equivalent emissions) in the base year (1990; 1995 for the F gases) and in the current year; these sources are then defined as key categories (●). Calculations were performed using Formula 4.1 of the 2006 IPCC Guidelines IPCC (2006a): Vol. 1).

The trend analysis identifies those categories as key categories (●) that have contributed significantly to the change in total greenhouse gas emissions in the most recent year in terms of the development of their emission contribution since the base year. It is irrelevant here whether these changes have led to a reduction or an increase in total emissions. Calculations were performed using Formula 4.2 of the 2006 IPCC Guidelines IPCC (2006a): Vol. 1).

The following table presents a complete list of all of the subcategories covered by the analysis.

Table 470: Key categories for Germany pursuant to the Approach 1 method (complete list, calculated with IPCC AR5-GWP)

			Level	Level	Level	Level	Level	Level	Trend	Trend	
IPCC Categories	Activity	Emissions of	Base year	Base year +LULUCF	1990	1990 +LULUCF	2023	2024 +LULUCF	2024	2024 +LULUCF	KCA decision
1 A 1 a, Public Electricity and Heat Production	fossil fuels	CO_2	•	•	•	•	•	•	•	•	L/T
1 A 1 a, Public Electricity and Heat Production		CH_4	-	-	-	-	•	•	•	•	L/T
1 A 1 a, Public Electricity and Heat Production		N_2O	-	-	-	-	-	-	-	-	-/-
1 A 1 b, Petroleum Refining	fossil fuels	CO_2	•	•	•	•	•	•	•	•	L/T
1 A 1 b, Petroleum Refining		CH_4	-	-	-	-	-	-	-	-	-/-
1 A 1 b, Petroleum Refining		N_2O	-	-	-	-	-	-	-	-	-/-
1 A 1 c, Manufacture of Solid Fuels and Other Energy Industries	fossil fuels	CO_2	•	•	•	•	•	•	•	•	L/T
1 A 1 c, Manufacture of Solid Fuels and Other Energy Industries		CH_4	-	-	-	-	-	-	-	-	-/-
1 A 1 c, Manufacture of Solid Fuels and Other Energy Industries		N_2O	-	-	-	-	-	-	-	-	-/-
1 A 2 a, Iron and Steel	fossil fuels	CO_2	•	•	•	•	•	•	•	•	L/T
1 A 2 a, Iron and Steel		CH_4	-	-	-	-	-	-	-	-	-/-
1 A 2 a, Iron and Steel		N_2O	-	-	-	-	-	-	-	-	-/-
1 A 2 b, Non-ferrous metals	fossil fuels	CO_2	-	-	-	-	•	-	-	-	L/-
1 A 2 b, Non-ferrous metals		CH_4	-	-	-	-	-	-	-	-	-/-
1 A 2 b, Non-ferrous metals		N_2O	-	-	-	-	-	-	-	-	-/-
1 A 2 d, Pulp, Paper and Print	fossil fuels	CO_2	-	-	-	-	-	-	-	-	-/-
1 A 2 d, Pulp, Paper and Print		CH_4	-	-	-	-	-	-	-	-	-/-
1 A 2 d, Pulp, Paper and Print		N_2O	-	-	-	-	-	-	-	-	-/-
1 A 2 e, Food Processing, Beverages and Tobacco	fossil fuels	CO_2	-	-	-	-	-	-	•	-	-/T
1 A 2 e, Food Processing, Beverages and Tobacco		CH_4	-	-	-	-	-	-	-	-	-/-
1 A 2 e, Food Processing, Beverages and Tobacco		N_2O	-	-	-	-	-	-	-	-	-/-
1 A 2 f, Non-metallic minerals	fossil fuels	CO_2	•	•	•	•	•	•	-	-	L/-
1 A 2 f, Non-metallic minerals		CH_4	-	-	-	-	-	-	-	-	-/-
1 A 2 f, Non-metallic minerals		N_2O	-	-	-	-	-	-	-	-	-/-
1 A 2 g, Other Manufacturing Industries and Construction	fossil fuels	CO_2	•	•	•	•	•	•	•	•	L/T
1 A 2 g, Other Manufacturing Industries and Construction		CH_4	-	-	-	-	-	-	-	-	-/-
1 A 2 g, Other Manufacturing Industries and Construction		N_2O	-	-	-	-	-	-	-	-	-/-
1 A 3 a, Civil Aviation	fossil fuels	CO_2	-	-	-	-	-	-	-	-	-/-
1 A 3 a, Civil Aviation		CH_4	-	-	-	-	-	-	-	-	-/-
1 A 3 a, Civil Aviation		N_2O	-	-	-	-	-	-	-	-	-/-
1 A 3 b, Road transport	fossil fuels	CO_2	•	•	•	•	•	•	•	•	L/T
1 A 3 b, Road transport		CH_4	-	-	-	-	-	-	-	-	-/-
1 A 3 b, Road transport		N_2O	-	-	-	-	-	-	-	-	-/-
1 A 3 c, Rail Transport	fossil fuels	CO_2	•	•	•	•	-	-	•	•	L/T
1 A 3 c, Rail Transport		CH_4	-	-	-	-	-	-	-	-	-/-

			Level	Level	Level	Level	Level	Level	Trend	Trend	
1 A 3 c, Rail Transport		N_2O	-	-	-	-	-	-	-	-	-/-
1 A 3 d, National Shipping	fossil fuels	CO_2	•	•	-	-	-	-	-	-	L/-
1 A 3 d, National Shipping		CH_4	-	-	-	-	-	-	-	-	-/-
1 A 3 d, National Shipping		N_2O	-	-	-	-	-	-	-	-	-/-
1 A 3 e, Other Transport	fossil fuels	CO_2	-	-	-	-	-	-	-	-	-/-
1 A 3 e, Other Transport		CH_4	-	-	-	-	-	-	-	-	-/-
1 A 3 e, Other Transport		N_2O	-	-	-	-	-	-	-	-	-/-
1 A 4 a, Commercial/Institutional	fossil fuels	CO_2	•	•	•	•	•	•	•	•	L/T
1 A 4 a, Commercial/Institutional		CH_4	-	-	-	-	-	-	•	-	-/T
1 A 4 a, Commercial/Institutional		N_2O	-	-	-	-	-	-	-	-	-/-
1 A 4 b, Residential	fossil fuels	CO_2	•	•	•	•	•	•	•	•	L/T
1 A 4 b, Residential		CH_4	-	-	-	-	-	-	-	-	-/-
1 A 4 b, Residential		N_2O	-	-	-	-	-	-	-	-	-/-
1 A 4 c, Agriculture/Forestry/Fishing	fossil fuels	CO_2	•	•	•	•	•	•	•	•	L/T
1 A 4 c, Agriculture/Forestry/Fishing		CH_4	-	-	-	-	-	-	-	-	-/-
1 A 4 c, Agriculture/Forestry/Fishing		N_2O	-	-	-	-	-	-	-	-	-/-
1 A 5, Military	fossil fuels	CO_2	•	•	•	•	-	-	•	•	L/T
1 A 5, Military		CH_4	-	-	-	-	-	-	-	-	-/-
1 A 5, Military		N_2O	-	-	-	-	-	-	-	-	-/-
1 B 1, Solid Fuels		CO_2	-	-	-	-	-	-	-	-	-/-
1 B 1, Solid Fuels		CH_4	•	•	•	•	-	-	•	•	L/T
1 B 2 a, Fugitive Emissions from Oil		CO_2	-	-	-	-	-	-	-	-	-/-
1 B 2 a, Fugitive Emissions from Oil		CH_4	-	-	-	-	-	-	-	-	-/-
1 B 2 a, Fugitive Emissions from Oil		N_2O	-	-	-	-	-	-	-	-	-/-
1 B 2 b, Fugitive Emissions from Natural Gas		CO_2	-	-	-	-	-	-	-	-	-/-
1 B 2 b, Fugitive Emissions from Natural Gas		CH_4	•	•	•	•	•	•	•	•	L/T
1 B 2 c, Venting and Flaring (oil, gas, combined oil and gas)		CO_2	-	-	-	-	-	-	-	-	-/-
1 B 2 c, Venting and Flaring (oil, gas, combined oil and gas)		CH_4	-	-	-	-	-	-	-	-	-/-
1 B 2 c, Venting and Flaring (oil, gas, combined oil and gas)		N_2O	-	-	-	-	-	-	-	-	-/-
2 A 1, Cement Production		CO_2	•	•	•	•	•	•	•	•	L/T
2 A 2, Lime Production		CO_2	•	•	•	•	•	•	•	-	L/T
2 A 3, Glass Production		CO_2	-	-	-	-	-	-	-	-	-/-
2 A 4, Other Process Uses of Carbonates		CO_2	-	-	-	-	-	-	-	-	-/-
2 B 1, Ammonia Production		CO_2	•	•	•	•	•	•	-	-	L/-
2 B 2, Nitric Acid Production		N_2O	-	-	-	-	-	-	•	•	-/T
2 B 3, Adipic Acid Production		N_2O	•	•	•	•	-	-	•	•	L/T
2 B 5, Carbide Production		CO_2	-	-	-	-	-	-	-	-	-/-
2 B 7, Soda Ash Production		CO_2	-	-	-	-	-	-	-	-	-/-
2 B 8, Petrochemical and Carbon Black Production		CO_2	-	-	-	-	-	-	-	-	-/-

			Level	Level	Level	Level	Level	Level	Trend	Trend	
2 B 8, Petrochemical and Carbon Black Production		CH_4	-	-	-	-	-	-	-	-	-/-
2 B 9 a, By-product Emissions		HFC23	•	•	•	•	-	-	•	•	L/T
2 B 9 b, Fugitive Emissions		CF_4	-	-	-	-	-	-	-	-	-/-
2 B 9 b, Fugitive Emissions		HFC134a	-	-	-	-	-	-	-	-	-/-
2 B 9 b, Fugitive Emissions		HFC227ea	-	-	-	-	-	-	-	-	-/-
2 B 9 b, Fugitive Emissions		SF_6	-	-	-	-	-	-	-	-	-/-
2 B 10, Other Chemical Industry		CH_4	-	-	-	-	-	-	-	-	-/-
2 B 10, Other Chemical Industry		N_2O	-	-	-	-	-	-	-	-	-/-
2 C 1, Iron and Steel Production		CO_2	•	•	•	•	•	•	•	•	L/T
2 C 1, Iron and Steel Production		CH_4	-	-	-	-	-	-	-	-	-/-
2 C 1, Iron and Steel Production		N_2O	-	-	-	-	-	-	-	-	-/-
2 C 2, Ferroalloys Production		CO_2	-	-	-	-	-	-	-	-	-/-
2 C 2, Ferroalloys Production		CH_4	-	-	-	-	-	-	-	-	-/-
2 C 3, Aluminium Production		CO_2	-	-	-	-	-	-	-	-	-/-
2 C 3, Aluminium Production		CF4	-	-	-	-	-	-	-	-	-/-
2 C 3, Aluminium Production		C_2F_6	-	-	-	-	-	-	-	-	-/-
2 C 3, Aluminium Production		SF_6	-	-	-	-	-	-	-	-	-/-
2 C 4, Magnesium Production		HFC134a	-	-	-	-	-	-	-	-	-/-
2 C 4, Magnesium Production		SF_6	-	-	-	-	-	-	-	-	-/-
2 C 5, Lead Production		CO_2	-	-	-	-	-	-	-	-	-/-
2 C 6, Zinc Production		CO_2	-	-	-	-	-	-	-	-	-/-
2 D 1, Lubricant Use		CO_2	-	-	-	-	-	-	-	-	-/-
2 D 2, Paraffin Wax Use		CO_2	-	-	-	-	-	-	-	-	-/-
2 D 2, Paraffin Wax Use		N2O	-	-	-	-	-	-	-	-	-/-
2 D 3, Other Non-Energy Products from Fuels		CO_2	-	-	-	-	-	-	-	-	-/-
2 E, Electronics Industry		N_2O	-	-	-	-	-	-	-	-	-/-
2 E, Electronics Industry		CF_4	-	-	-	-	-	-	-	-	-/-
2 E, Electronics Industry		C_2F_6	-	-	-	-	-	-	-	-	-/-
2 E, Electronics Industry		C_3F_8	-	-	-	-	-	-	-	-	-/-
2 E, Electronics Industry		cC_4F_8	-	-	-	-	-	-	-	-	-/-
2 E, Electronics Industry		C_6F_{14}	-	-	-	-	-	-	-	-	-/-
2 E, Electronics Industry		HFC23	-	-	-	-	-	-	-	-	-/-
2 E, Electronics Industry		HFC32	-	-	-	-	-	-	-	-	-/-
2 E, Electronics Industry		SF_6	-	-	-	-	-	-	-	-	-/-
2 E, Electronics Industry		NF_3	-	-	-	-	-	-	-	-	-/-
2 F, Product Uses as Substitutes for ODS		C_2F_6	-	-	-	-	-	-	-	-	-/-
2 F, Product Uses as Substitutes for ODS		C_3F_8	-	-	-	-	-	-	-	-	-/-
2 F, Product Uses as Substitutes for ODS		C_6F_{14}	-	-	-	-	-	-	-	-	-/-
2 F, Product Uses as Substitutes for ODS		HFC23	-	-	-	-	-	-	-	-	-/-

			Level	Level	Level	Level	Level	Level	Trend	Trend	
2 F, Product Uses as Substitutes for ODS		HFC32	-	-	-	-	-	-	-	-	-/-
2 F, Product Uses as Substitutes for ODS		HFC4310mee	-	-	-	-	-	-	-	-	-/-
2 F, Product Uses as Substitutes for ODS		HFC125	-	-	-	-	•	•	•	•	L/T
2 F, Product Uses as Substitutes for ODS		HFC134a	-	-	-	-	•	•	•	•	L/T
2 F, Product Uses as Substitutes for ODS		HFC143a	-	-	-	-	-	-	•	•	-/T
2 F, Product Uses as Substitutes for ODS		HFC152a	-	-	-	-	-	-	-	-	-/-
2 F, Product Uses as Substitutes for ODS		HFC227ea	-	-	-	-	-	-	-	-	-/-
2 F, Product Uses as Substitutes for ODS		HFC236fa	-	-	-	-	-	-	-	-	-/-
2 F, Product Uses as Substitutes for ODS		HFC245fa	-	-	-	-	-	-	-	-	-/-
2 F, Product Uses as Substitutes for ODS		HFC365mfc	-	-	-	-	-	-	-	-	-/-
2 G, Other Product Manufacture and Use		CH_4	-	-	-	-	-	-	-	-	-/-
2 G, Other Product Manufacture and Use		N_2O	-	-	-	-	-	-	-	-	-/-
2 G, Other Product Manufacture and Use		C10F18	-	-	-	-	-	-	-	-	-/-
2 G, Other Product Manufacture and Use		HFC134a	-	-	-	-	-	-	-	-	-/-
2 G, Other Product Manufacture and Use		HFC245fa	-	-	-	-	-	-	-	-	-/-
2 G, Other Product Manufacture and Use		HFC365mfc	-	-	-	-	-	-	-	-	-/-
2 G, Other Product Manufacture and Use		SF_6	•	•	•	•	-	-	•	•	L/T
3 A, Enteric Fermentation	dairy cows	CH_4	•	•	•	•	•	•	•	•	L/T
3 A, Enteric Fermentation	non-dairy cattle	CH_4	•	•	•	•	•	•	•	•	L/T
3 A, Enteric Fermentation	other animals	CH_4	-	-	-	-	•	•	-	-	L/-
3 B, Manure Management	dairy cows	CH_4	-	-	-	-	•	•	•	•	L/T
3 B, Manure Management	non-dairy cattle	CH_4	-	-	-	-	-	-	-	-	-/-
3 B, Manure Management	swine	CH_4	•	•	•	•	•	•	-	-	L/-
3 B, Manure Management	other animals	CH_4	-	-	-	-	-	-	-	-	-/-
3 B, Manure Management	dairy cows	N_2O	-	-	-	-	-	-	-	-	-/-
3 B, Manure Management	non-dairy cattle	N_2O	-	-	-	-	-	-	-	-	-/-
3 B, Manure Management	swine	N_2O	-	-	-	-	-	-	-	-	-/-
3 B, Manure Management	other animals	N_2O	-	-	-	-	-	-	-	-	-/-
3 B, Manure Management	deposition and leaching	N_2O	-	-	-	-	-	-	-	-	-/-
3 D, Agricultural Soils		N_2O	•	•	•	•	•	•	•	•	L/T
3 G, Liming		CO_2	-	-	-	-	•	•	•	-	L/T
3 H, Urea Application		CO_2	-	-	-	-	-	-	-	-	-/-
3 I, Other carbon-containing fertilisers		CO_2	-	-	-	-	-	-	-	-	-/-
3 J, Other Agriculture		CH_4	-	-	-	-	-	-	•	•	-/T
3 J, Other Agriculture		N_2O	-	-	-	-	-	-	-	-	-/-
4 A, Forest Land		CO_2	-	•	-	•	-	•	-	•	L/T
4 A, Forest Land		CH_4	-	-	-	-	-	-	-	-	-/-
4 A, Forest Land		N_2O	-	-	-	-	-	-	-	-	-/-
4 B, Cropland		CO_2	-	•	-	•	-	•	-	•	L/T

			Level	Level	Level	Level	Level	Level	Trend	Trend	
4 B, Cropland		CH_4	-	-	-	-	-	-	-	-	-/-
4 B, Cropland		N_2O	-	-	-	-	-	-	-	-	-/-
4 C, Grassland		CO_2	-	•	-	•	-	•	-	•	L/T
4 C, Grassland		CH_4	-	-	-	-	-	•	-	•	L/T
4 C, Grassland		N_2O	-	-	-	-	-	-	-	-	-/-
4 D, Wetlands		CO_2	-	•	-	•	-	•	-	•	L/T
4 D, Wetlands		CH_4	-	•	-	•	-	•	-	•	L/T
4 D, Wetlands		N_2O	-	-	-	-	-	-	-	-	-/-
4 E, Settlements		CO_2	-	•	-	•	-	•	-	•	L/T
4 E, Settlements		CH_4	-	-	-	-	-	-	-	-	-/-
4 E, Settlements		N_2O	-	-	-	-	-	-	-	-	-/-
4 G, Harvested Wood Products		CO_2	-	-	-	-	-	-	-	•	-/T
5 A, Solid Waste Disposal		CH_4	•	•	•	•	•	•	•	•	L/T
5 B, Biological Treatment of Solid Waste		CH_4	-	-	-	-	-	-	•	•	-/T
5 B, Biological Treatment of Solid Waste		N_2O	-	-	-	-	-	-	-	-	-/-
5 D 1, Domestic Wastewater		CH_4	•	•	•	•	-	-	•	•	L/T
5 D 1, Domestic Wastewater		N_2O	-	-	-	-	-	-	•	•	-/T
5 D 2, Industrial Wastewater		CH_4	-	-	-	-	-	-	-	-	-/-
5 D 2, Industrial Wastewater		N_2O	-	-	-	-	-	-	-	-	-/-
5 E, Other Waste		CH_4	-	-	-	-	-	-	-	-	-/-
5 E, Other Waste		N_2O	-	-	-	-	-	-	-	-	-/-

Annex 1.1.2 Approach 2 method

Key category analysis using the Approach 2 method is based on the results of current uncertainties determination in accordance with Approach 1. The results largely confirmed the findings of the Approach 1 key category analyses. The categories listed in Table 9, Chapter 1.4, also have to be considered, however.

Annex 1.1.3 Assessment with qualitative criteria

Germany assesses key categories using qualitative criteria. Chapter 4.3.3 of the 2006 IPCC Guidelines IPCC (2006a) recommends which criteria are to be applied and include an assessment based on the use of mitigation techniques, the expectation of a disproportionate increase in emissions, high uncertainty or unexpectedly low or high emissions in a category. The criteria may be used as a basis for defining additional categories as key categories.

In the category adipic acid production (2.B.3), a redundant waste gas treatment system was installed. On this basis, it is classified as a key category according to qualitative criteria. 2.B.3 is already a key category, however, in terms of Approach 1 Level and Trend assessment.

SF_6 emissions from soundproof windows are reported under 2.G.2. Even though a trend cannot yet be recognised, it is clear that SF_6 emissions must be expected to increase sharply in the coming years as disposal of old windows increases. For this reason – i.e. on the basis of qualitative criteria – it is already a key category. This classification leads to no change, however, since 2.G is already a key category for SF_6 according to Approach 1 Level and Trend. Qualitative assessment on the basis of high uncertainties is not required, since Germany carries out Approach 2 key category analysis for the entire inventory every year. No unexpectedly low or high emissions were recorded in the inventory.

No additional key categories were identified in Germany using qualitative criteria.

Germany uses all recommended approaches for identifying and evaluating categories. The IPCC Guidelines mandate that 95% of emissions from sources/removals in sinks be classified in key categories. The key categories that Germany has identified comprise emission-causing activities that account for about 98% of the total inventory. This high percentage results from Germany's practice of identifying key categories by combining the results of all analysis approaches and assessments.

Annex 2 Evaluation of uncertainty: Uncertainties by categories

The uncertainties for the German greenhouse gas inventories have been determined completely for all categories. In each case, they have been determined for the base year, for the current report year and for the relevant trend. In Germany, uncertainties are calculated each year in accordance with both Approach 1 (error propagation) and Approach 2 (Monte Carlo simulation).

The results of this year's uncertainties analysis are shown in accordance with the specifications in Tables 3.4 and 3.5 of the 2006 IPCC Guidelines(IPCC, 2006a) in Table 471 and Table 472.

Table 471: Uncertainties by categories (Approach 1; error propagation pursuant to Table 3.4 of the IPCC Guidelines)

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC Category	**Gas**	**Base year emissions or removals**	**2024 emissions or removals**	**Activity data uncertainty**	**Emission factor/estimation parameter uncertainty**	**Combined uncertainty**	**Contribution to Variance by Category in Year x**	**Type A sensitivity**	**Type B sensitivity**	**Uncertainty in trend in national emissions introduced by emission factor/estimation parameter uncertainty**	**Uncertainty in trend in national emissions introduced by activity data uncertainty**	**Uncertainty introduced into the trend in total national emissions**
		Input data	**Input data**	**Input data Note A**	**Input data Note A**	$\sqrt{E^2 + F^2}$	$\frac{(G * D)^2}{(\sum D)^2}$	**Note B**	$\lvert\frac{D}{\sum C}\rvert$	**I * F Note C**	**J * E * Note D**	$\sqrt{2\ K^2 + L^2}$
		kt CO2 equivalent	**kt CO2 equivalent**	**%**	**%**	**%**		**%**	**%**	**%**	**%**	**%**
Sum	**GHG**	**1,293,320.67**	**707,608.32**			**3.10**						**3.07**
1 A 1 a, Public Electricity and Heat Production	CO_2	338,451.16	151,375.41	3.12	1.04	3.29	0.50	0.02	0.12	0.52	0.17	0.30
1 A 1 a, Public Electricity and Heat Production	CH_4	192.83	2,637.87	7.66	55.66	56.18	0.04	0.00	0.00	0.02	0.16	0.03
1 A 1 a, Public Electricity and Heat Production	N_2O	2,140.86	1,241.79	3.01	17.57	17.83	0.00	0.00	0.00	0.00	0.02	0.00
1 A 1 b, Petroleum Refining	CO_2	24,212.49	21,079.80	0.00	5.11	5.11	0.02	0.01	0.02	0.00	0.12	0.01
1 A 1 b, Petroleum Refining	CH_4	17.99	17.28	0.00	16.60	16.60	0.00	0.00	0.00	0.00	0.00	0.00
1 A 1 b, Petroleum Refining	N_2O	89.27	56.08	0.00	29.45	29.45	0.00	0.00	0.00	0.00	0.00	0.00
1 A 1 c, Manufacture of Solid Fuels and Other Energy Industries	CO_2	65,289.06	8,735.95	0.00	5.73	5.73	0.01	0.01	0.01	0.00	0.05	0.00
1 A 1 c, Manufacture of Solid Fuels and Other Energy Industries	CH_4	103.02	113.12	0.00	115.60	115.60	0.00	0.00	0.00	0.00	0.01	0.00
1 A 1 c, Manufacture of Solid Fuels and Other Energy Industries	N_2O	586.23	116.43	0.00	24.88	24.88	0.00	0.00	0.00	0.00	0.00	0.00
1 A 2 a, Iron and Steel	CO_2	35,269.33	33,166.23	4.71	3.36	5.78	0.07	0.01	0.03	0.17	0.12	0.04
1 A 2 a, Iron and Steel	CH_4	69.95	63.73	8.43	25.36	26.73	0.00	0.00	0.00	0.00	0.00	0.00
1 A 2 a, Iron and Steel	N_2O	137.93	88.33	4.81	35.42	35.75	0.00	0.00	0.00	0.00	0.00	0.00
1 A 2 b, Non-ferrous metals	CO_2	1,629.22	1,524.28	10.63	0.94	10.67	0.00	0.00	0.00	0.02	0.00	0.00
1 A 2 b, Non-ferrous metals	CH_4	1.55	1.86	10.83	67.68	68.54	0.00	0.00	0.00	0.00	0.00	0.00
1 A 2 b, Non-ferrous metals	N_2O	15.25	7.39	9.35	58.81	59.55	0.00	0.00	0.00	0.00	0.00	0.00
1 A 2 d, Pulp, Paper and Print	CO_2	3.65	8.85	5.22	2.24	5.68	0.00	0.00	0.00	0.00	0.00	0.00
1 A 2 d, Pulp, Paper and Print	CH_4	0.73	2.67	4.04	43.24	43.43	0.00	0.00	0.00	0.00	0.00	0.00
1 A 2 d, Pulp, Paper and Print	N_2O	2.50	9.09	4.04	51.54	51.70	0.00	0.00	0.00	0.00	0.00	0.00
1 A 2 e, Food Processing, Beverages and Tobacco	CO_2	2,015.91	280.87	5.69	1.50	5.89	0.00	0.00	0.00	0.00	0.00	0.00
1 A 2 e, Food Processing, Beverages and Tobacco	CH4	5.02	0.19	6.33	41.29	41.77	0.00	0.00	0.00	0.00	0.00	0.00

A	B	C	D	E	F	G	H	I	J	K	L	M
1 A 2 e, Food Processing, Beverages and Tobacco	N_2O	21.92	2.23	5.87	55.16	55.48	0.00	0.00	0.00	0.00	0.00	0.00
1 A 2 f, Non-metallic minerals	CO_2	18,507.38	9,581.88	3.99	0.89	4.09	0.00	0.00	0.01	0.04	0.01	0.00
1 A 2 f, Non-metallic minerals	CH_4	56.31	12.55	3.64	24.89	25.15	0.00	0.00	0.00	0.00	0.00	0.00
1 A 2 f, Non-metallic minerals	N_2O	182.53	76.25	3.16	28.72	28.89	0.00	0.00	0.00	0.00	0.00	0.00
1 A 2 g, Other Manufacturing Industries and Construction	CO_2	125,527.76	56,437.66	0.00	3.77	3.77	0.09	0.01	0.04	0.00	0.23	0.05
1 A 2 g, Other Manufacturing Industries and Construction	CH_4	146.88	202.46	0.00	30.63	30.63	0.00	0.00	0.00	0.00	0.01	0.00
1 A 2 g, Other Manufacturing Industries and Construction	N_2O	831.54	411.25	0.00	15.25	15.25	0.00	0.00	0.00	0.00	0.01	0.00
1 A 3 a, Civil Aviation	CO_2	2,310.48	1,087.32	7.19	3.83	8.15	0.00	0.00	0.00	0.01	0.00	0.00
1 A 3 a, Civil Aviation	CH_4	3.48	1.52	16.40	76.39	78.13	0.00	0.00	0.00	0.00	0.00	0.00
1 A 3 a, Civil Aviation	N_2O	20.68	9.70	0.00	21.32	21.32	0.00	0.00	0.00	0.00	0.00	0.00
1 A 3 b, Road transport	CO_2	151,889.81	139,371.62	0.00	5.29	5.29	1.09	0.04	0.11	0.00	0.81	0.65
1 A 3 b, Road transport	CH_4	1,812.75	229.38	6.50	10.01	11.93	0.00	0.00	0.00	0.00	0.00	0.00
1 A 3 b, Road transport	N_2O	1,123.44	1,306.82	6.75	14.43	15.93	0.00	0.00	0.00	0.01	0.02	0.00
1 A 3 c, Rail Transport	CO_2	3,133.05	742.99	0.00	10.01	10.01	0.00	0.00	0.00	0.00	0.01	0.00
1 A 3 c, Rail Transport	CH_4	19.73	0.26	8.59	28.90	30.15	0.00	0.00	0.00	0.00	0.00	0.00
1 A 3 c, Rail Transport	N_2O	6.83	1.64	8.84	65.47	66.06	0.00	0.00	0.00	0.00	0.00	0.00
1 A 3 d, National Shipping	CO_2	3,013.77	1,410.58	0.00	24.24	24.24	0.00	0.00	0.00	0.00	0.04	0.00
1 A 3 d, National Shipping	CH_4	2.65	10.07	9.26	135.78	136.10	0.00	0.00	0.00	0.00	0.00	0.00
1 A 3 d, National Shipping	N_2O	18.68	10.42	12.18	98.29	99.04	0.00	0.00	0.00	0.00	0.00	0.00
1 A 3 e, Other Transport	CO_2	1,083.27	675.05	2.72	0.91	2.86	0.00	0.00	0.00	0.00	0.00	0.00
1 A 3 e, Other Transport	CH_4	5.95	3.66	2.72	67.90	67.96	0.00	0.00	0.00	0.00	0.00	0.00
1 A 3 e, Other Transport	N_2O	12.88	5.11	2.85	47.58	47.66	0.00	0.00	0.00	0.00	0.00	0.00
1 A 4 a, Commercial/Institutional	CO_2	64,025.93	21,323.69	0.00	9.43	9.43	0.08	0.01	0.02	0.00	0.22	0.05
1 A 4 a, Commercial/Institutional	CH_4	1,636.92	100.24	15.14	103.02	104.12	0.00	0.00	0.00	0.00	0.01	0.00
1 A 4 a, Commercial/Institutional	N_2O	130.28	70.04	8.30	71.31	71.79	0.00	0.00	0.00	0.00	0.01	0.00
1 A 4 b, Residential	CO_2	128,635.75	76,863.21	0.00	8.58	8.58	0.87	0.00	0.06	0.00	0.72	0.52
1 A 4 b, Residential	CH_4	2,782.86	813.85	14.82	137.67	138.47	0.03	0.00	0.00	0.01	0.12	0.02
1 A 4 b, Residential	N_2O	683.71	226.93	9.57	87.32	87.84	0.00	0.00	0.00	0.00	0.02	0.00
1 A 4 c, Agriculture/Forestry/Fishing	CO_2	11,359.76	7,263.37	0.00	13.58	13.58	0.02	0.00	0.01	0.00	0.11	0.01
1 A 4 c, Agriculture/Forestry/Fishing	CH_4	272.15	203.52	8.21	52.63	53.26	0.00	0.00	0.00	0.00	0.01	0.00
1 A 4 c, Agriculture/Forestry/Fishing	N_2O	66.84	71.36	14.31	101.26	102.27	0.00	0.00	0.00	0.00	0.01	0.00
1 A 5, Military	CO_2	11,764.62	597.06	0.00	6.19	6.19	0.00	0.00	0.00	0.00	0.00	0.00
1 A 5, Military	CH_4	312.97	1.51	0.00	50.66	50.66	0.00	0.00	0.00	0.00	0.00	0.00

A	B	C	D	E	F	G	H	I	J	K	L	M
1 A 5, Military	N_2O	54.14	1.51	0.00	61.34	61.34	0.00	0.00	0.00	0.00	0.00	0.00
1 B 1, Solid Fuels	CO_2	1,832.80	699.81	0.00	36.49	36.49	0.00	0.00	0.00	0.00	0.03	0.00
1 B 1, Solid Fuels	CH_4	28,579.16	78.09	0.00	43.52	43.52	0.00	0.01	0.00	0.00	0.00	0.00
1 B 2 a, Fugitive Emissions from Oil	CO_2	477.63	387.01	0.00	24.92	24.92	0.00	0.00	0.00	0.00	0.01	0.00
1 B 2 a, Fugitive Emissions from Oil	CH_4	275.47	23.60	0.00	30.72	30.72	0.00	0.00	0.00	0.00	0.00	0.00
1 B 2 a, Fugitive Emissions from Oil	N_2O	0.28	0.23	0.00	30.00	30.00	0.00	0.00	0.00	0.00	0.00	0.00
1 B 2 b, Fugitive Emissions from Natural Gas	CO_2	986.72	398.54	0.00	22.30	22.30	0.00	0.00	0.00	0.00	0.01	0.00
1 B 2 b, Fugitive Emissions from Natural Gas	CH_4	9,892.63	1,732.86	0.00	24.96	24.96	0.00	0.00	0.00	0.00	0.05	0.00
1 B 2 c, Venting and Flaring (oil, gas, combined oil and gas)	CO_2	543.52	319.64	0.00	143.67	143.67	0.00	0.00	0.00	0.00	0.05	0.00
1 B 2 c, Venting and Flaring (oil, gas, combined oil and gas)	CH_4	1.85	0.63	0.00	133.13	133.13	0.00	0.00	0.00	0.00	0.00	0.00
1 B 2 c, Venting and Flaring (oil, gas, combined oil and gas)	N_2O	1.74	0.62	0.00	70.04	70.04	0.00	0.00	0.00	0.00	0.00	0.00
2 A 1, Cement Production	CO_2	15,297.27	9,830.97	2.50	1.00	2.69	0.00	0.00	0.01	0.03	0.01	0.00
2 A 2, Lime Production	CO_2	5,986.62	3,979.72	2.37	10.54	10.81	0.00	0.00	0.00	0.01	0.05	0.00
2 A 3, Glass Production	CO_2	780.48	763.49	3.11	11.25	11.67	0.00	0.00	0.00	0.00	0.01	0.00
2 A 4, Other Process Uses of Carbonates	CO_2	1,458.01	505.61	8.78	8.31	12.09	0.00	0.00	0.00	0.00	0.00	0.00
2 B 1, Ammonia Production	CO_2	6,025.00	3,267.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
2 B 2, Nitric Acid Production	N_2O	2,896.77	114.29	0.50	2.67	2.72	0.00	0.00	0.00	0.00	0.00	0.00
2 B 3, Adipic Acid Production	N_2O	16,074.90	32.92	2.00	6.00	6.32	0.00	0.01	0.00	0.00	0.00	0.00
2 B 5, Carbide Production	CO_2	443.16	4.39	1.00	10.00	10.05	0.00	0.00	0.00	0.00	0.00	0.00
2 B 7, Soda Ash Production	CO_2	615.50	404.45	0.00	4.18	4.18	0.00	0.00	0.00	0.00	0.00	0.00
2 B 8, Petrochemical and Carbon Black Production	CO_2	973.97	756.98	11.68	13.80	18.08	0.00	0.00	0.00	0.01	0.01	0.00
2 B 8, Petrochemical and Carbon Black Production	CH_4	373.73	423.06	16.33	13.05	20.90	0.00	0.00	0.00	0.01	0.01	0.00
2 B 9 a, By-product Emissions	HFC23	C	C	0.00	3.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00
2 B 9 b, Fugitive Emissions	CF_4	C	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 B 9 b, Fugitive Emissions	HFC134a	C	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 B 9 b, Fugitive Emissions	HFC227ea	C	C	0.00	3.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00
2 B 9 b, Fugitive Emissions	SF_6	164.50	8.88	0.00	3.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00
2 B 10, Other Chemical Industry	CH_4	3.87	1.11	0.00	202.26	202.26	0.00	0.00	0.00	0.00	0.00	0.00
2 B 10, Other Chemical Industry	N_2O	C	C	0.00	40.00	40.00	0.00	0.00	0.00	0.00	0.00	0.00
2 C 1, Iron and Steel Production	CO_2	22,810.29	16,386.42	0.00	8.45	8.45	0.04	0.00	0.01	0.00	0.15	0.02
2 C 1, Iron and Steel Production	CH_4	5.22	5.04	0.00	68.09	68.09	0.00	0.00	0.00	0.00	0.00	0.00
2 C 1, Iron and Steel Production	N_2O	23.60	12.92	7.74	64.39	64.85	0.00	0.00	0.00	0.00	0.00	0.00

A	B	C	D	E	F	G	H	I	J	K	L	M
2 C 2, Ferroalloys Production	CO_2	429.00	5.74	50.00	7.00	50.49	0.00	0.00	0.00	0.00	0.00	0.00
2 C 2, Ferroalloys Production	CH_4	9.61	1.75	50.00	50.00	70.71	0.00	0.00	0.00	0.00	0.00	0.00
2 C 3, Aluminium Production	CO_2	1,011.92	302.62	1.00	5.00	5.10	0.00	0.00	0.00	0.00	0.00	0.00
2 C 3, Aluminium Production	CF_4	1,385.67	69.98	0.00	15.00	15.00	0.00	0.00	0.00	0.00	0.00	0.00
2 C 3, Aluminium Production	C_2F_6	233.10	14.17	0.00	15.03	15.03	0.00	0.00	0.00	0.00	0.00	0.00
2 C 3, Aluminium Production	SF_6	C	C	0.00	50.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00
2 C 4, Magnesium Production	HFC134a	0.00	7.19	0.00	35.00	35.00	0.00	0.00	0.00	0.00	0.00	0.00
2 C 4, Magnesium Production	SF_6	C	C	0.00	30.04	30.04	0.00	0.00	0.00	0.00	0.00	0.00
2 C 5, Lead Production	CO_2	157.87	64.89	5.72	40.87	41.27	0.00	0.00	0.00	0.00	0.00	0.00
2 C 6, Zinc Production	CO_2	670.80	81.65	0.00	50.25	50.25	0.00	0.00	0.00	0.00	0.00	0.00
2 D 1, Lubricant Use	CO_2	188.64	191.41	0.00	19.16	19.16	0.00	0.00	0.00	0.00	0.00	0.00
2 D 2, Paraffin Wax Use	CO_2	242.70	442.71	0.00	70.71	70.71	0.00	0.00	0.00	0.00	0.03	0.00
2 D 2, Paraffin Wax Use	N_2O	0.62	1.13	0.00	60.57	60.57	0.00	0.00	0.00	0.00	0.00	0.00
2 D 3, Other Non-Energy Products from Fuels	CO2	2,551.10	1,224.63	0.00	10.08	10.08	0.00	0.00	0.00	0.00	0.01	0.00
2 E, Electronics Industry	N_2O	0.66	36.00	0.00	18.03	18.03	0.00	0.00	0.00	0.00	0.00	0.00
2 E, Electronics Industry	CF_4	92.06	72.53	0.00	6.41	6.41	0.00	0.00	0.00	0.00	0.00	0.00
2 E, Electronics Industry	C_2F_6	147.83	37.63	0.00	7.00	7.00	0.00	0.00	0.00	0.00	0.00	0.00
2 E, Electronics Industry	C_3F_8	0.00	14.58	0.00	7.00	7.00	0.00	0.00	0.00	0.00	0.00	0.00
2 E, Electronics Industry	cC4F8	0.00	5.15	0.00	7.00	7.00	0.00	0.00	0.00	0.00	0.00	0.00
2 E, Electronics Industry	C6F14	21.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 E, Electronics Industry	HFC23	14.34	13.14	0.00	7.00	7.00	0.00	0.00	0.00	0.00	0.00	0.00
2 E, Electronics Industry	HFC32	0.00	0.10	0.00	7.00	7.00	0.00	0.00	0.00	0.00	0.00	0.00
2 E, Electronics Industry	SF_6	48.73	63.92	0.00	7.00	7.00	0.00	0.00	0.00	0.00	0.00	0.00
2 E, Electronics Industry	NF_3	4.95	20.45	0.00	7.00	7.00	0.00	0.00	0.00	0.00	0.00	0.00
2 F, Product Uses as Substitutes for ODS	C2F6	0.00	3.32	0.00	19.98	19.98	0.00	0.00	0.00	0.00	0.00	0.00
2 F, Product Uses as Substitutes for ODS	C3F8	20.07	0.49	0.00	19.14	19.14	0.00	0.00	0.00	0.00	0.00	0.00
2 F, Product Uses as Substitutes for ODS	C6F14	C	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 F, Product Uses as Substitutes for ODS	HFC23	13.62	36.76	0.00	17.56	17.56	0.00	0.00	0.00	0.00	0.00	0.00
2 F, Product Uses as Substitutes for ODS	HFC32	0.76	262.22	0.00	8.37	8.37	0.00	0.00	0.00	0.00	0.00	0.00
2 F, Product Uses as Substitutes for ODS	HFC4310 mee	C	C	0.00	2.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00
2 F, Product Uses as Substitutes for ODS	HFC125	135.68	1,604.04	0.00	6.66	6.66	0.00	0.00	0.00	0.00	0.01	0.00

A	B	C	D	E	F	G	H	I	J	K	L	M
2 F, Product Uses as Substitutes for ODS	HFC134a	2,062.32	3,863.22	0.00	5.24	5.24	0.00	0.00	0.00	0.00	0.02	0.00
2 F, Product Uses as Substitutes for ODS	HFC143a	76.48	988.39	0.00	10.86	10.86	0.00	0.00	0.00	0.00	0.01	0.00
2 F, Product Uses as Substitutes for ODS	HFC152a	100.24	0.00	0.00	24.28	24.28	0.00	0.00	0.00	0.00	0.00	0.00
2 F, Product Uses as Substitutes for ODS	HFC227ea	0.67	106.84	0.00	3.06	3.06	0.00	0.00	0.00	0.00	0.00	0.00
2 F, Product Uses as Substitutes for ODS	HFC236fa	C	C	0.00	9.20	9.20	0.00	0.00	0.00	0.00	0.00	0.00
2 F, Product Uses as Substitutes for ODS	HFC245fa	C	C	0.00	22.36	22.36	0.00	0.00	0.00	0.00	0.00	0.00
2 F, Product Uses as Substitutes for ODS	HFC365mfc	C	C	0.00	14.90	14.90	0.00	0.00	0.00	0.00	0.00	0.00
2 G, Other Product Manufacture and Use	CH_4	5.07	16.73	20.00	20.00	28.28	0.00	0.00	0.00	0.00	0.00	0.00
2 G, Other Product Manufacture and Use	N_2O	C	C	0.00	51.54	51.54	0.00	0.00	0.00	0.00	0.01	0.00
2 G, Other Product Manufacture and Use	C10F18	C	C	0.00	24.87	24.87	0.00	0.00	0.00	0.00	0.00	0.00
2 G, Other Product Manufacture and Use	HFC134a	0.00	0.18	0.00	22.36	22.36	0.00	0.00	0.00	0.00	0.00	0.00
2 G, Other Product Manufacture and Use	HFC245fa	0.00	21.54	0.00	20.71	20.71	0.00	0.00	0.00	0.00	0.00	0.00
2 G, Other Product Manufacture and Use	HFC365mfc	0.00	0.71	0.00	22.36	22.36	0.00	0.00	0.00	0.00	0.00	0.00
2 G, Other Product Manufacture and Use	SF6	C	C	0.00	8.01	8.01	0.00	0.00	0.00	0.00	0.01	0.00
3 A, Enteric Fermentation	CH_4	20,188.82	14,788.07	4.00	20.00	20.40	0.18	0.00	0.01	0.06	0.32	0.11
3 A, Enteric Fermentation	CH_4	15,273.58	9,267.27	2.15	10.73	10.94	0.02	0.00	0.01	0.02	0.11	0.01
3 A, Enteric Fermentation	CH_4	2,161.42	1,792.61	18.65	13.47	23.00	0.00	0.00	0.00	0.04	0.03	0.00
3 B, Manure Management	CH_4	2,521.46	2,499.53	4.00	20.00	20.40	0.01	0.00	0.00	0.01	0.05	0.00
3 B, Manure Management	CH_4	2,683.78	1,468.79	2.22	11.08	11.30	0.00	0.00	0.00	0.00	0.02	0.00
3 B, Manure Management	CH_4	3,045.17	1,945.35	3.21	16.04	16.35	0.00	0.00	0.00	0.01	0.03	0.00
3 B, Manure Management	CH_4	238.01	313.14	5.73	15.67	16.69	0.00	0.00	0.00	0.00	0.01	0.00
3 B, Manure Management	N_2O	1,313.24	643.84	4.00	100.00	100.08	0.01	0.00	0.00	0.00	0.07	0.00
3 B, Manure Management	N_2O	1,068.01	680.49	2.08	52.04	52.08	0.00	0.00	0.00	0.00	0.04	0.00
3 B, Manure Management	N_2O	444.50	270.47	3.14	78.53	78.60	0.00	0.00	0.00	0.00	0.02	0.00
3 B, Manure Management	N_2O	390.15	417.04	8.32	82.88	83.30	0.00	0.00	0.00	0.00	0.04	0.00
3 B, Manure Management	N_2O	1,266.26	828.68	39.99	119.98	126.47	0.02	0.00	0.00	0.04	0.11	0.01
3 D, Agricultural Soils	N_2O	20,292.80	14,473.14	16.81	46.19	49.15	1.01	0.00	0.01	0.27	0.73	0.60

A	B	C	D	E	F	G	H	I	J	K	L	M
3 G, Liming	CO_2	2,200.01	1,906.50	3.57	2.94	4.63	0.00	0.00	0.00	0.01	0.01	0.00
3 H, Urea Application	CO_2	480.00	330.20	1.00	1.00	1.41	0.00	0.00	0.00	0.00	0.00	0.00
3 I, Other carbon-containing fertilisers	CO_2	510.45	144.75	3.00	3.00	4.24	0.00	0.00	0.00	0.00	0.00	0.00
3 J, Other Agriculture	CH_4	0.31	1,445.31	10.00	20.00	22.36	0.00	0.00	0.00	0.02	0.03	0.00
3 J, Other Agriculture	N_2O	0.11	92.70	9.41	94.20	94.67	0.00	0.00	0.00	0.00	0.01	0.00
4 A, Forest Land	CO_2	-26,920.55	1,648.08	0.00	10.42	10.42	0.00	0.03	0.01	0.00	0.17	0.03
4 A, Forest Land	CH_4	32.44	26.91	0.00	93.16	93.16	0.00	0.00	0.00	0.00	0.00	0.00
4 A, Forest Land	N_2O	435.49	465.46	0.00	80.24	80.24	0.00	0.00	0.00	0.00	0.04	0.00
4 B, Cropland	CO_2	25,789.59	16,833.12	0.00	19.25	19.25	0.21	0.00	0.01	0.00	0.37	0.14
4 B, Cropland	CH_4	413.90	312.23	0.00	67.34	67.34	0.00	0.00	0.00	0.00	0.02	0.00
4 B, Cropland	N_2O	543.02	370.18	0.00	142.48	142.48	0.01	0.00	0.00	0.00	0.06	0.00
4 C, Grassland	CO_2	22,519.88	21,469.12	0.00	44.40	44.40	1.81	0.01	0.03	0.00	2.15	4.61
4 C, Grassland	CH_4	2,582.33	2,657.31	0.00	360.45	360.45	1.83	0.00	0.00	0.00	1.05	1.09
4 C, Grassland	N_2O	80.60	51.98	0.00	62.00	62.00	0.00	0.00	0.00	0.00	0.00	0.00
4 D, Wetlands	CO_2	3,586.67	3,478.53	0.00	26.94	26.94	0.02	0.00	0.00	0.00	0.13	0.02
4 D, Wetlands	CH_4	5,368.71	5,447.38	0.00	63.47	63.47	0.24	0.00	0.00	0.00	0.38	0.14
4 D, Wetlands	N_2O	26.27	26.76	0.00	177.99	177.99	0.00	0.00	0.00	0.00	0.01	0.00
4 E, Settlements	CO_2	3,141.45	4,370.55	0.00	18.14	18.14	0.01	0.00	0.00	0.00	0.11	0.01
4 E, Settlements	CH_4	53.82	96.43	0.00	59.40	59.40	0.00	0.00	0.00	0.00	0.01	0.00
4 E, Settlements	N_2O	136.11	177.18	0.00	144.89	144.89	0.00	0.00	0.00	0.00	0.03	0.00
4 G, Harvested Wood Products	CO_2	-1,294.86	407.62	0.00	25.87	25.87	0.00	0.00	0.01	0.00	0.32	0.10
5 A, Solid Waste Disposal	CH_4	37,191.25	1,997.16	0.00	20.00	20.00	0.00	0.02	0.00	0.00	0.04	0.00
5 B, Biological Treatment of Solid Waste	CH_4	59.39	918.33	1.49	149.84	149.85	0.04	0.00	0.00	0.00	0.15	0.02
5 B, Biological Treatment of Solid Waste	N_2O	19.67	194.29	1.42	109.81	109.82	0.00	0.00	0.00	0.00	0.02	0.00
5 D 1, Domestic Wastewater	CH_4	3,725.66	926.91	3.04	388.41	388.43	0.26	0.00	0.00	0.00	0.39	0.15
5 D 1, Domestic Wastewater	N_2O	515.78	1,131.75	5.29	639.14	639.17	1.05	0.00	0.00	0.01	0.79	0.62
5 D 2, Industrial Wastewater	CH_4	10.36	56.61	0.00	50.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00
5 D 2, Industrial Wastewater	N_2O	28.09	24.01	50.00	310.00	314.01	0.00	0.00	0.00	0.00	0.01	0.00
5 E, Other Waste	CH_4	0.00	2.36	2.00	20.00	20.10	0.00	0.00	0.00	0.00	0.00	0.00
5 E, Other Waste	N_2O	0.00	25.90	2.00	20.00	20.10	0.00	0.00	0.00	0.00	0.00	0.00

Table 472: Uncertainties by sectors (Approach 2, Monte Carlo simulation, pursuant to Table 3.5 of the 2006 IPCC Guidelines)

A1	A2	B	C	D	E-	E+	F-	F+	G-	G+	H	I	J-	J+
IPCC Category	Qualifier	gas	Base year emissions or removals	Emissions or removals 2024	Activity data uncertainty		Emission factor uncertainty		Combined uncertainty		Contribution to variance 2024		Inventory trend in national emissions for 2024 increase with respect to base year	
			kt CO_2 equivalent	kt CO_2 equivalent	-%	+%	-%	+%	-%	+%	fraction	% of base year	-%	+%
Sum		GHG	1,293,320.67	707,608.32					2.58	2.53		-45.29	6.68	6.76
1 A 1 a, Public Electricity and Heat Production	fossil fuels	CO2	338,451.16	151,375.41	7.98	8.29	2.83	2.81	3.24	3.27	0.08	-55.27	5.70	5.82
1 A 1 a, Public Electricity and Heat Production		CH4	192.83	2,637.87	28.19	42.78	48.81	114.98	28.32	39.20	0.00	1,267.99	47.47	64.94
1 A 1 a, Public Electricity and Heat Production		N2O	2,140.86	1,241.79	27.42	22.98	50.37	44.65	20.16	20.73	0.00	-42.00	63.62	88.48
1 A 1 b, Petroleum Refining	fossil fuels	CO2	24,212.49	21,079.80	10.83	11.36	10.02	11.00	4.95	5.12	0.00	-12.94	87.03	90.95
1 A 1 b, Petroleum Refining		CH4	17.99	17.28	50.93	62.45	27.04	45.51	17.35	17.82	0.00	-3.97	5,967.97	7,412.06
1 A 1 b, Petroleum Refining		N2O	89.27	56.08	63.41	53.13	29.96	37.35	32.22	32.39	0.00	-37.18	8,685.67	12,184.62
1 A 1 c, Manufacture of Solid Fuels and Other Energy Industries	fossil fuels	CO2	65,289.06	8,735.95	9.28	9.89	10.99	11.34	5.61	5.75	0.00	-86.62	2.12	2.21
1 A 1 c, Manufacture of Solid Fuels and Other Energy Industries		CH4	103.02	113.12	31.41	42.16	59.77	125.16	49.87	83.74	0.00	9.81	270.83	489.55
1 A 1 c, Manufacture of Solid Fuels and Other Energy Industries		N2O	586.23	116.43	17.10	18.90	50.05	64.90	28.49	29.48	0.00	-80.14	19.14	23.42
1 A 2 a, Iron and Steel	fossil fuels	CO2	35,269.33	33,166.23	13.46	14.92	10.19	10.70	5.39	5.78	0.01	-5.96	2,304.78	2,448.20
1 A 2 a, Iron and Steel		CH4	69.95	63.73	9.91	9.36	32.50	33.76	25.73	26.02	0.00	-8.89	622.17	841.42
1 A 2 a, Iron and Steel		N2O	137.93	88.33	40.68	36.07	73.93	98.64	37.73	38.21	0.00	-35.96	371.25	577.48
1 A 2 b, Non-ferrous metals	fossil fuels	CO2	1,629.22	1,524.28	10.00	10.66	1.55	1.52	7.97	8.48	0.00	-6.44	27.76	29.79
1 A 2 b, Non-ferrous metals		CH4	1.55	1.86	23.42	15.61	66.23	74.66	67.70	69.80	0.00	19.71	785.70	1,647.04
1 A 2 b, Non-ferrous metals		N2O	15.25	7.39	40.83	26.29	49.88	63.63	59.97	62.25	0.00	-51.54	123.18	219.44
1 A 2 d, Pulp, Paper and Print	fossil fuels	CO2	3.65	8.85	8.61	8.83	3.02	3.17	5.65	5.75	0.00	142.57	34.65	36.98
1 A 2 d, Pulp, Paper and Print		CH4	0.73	2.67	43.20	42.74	55.85	65.73	47.97	48.82	0.00	264.38	98.91	159.04
1 A 2 d, Pulp, Paper and Print		N2O	2.50	9.09	10.61	11.12	10.40	11.86	7.09	7.47	0.00	264.38	17.38	18.58
1 A 2 e, Food Processing, Beverages and Tobacco	fossil fuels	CO2	2,015.91	280.87	6.23	6.55	4.26	4.47	3.96	4.10	0.00	-86.07	0.89	0.93
1 A 2 e, Food Processing, Beverages and Tobacco		CH4	5.02	0.19	39.42	40.17	45.24	62.09	42.20	42.52	0.00	-96.14	5.14	8.21

A1	A2	B	C	D	E-	E+	F-	F+	G-	G+	H	I	J-	J+
1 A 2 e, Food Processing, Beverages and Tobacco		N2O	21.92	2.23	33.98	32.69	62.55	81.44	46.67	49.33	0.00	-89.81	10.22	18.69
1 A 2 f, Non-metallic minerals	fossil fuels	CO2	18,507.38	9,581.88	13.29	15.33	1.99	2.07	3.09	3.19	0.00	-48.23	5.00	5.11
1 A 2 f, Non-metallic minerals		CH4	56.31	12.55	51.49	59.37	37.97	38.42	28.63	28.81	0.00	-77.71	62.17	84.42
1 A 2 f, Non-metallic minerals		N2O	182.53	76.25	34.43	49.10	36.11	45.78	25.37	25.71	0.00	-58.23	38.52	58.34
1 A 2 g, Other Manufacturing Industries and Construction	fossil fuels	CO2	125,527.76	56,437.66	14.74	16.60	3.99	4.28	3.01	3.10	0.01	-55.04	7.75	7.93
1 A 2 g, Other Manufacturing Industries and Construction		CH4	146.88	202.46	40.06	48.48	65.90	157.97	18.64	22.56	0.00	37.85	103.80	127.98
1 A 2 g, Other Manufacturing Industries and Construction		N2O	831.54	411.25	39.19	46.80	30.38	40.83	13.82	14.09	0.00	-50.54	48.72	55.78
1 A 3 a, Civil Aviation	fossil fuels	CO2	2,310.48	1,087.32	12.37	12.49	5.26	5.52	8.06	8.17	0.00	-52.94	10.08	10.89
1 A 3 a, Civil Aviation		CH4	3.48	1.52	21.17	9.23	64.55	273.54	49.46	77.88	0.00	-56.28	99.94	187.41
1 A 3 a, Civil Aviation		N2O	20.68	9.70	17.12	18.55	20.91	21.81	20.99	21.81	0.00	-53.11	25.75	32.08
1 A 3 b, Road transport	fossil fuels	CO2	151,889.81	139,371.62	24.92	34.91	4.02	5.10	4.61	4.85	0.13	-8.24	40.52	42.65
1 A 3 b, Road transport		CH4	1,812.75	229.38	28.42	52.06	29.48	40.02	9.48	10.96	0.00	-87.35	6.86	7.76
1 A 3 b, Road transport		N2O	1,123.44	1,306.82	36.94	58.85	31.69	61.70	12.40	15.06	0.00	16.32	121.06	139.89
1 A 3 c, Rail Transport	fossil fuels	CO2	3,133.05	742.99	10.52	10.51	3.23	3.22	10.01	10.09	0.00	-76.29	5.88	6.44
1 A 3 c, Rail Transport		CH4	19.73	0.26	13.71	13.28	53.98	93.14	29.68	30.87	0.00	-98.66	0.81	1.05
1 A 3 c, Rail Transport		N2O	6.83	1.64	15.19	14.01	39.08	62.80	38.08	55.74	0.00	-76.00	25.18	40.99
1 A 3 d, National Shipping	fossil fuels	CO2	3,013.77	1,410.58	21.23	41.96	3.16	4.41	24.48	24.18	0.00	-53.20	52.61	79.66
1 A 3 d, National Shipping		CH4	2.65	10.07	39.17	111.92	80.78	189.84	68.17	156.93	0.00	280.56	89.05	214.83
1 A 3 d, National Shipping		N2O	18.68	10.42	11.90	13.19	48.41	74.92	32.72	43.66	0.00	-44.22	132.12	194.41
1 A 3 e, Other Transport	fossil fuels	CO2	1,083.27	675.05	1.25	1.81	1.10	1.10	1.45	1.73	0.00	-37.68	2.09	2.21
1 A 3 e, Other Transport		CH4	5.95	3.66	9.35	6.36	43.27	67.14	38.75	56.28	0.00	-38.43	51.45	80.86
1 A 3 e, Other Transport		N2O	12.88	5.11	6.33	4.11	52.03	52.21	47.57	47.44	0.00	-60.34	29.30	47.35
1 A 4 a, Commercial/Institutional	fossil fuels	CO2	64,025.93	21,323.69	9.44	10.10	2.19	2.25	5.71	6.10	0.00	-66.70	5.61	6.19
1 A 4 a, Commercial/Institutional		CH4	1,636.92	100.24	44.76	51.13	48.47	107.81	35.77	52.23	0.00	-93.88	41.46	78.80
1 A 4 a, Commercial/Institutional		N2O	130.28	70.04	43.60	48.58	42.04	67.08	30.42	35.71	0.00	-46.24	34.93	48.48
1 A 4 b, Residential	fossil fuels	CO2	128,635.75	76,863.21	9.44	10.35	1.22	1.28	6.20	6.26	0.07	-40.25	13.14	14.25
1 A 4 b, Residential		CH4	2,782.86	813.85	18.96	21.10	45.82	73.85	40.97	59.22	0.00	-70.76	224.23	365.45
1 A 4 b, Residential		N2O	683.71	226.93	25.51	43.03	54.38	92.24	35.13	41.16	0.00	-66.81	54.86	77.37
1 A 4 c, Agriculture/Forestry/Fishing	fossil fuels	CO2	11,359.76	7,263.37	26.13	26.98	7.31	6.70	13.49	13.61	0.00	-36.06	48.67	54.91
1 A 4 c, Agriculture/Forestry/Fishing		CH4	272.15	203.52	22.18	24.12	46.63	79.74	30.94	42.74	0.00	-25.22	70.04	99.17
1 A 4 c, Agriculture/Forestry/Fishing		N2O	66.84	71.36	30.98	31.88	47.52	74.00	31.21	44.22	0.00	6.77	878.52	1,303.43

A1	A2	B	C	D	E-	E+	F-	F+	G-	G+	H	I	J-	J+
1 A 5, Military	fossil fuels	CO2	11,764.62	597.06	10.55	11.54	1.70	1.85	4.23	4.37	0.00	-94.92	0.90	0.95
1 A 5, Military		CH4	312.97	1.51	24.79	61.23	80.37	100.33	50.04	50.73	0.00	-99.52	6.10	8.60
1 A 5, Military		N2O	54.14	1.51	39.85	50.01	41.05	94.06	29.94	32.03	0.00	-97.21	3.43	4.31
1 B 1, Solid Fuels		CO2	1,832.80	699.81	31.09	45.31	64.27	70.22	33.10	33.16	0.00	-61.82	135.22	188.20
1 B 1, Solid Fuels		CH4	28,579.16	78.09	15.22	15.05	28.80	30.87	43.80	43.99	0.00	-99.73	0.89	1.73
1 B 2 a, Fugitive Emissions from Oil		CO2	477.63	387.01	35.29	45.75	31.08	31.74	26.28	28.30	0.00	-18.97	229.08	304.77
1 B 2 a, Fugitive Emissions from Oil		CH4	275.47	23.60	20.13	17.13	49.29	64.46	23.06	35.39	0.00	-91.43	4.70	6.98
1 B 2 a, Fugitive Emissions from Oil		N2O	0.28	0.23	0.00	0.00	0.00	0.00	30.18	29.84	0.00	-20.23	370.14	509.10
1 B 2 b, Fugitive Emissions from Natural Gas		CO2	986.72	398.54	4.99	5.00	24.91	25.06	17.06	17.41	0.00	-59.61	21.95	26.33
1 B 2 b, Fugitive Emissions from Natural Gas		CH4	9,892.63	1,732.86	44.53	52.54	41.64	54.33	26.17	28.01	0.00	-82.48	2.28	2.53
1 B 2 c, Venting and Flaring (oil, gas, combined oil and gas)		CO2	543.52	319.64	3.01	3.00	10.00	10.00	15.95	16.00	0.00	-41.19	62.51	73.33
1 B 2 c, Venting and Flaring (oil, gas, combined oil and gas)		CH4	1.85	0.63	0.00	0.00	0.00	0.00	19.24	19.13	0.00	-65.94	33.87	43.93
1 B 2 c, Venting and Flaring (oil, gas, combined oil and gas)		N2O	1.74	0.62	3.01	3.00	25.15	24.92	74.89	74.75	0.00	-64.51	264.01	532.07
2 A 1, Cement Production		CO2	15,297.27	9,830.97	2.51	2.50	1.00	1.00	2.71	2.70	0.00	-35.73	6.46	6.65
2 A 2, Lime Production		CO2	5,986.62	3,979.72	2.73	2.74	7.38	5.97	7.13	6.14	0.00	-33.52	17.08	18.12
2 A 3, Glass Production		CO2	780.48	763.49	8.72	10.16	25.42	29.84	11.56	11.83	0.00	-2.18	101.09	112.91
2 A 4, Other Process Uses of Carbonates		CO2	1,458.01	505.61	12.37	13.32	11.25	11.51	11.68	11.81	0.00	-65.32	6.72	8.14
2 B 1, Ammonia Production		CO2	6,025.00	3,267.00	0.00	0.00	0.00	0.00	0.99	1.00	0.00	-45.78	1.42	1.42
2 B 2, Nitric Acid Production		N2O	2,896.77	114.29	3.12	3.18	15.29	16.33	2.71	2.75	0.00	-96.05	0.14	0.15
2 B 3, Adipic Acid Production		N2O	16,074.90	32.92	2.01	1.99	6.05	5.94	6.30	6.33	0.00	-99.80	0.02	0.02
2 B 5, Carbide Production		CO2	443.16	4.39	1.01	1.00	10.00	10.11	10.04	10.14	0.00	-99.01	2.78	3.11
2 B 7, Soda Ash Production		CO2	615.50	404.45	0.00	0.00	0.00	0.00	4.16	4.17	0.00	-34.29	25.85	26.87
2 B 8, Petrochemical and Carbon Black Production		CO2	973.97	756.98	42.09	56.26	20.67	21.30	17.45	18.76	0.00	-22.28	158.26	189.54
2 B 8, Petrochemical and Carbon Black Production		CH4	373.73	423.06	24.48	24.95	13.49	14.04	19.51	20.05	0.00	13.20	233.66	290.96
2 B 9 a, By-product Emissions		HFC23	C	C	0.00	0.00	0.00	0.00	2.99	2.99	0.00	-100.00	0.00	0.00
2 B 9 b, Fugitive Emissions		CF4	C	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00
2 B 9 b, Fugitive Emissions		HFC134a	C	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-100.00	0.00	0.00
2 B 9 b, Fugitive Emissions		HFC227ea	C	C	0.00	0.00	0.00	0.00	3.02	3.03	0.00		0.00	0.00

A1	A2	B	C	D	E-	E+	F-	F+	G-	G+	H	I	J-	J+
2 B 9 b, Fugitive Emissions		SF6	164.50	8.88	0.00	0.00	0.00	0.00	2.99	2.96	0.00	-94.60	0.24	0.25
2 B 10, Other Chemical Industry		CH4	3.87	1.11	60.44	105.28	85.25	276.46	73.02	210.90	0.00	-71.26	53.04	154.74
2 B 10, Other Chemical Industry		N2O	C	C	0.00	0.00	0.00	0.00	39.98	39.88	0.00	-99.52	0.24	0.38
2 C 1, Iron and Steel Production		CO2	22,810.29	16,386.42	20.46	22.67	8.19	8.41	8.35	8.62	0.01	-28.16	64.73	70.83
2 C 1, Iron and Steel Production		CH4	5.22	5.04	1.00	1.01	77.93	80.25	67.23	67.92	0.00	-3.51	178.89	331.95
2 C 1, Iron and Steel Production		N2O	23.60	12.92	35.39	22.13	68.79	73.26	66.49	68.26	0.00	-45.26	1,508.36	3,567.47
2 C 2, Ferroalloys Production		CO2	429.00	5.74	50.43	50.20	7.02	7.03	50.68	51.03	0.00	-98.66	128.46	231.15
2 C 2, Ferroalloys Production		CH4	9.61	1.75	50.44	50.22	50.15	49.33	62.58	79.97	0.00	-81.75	207.99	461.16
2 C 3, Aluminium Production		CO2	1,011.92	302.62	1.00	1.00	5.03	5.01	5.12	5.12	0.00	-70.09	4.38	4.66
2 C 3, Aluminium Production		CF4	1,385.67	69.98	0.00	0.00	0.00	0.00	14.88	15.14	0.00	-94.95	1.05	1.24
2 C 3, Aluminium Production		C2F6	233.10	14.17	0.00	0.00	0.00	0.00	15.13	15.15	0.00	-93.92	1.28	1.50
2 C 3, Aluminium Production		SF6	C	C	0.00	0.00	0.00	0.00	10.04	10.74	0.00	-67.60	6.70	7.42
2 C 4, Magnesium Production		HFC134a	0.00	7.19	0.00	0.00	0.00	0.00	20.49	12.99	0.00		0.00	0.00
2 C 4, Magnesium Production		SF6	C	C	0.00	0.00	0.00	0.00	17.25	11.02	0.00	-39.02	33.89	40.65
2 C 5, Lead Production		CO2	157.87	64.89	20.10	15.96	39.64	49.54	40.62	41.47	0.00	-58.89	64.33	92.99
2 C 6, Zinc Production		CO2	670.80	81.65	0.00	0.00	0.00	0.00	50.55	50.08	0.00	-87.83	14.26	25.02
2 D 1, Lubricant Use		CO2	188.64	191.41	24.86	24.90	10.01	9.99	18.78	19.53	0.00	1.47	370.75	444.97
2 D 2, Paraffin Wax Use		CO2	242.70	442.71	0.00	0.00	0.00	0.00	70.70	71.31	0.00	82.41	196.37	494.24
2 D 2, Paraffin Wax Use		N2O	0.62	1.13	0.00	0.00	0.00	0.00	60.56	60.40	0.00	82.41	184.67	371.95
2 D 3, Other Non-Energy Products from Fuels		CO2	2,551.10	1,224.63	20.00	20.12	10.07	10.08	10.08	10.11	0.00	-52.00	19.36	21.09
2 E, Electronics Industry		N2O	0.66	36.00	0.00	0.00	0.00	0.00	17.98	17.89	0.00	5,333.96	24.69	29.82
2 E, Electronics Industry		CF4	92.06	72.53	0.00	0.00	0.00	0.00	6.41	6.44	0.00	-21.21	32.77	35.23
2 E, Electronics Industry		C2F6	147.83	37.63	0.00	0.00	0.00	0.00	7.01	7.03	0.00	-74.55	3.28	3.57
2 E, Electronics Industry		C3F8	0.00	14.58	0.00	0.00	0.00	0.00	7.03	6.99	0.00		0.00	0.00
2 E, Electronics Industry		cC4F8	0.00	5.15	0.00	0.00	0.00	0.00	7.01	6.98	0.00		0.00	0.00
2 E, Electronics Industry		C6F14	21.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-100.00	0.00	0.00
2 E, Electronics Industry		HFC23	14.34	13.14	0.00	0.00	0.00	0.00	7.02	7.03	0.00	-8.32	107.38	115.05
2 E, Electronics Industry		HFC32	0.00	0.10	0.00	0.00	0.00	0.00	6.97	6.94	0.00		0.00	0.00
2 E, Electronics Industry		SF6	48.73	63.92	0.00	0.00	0.00	0.00	6.98	7.03	0.00	31.16	40.13	42.72
2 E, Electronics Industry		NF3	4.95	20.45	0.00	0.00	0.00	0.00	6.94	7.04	0.00	312.95	12.67	13.52
2 F, Product Uses as Substitutes for ODS		C2F6	0.00	3.32	0.00	0.00	0.00	0.00	19.93	19.78	0.00		0.00	0.00
2 F, Product Uses as Substitutes for ODS		C3F8	20.07	0.49	0.00	0.00	0.00	0.00	19.16	19.14	0.00	-97.57	0.72	0.96

A1	A2	B	C	D	E-	E+	F-	F+	G-	G+	H	I	J-	J+
2 F, Product Uses as Substitutes for ODS		C6F14	C	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00
2 F, Product Uses as Substitutes for ODS		HFC23	13.62	36.76	0.00	0.00	0.00	0.00	17.53	17.50	0.00	169.95	35.14	42.65
2 F, Product Uses as Substitutes for ODS		HFC32	0.76	262.22	0.00	0.00	0.00	0.00	8.38	8.44	0.00	34,492.77	13.99	16.31
2 F, Product Uses as Substitutes for ODS		HFC4310mee	C	C	0.00	0.00	0.00	0.00	1.98	2.00	0.00		0.00	0.00
2 F, Product Uses as Substitutes for ODS		HFC125	135.68	1,604.04	0.00	0.00	0.00	0.00	6.67	6.68	0.00	1,082.21	17.34	21.93
2 F, Product Uses as Substitutes for ODS		HFC134a	2,062.32	3,863.22	0.00	0.00	0.00	0.00	5.25	5.28	0.00	87.32	19.95	22.35
2 F, Product Uses as Substitutes for ODS		HFC143a	76.48	988.39	0.00	0.00	0.00	0.00	11.00	10.86	0.00	1,192.35	15.57	17.47
2 F, Product Uses as Substitutes for ODS		HFC152a	100.24	0.00	0.00	0.00	0.00	0.00	24.22	24.11	0.00	-100.00	0.11	0.15
2 F, Product Uses as Substitutes for ODS		HFC227ea	0.67	106.84	0.00	0.00	0.00	0.00	3.07	3.07	0.00	15,781.00	18.75	25.76
2 F, Product Uses as Substitutes for ODS		HFC236fa	C	C	0.00	0.00	0.00	0.00	9.23	9.18	0.00		0.00	0.00
2 F, Product Uses as Substitutes for ODS		HFC245fa	C	C	0.00	0.00	0.00	0.00	22.03	22.26	0.00		0.00	0.00
2 F, Product Uses as Substitutes for ODS		HFC365mfc	C	C	0.00	0.00	0.00	0.00	14.93	14.89	0.00		0.00	0.00
2 G, Other Product Manufacture and Use		CH4	5.07	16.73	20.03	20.20	19.92	20.04	26.87	29.99	0.00	229.90	136.01	185.46
2 G, Other Product Manufacture and Use		N2O	C	C	88.28	102.86	48.25	88.28	51.38	51.06	0.00	-90.64	8.34	13.92
2 G, Other Product Manufacture and Use		C10F18	C	C	0.00	0.00	0.00	0.00	24.84	24.78	0.00		0.00	0.00
2 G, Other Product Manufacture and Use		HFC134a	0.00	0.18	0.00	0.00	0.00	0.00	22.50	22.56	0.00		0.00	0.00
2 G, Other Product Manufacture and Use		HFC245fa	0.00	21.54	0.00	0.00	0.00	0.00	20.59	21.08	0.00		0.00	0.00
2 G, Other Product Manufacture and Use		HFC365mfc	0.00	0.71	0.00	0.00	0.00	0.00	22.14	22.41	0.00		0.00	0.00
2 G, Other Product Manufacture and Use		SF6	C	C	0.00	0.00	0.00	0.00	7.99	7.97	0.00	-78.58	38.85	40.46
3 A, Enteric Fermentation	dairy cows	CH4	20,188.82	14,788.07	4.00	4.01	19.88	19.80	20.04	20.30	0.03	-26.75	133.08	164.34

A1	A2	B	C	D	E-	E+	F-	F+	G-	G+	H	I	J-	J+
3 A, Enteric Fermentation	non-dairy cattle	CH4	15,273.58	9,267.27	11.76	12.17	13.88	15.64	10.81	11.03	0.00	-39.32	35.52	39.92
3 A, Enteric Fermentation	other animals	CH4	2,161.42	1,792.61	22.89	23.71	36.47	44.46	16.80	22.44	0.00	-17.06	118.09	151.80
3 B, Manure Management	dairy cows	CH4	2,521.46	2,499.53	4.02	4.01	20.18	19.99	20.46	20.65	0.00	-0.87	248.46	305.65
3 B, Manure Management	non-dairy cattle	CH4	2,683.78	1,468.79	10.58	11.13	17.19	19.25	11.30	11.35	0.00	-45.27	29.12	32.54
3 B, Manure Management	swine	CH4	3,045.17	1,945.35	7.52	7.11	19.69	21.24	16.11	16.48	0.00	-36.12	71.83	84.52
3 B, Manure Management	other animals	CH4	238.01	313.14	21.49	25.45	43.23	46.97	16.37	16.79	0.00	31.56	147.61	180.16
3 B, Manure Management	dairy cows	N2O	1,313.24	643.84	4.02	4.01	56.55	98.19	56.70	97.70	0.00	-50.97	195.31	432.86
3 B, Manure Management	non-dairy cattle	N2O	1,068.01	680.49	33.45	43.33	44.32	92.53	33.89	48.34	0.00	-36.28	153.22	229.71
3 B, Manure Management	swine	N2O	444.50	270.47	27.56	20.00	52.62	97.65	46.31	77.03	0.00	-39.15	164.54	296.36
3 B, Manure Management	other animals	N2O	390.15	417.04	52.58	98.91	65.73	116.07	48.07	82.02	0.00	6.89	10,989.84	20,756.74
3 B, Manure Management	deposition and leaching	N2O	1,266.26	828.68	39.85	39.87	0.05	0.02	39.85	39.88	0.00	-34.56	151.11	238.24
3 D, Agricultural Soils		N2O	20,292.80	14,473.14	18.91	17.38	29.71	90.38	15.55	22.27	0.02	-28.68	130.66	148.70
3 G, Liming		CO2	2,200.01	1,906.50	3.55	3.34	3.49	3.37	4.37	4.54	0.00	-13.34	44.78	36.24
3 H, Urea Application		CO2	480.00	330.20	1.00	1.00	1.00	1.00	1.43	1.43	0.00	-31.21	5.09	5.20
3 I, Other carbon-containing fertilisers		CO2	510.45	144.75	3.00	3.02	2.99	3.01	4.21	4.29	0.00	-71.64	3.47	3.64
3 J, Other Agriculture		CH4	0.31	1,445.31	10.07	10.02	19.99	20.31	22.10	23.14	0.00	460,915.75	28.81	36.32
3 J, Other Agriculture		N2O	0.11	92.70	20.38	22.75	0.91	0.83	9.40	9.35	0.00	87,107.90	12.93	14.22
4 A, Forest Land		CO2	-26,920.55	1,648.08	0.00	0.00	0.00	0.00	103.60	103.50	0.01	-106.12	2.42	2.40
4 A, Forest Land		CH4	32.44	26.91	15.03	14.98	35.04	34.98	63.43	143.40	0.00	-17.04	393.96	972.06
4 A, Forest Land		N2O	435.49	465.46	15.03	14.98	34.76	35.02	48.27	48.28	0.00	6.88	315.02	603.30
4 B, Cropland		CO2	25,789.59	16,833.12	0.00	0.00	0.00	0.00	13.39	11.56	0.01	-34.73	23.12	23.09
4 B, Cropland		CH4	413.90	312.23	0.00	0.00	0.00	0.00	44.79	71.85	0.00	-24.57	352.45	625.87
4 B, Cropland		N2O	543.02	370.18	0.00	0.00	0.00	0.00	55.12	103.95	0.00	-31.83	339.55	726.42
4 C, Grassland		CO2	22,519.88	21,469.12	0.00	0.00	0.00	0.00	74.66	64.46	0.49	-4.67	556.87	1,515.66
4 C, Grassland		CH4	2,582.33	2,657.31	0.00	0.00	0.00	0.00	49.62	88.76	0.01	2.90	343.20	663.10
4 C, Grassland		N2O	80.60	51.98	0.00	0.00	0.00	0.00	48.58	48.50	0.00	-35.51	176.85	325.59
4 D, Wetlands		CO2	3,586.67	3,478.53	0.00	0.00	0.00	0.00	42.73	132.61	0.04	-3.01	2,537.55	5,299.18
4 D, Wetlands		CH4	5,368.71	5,447.38	0.00	0.00	0.00	0.00	22.92	30.24	0.01	1.47	990.03	1,327.29

A1	A2	B	C	D	E-	E+	F-	F+	G-	G+	H	I	J-	J+
4 D, Wetlands		N2O	26.27	26.76	0.00	0.00	0.00	0.00	5.92	5.98	0.00	1.86	2,153.95	2,558.23
4 E, Settlements		CO2	3,141.45	4,370.55	0.00	0.00	0.00	0.00	18.45	19.95	0.00	39.13	82.91	95.40
4 E, Settlements		CH4	53.82	96.43	0.00	0.00	0.00	0.00	40.96	65.11	0.00	79.18	123.10	209.73
4 E, Settlements		N2O	136.11	177.18	0.00	0.00	0.00	0.00	50.84	135.15	0.00	30.17	252.45	587.52
4 G, Harvested Wood Products		CO2	-1,294.86	407.62	0.00	0.00	0.00	0.00	725.54	722.40	0.03	-131.48	96.77	94.92
5 A, Solid Waste Disposal		CH4	37,191.25	1,997.16	0.00	0.00	0.00	0.00	20.11	19.89	0.00	-94.63	1.46	1.82
5 B, Biological Treatment of Solid Waste		CH4	59.39	918.33	11.44	20.22	76.27	203.58	69.16	148.97	0.00	1,446.32	102.33	376.82
5 B, Biological Treatment of Solid Waste		N2O	19.67	194.29	6.30	16.50	63.75	148.47	57.75	106.01	0.00	887.61	103.93	248.10
5 D 1, Domestic Wastewater		CH4	3,725.66	926.91	30.29	29.75	36.13	36.00	43.36	50.73	0.00	-75.12	3.77	6.25
5 D 1, Domestic Wastewater		N2O	515.78	1,131.75	39.30	16.90	99.43	606.29	64.41	127.53	0.00	119.42	185.92	476.59
5 D 2, Industrial Wastewater		CH4	10.36	56.61	0.00	0.00	0.00	0.00	50.37	49.76	0.00	446.30	81.42	148.21
5 D 2, Industrial Wastewater		N2O	28.09	24.01	49.97	50.25	89.91	307.52	91.12	322.42	0.00	-14.53	158.71	792.10
5 E, Other Waste		CH4	0.00	2.36	2.00	2.01	20.01	20.18	20.08	20.28	0.00		39.11	48.34
5 E, Other Waste		N2O	0.00	25.90	2.00	1.99	20.07	19.89	20.12	19.99	0.00		72.46	166.73

Uncertainties for categories were determined successively, within the framework of data deliveries for current emissions reporting from specialist departments of the German Environment Agency. In addition, external experts determined additional uncertainties for categories for which no uncertainties information or incomplete information has been available to date in research projects. The results of these uncertainties analyses were integrated into the current report.

The uncertainties in the categories Agriculture and LULUCF are estimated by experts of the Thünen Institute (TI).

Annex 3 CO_2 Reference Approach and comparison with the Sectoral Approach

General information

The Reference Approach briefly described in Chapter 3.2.1.1 is intended to be applicable to all reporting countries. This abstraction and generalisation alone inevitably leads to discrepancies with the Sectoral Approach.

On the whole, the Sectoral Approach supports calculations that are considerably more differentiated and precise, with results that – especially at a detailed level – differ (sharply, in some cases) from those produced by the Reference Approach.

The efforts undertaken in recent years and continued with this submission, in particular to eliminate errors in the transfer of country-specific activity data into the structure of the Reference Approach, has resulted in extremely good agreement between the results obtained with both calculation approaches at the maximum aggregate level (cf. Chapter 3.2.1.1). Discrepancies that continue to exist at *fuel group* level, and especially at *fuel* level, can be explained – at least in part – as the result of country-specific circumstances, but it has not yet been possible to eliminate them satisfactorily.

The Reference Approach will thus continue to offer scope for further improvements. In addition to reviewing and, if necessary, revising the input data and calculation methods used, particularly for non-energy-related consumption, maximising the flexibility of data management in CRF Reporter would further improve the comparability of both approaches.

Annex 3.1 Comparison of the results of the Sectoral and Reference Approaches

The following section compares the results obtained from calculating the CO_2 emissions from fuel use calculated using the Sectoral and Reference Approaches.

In this report, the EU's Joint Annual Questionnaire (JAQ) is used for the second time as a data source for the Reference Approach

CRT report table 1.A (c) compares results obtained with the Sectoral Approach (1.AA) with results obtained with the Reference Approach (1.AB). Since the non-energy-related consumption (NEV, 1.AD) of the fuels considered occurs elsewhere (industrial processes and product use), the quantities that must be assigned to this consumption, pursuant to the *JAQ*, are deducted from the Reference Approach. In addition to lubricants, bitumen and naphtha, this also applies to diesel fuel, light and heavy fuel oil, LP gas, petroleum coke and other mineral oils, hard coal and lignite, coke and natural gas.

For the year 2024, this approach yields a (manually calculated) non-energy-related consumption of about 834 petajoules.

After this failed for Submission 2025 due to technical problems, the results shown below were generated within the *ETF Reporting Tool*. For 2024, this results in a 0.89% lower energy fuel consumption for the Reference Approach, with 2.48% lower reference emissions (cf. Chapter 3.2.1.1).

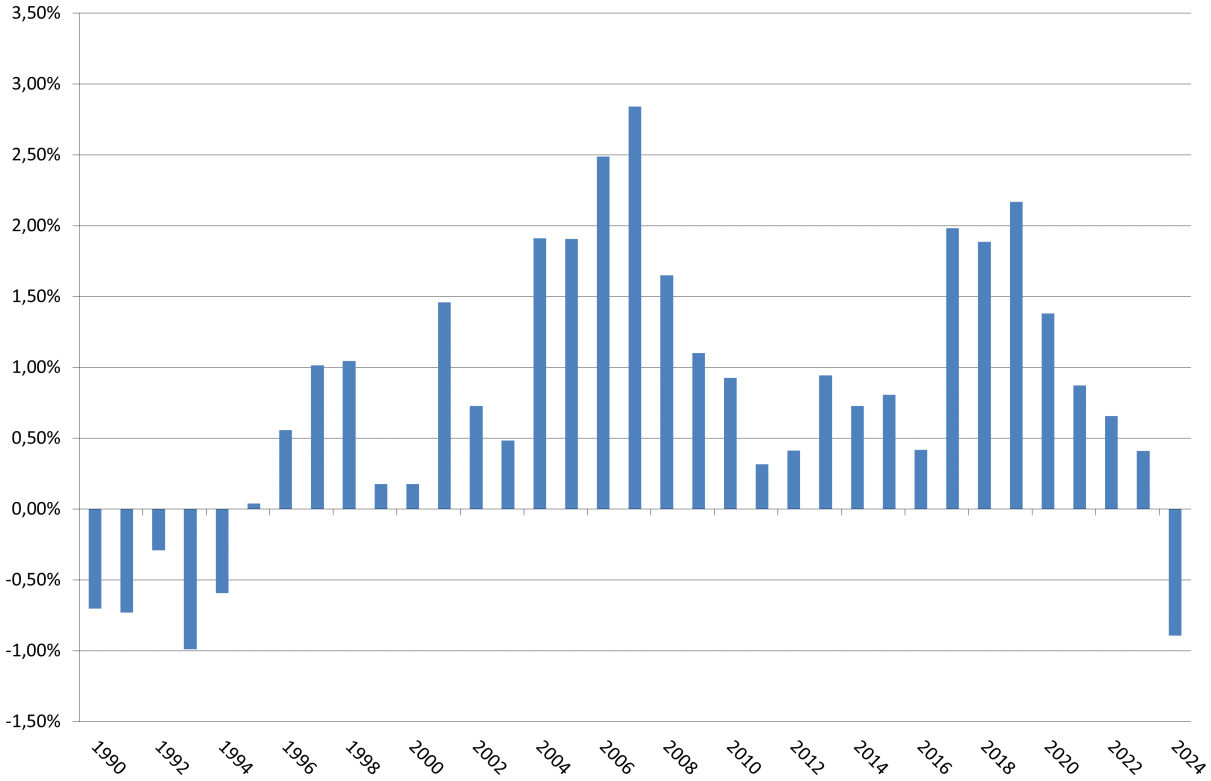
Looking at the entire period since 1990, most of the fuel inputs listed under the Reference Approach (less the quantities used for non-energy-related purposes) are higher than those listed under the Sectoral Approach. Exceptions to this are the years 1990 to 1994 and 2024.

Table 473: Comparison of the energy inputs determined using the Sectoral and Reference Approach (not including non-energy-related consumption), in terajoules

Year	1.AA	*1.AB (including non-energy-related consumption)*	1.AB (excluding non-energy-related consumption)	1.AB (excluding non-energy-related consumption) minus 1.AA	
1990	11,754	12,826	11,671	-82.7	-0.70%
1995	10,983	12,141	10,988	4.24	0.04%
2000	10,590	11,847	10,608	18.7	0.18%
2005	10,276	11,650	10,472	196	1.91%
2010	9,895	11,054	9,987	91.6	0.93%
2011	9,520	10,614	9,550	30.2	0.32%
2012	9,614	10,674	9,654	39.7	0.41%
2013	9,878	10,992	9,971	93.3	0.94%
2014	9,306	10,425	9,373	67.7	0.73%
2015	9,405	10,495	9,481	75.9	0.81%
2016	9,563	10,640	9,603	39.9	0.42%
2017	9,361	10,668	9,547	186	1.98%
2018	9,072	10,306	9,243	171	1.89%
2019	8,674	9,904	8,862	188	2.17%
2020	8,020	9,142	8,130	111	1.38%
2021	8,325	9,509	8,398	72.6	0.87%
2022	8,128	9,116	8,181	53.4	0.66%
2023	7,286	8,132	7,315	29.8	0.41%
2024	7,115	7,966	7,052	-63.5	-0.89%

Source: ETF Reporting Tool

Figure 119: Percentage discrepancies between the total annual activity data recorded in the Reference Approach and the total quantities in the Sectoral Approach



Source: own illustration, German Environment Agency

The situation is more varied when it comes to the carbon dioxide emissions calculated using the Reference Approach: These are lower than the quantities calculated using the Sectoral Approach for all years up to and including 2005, from 2010 to 2015, and from 2020 onwards. (cf. Chapter 3.2.1.1).

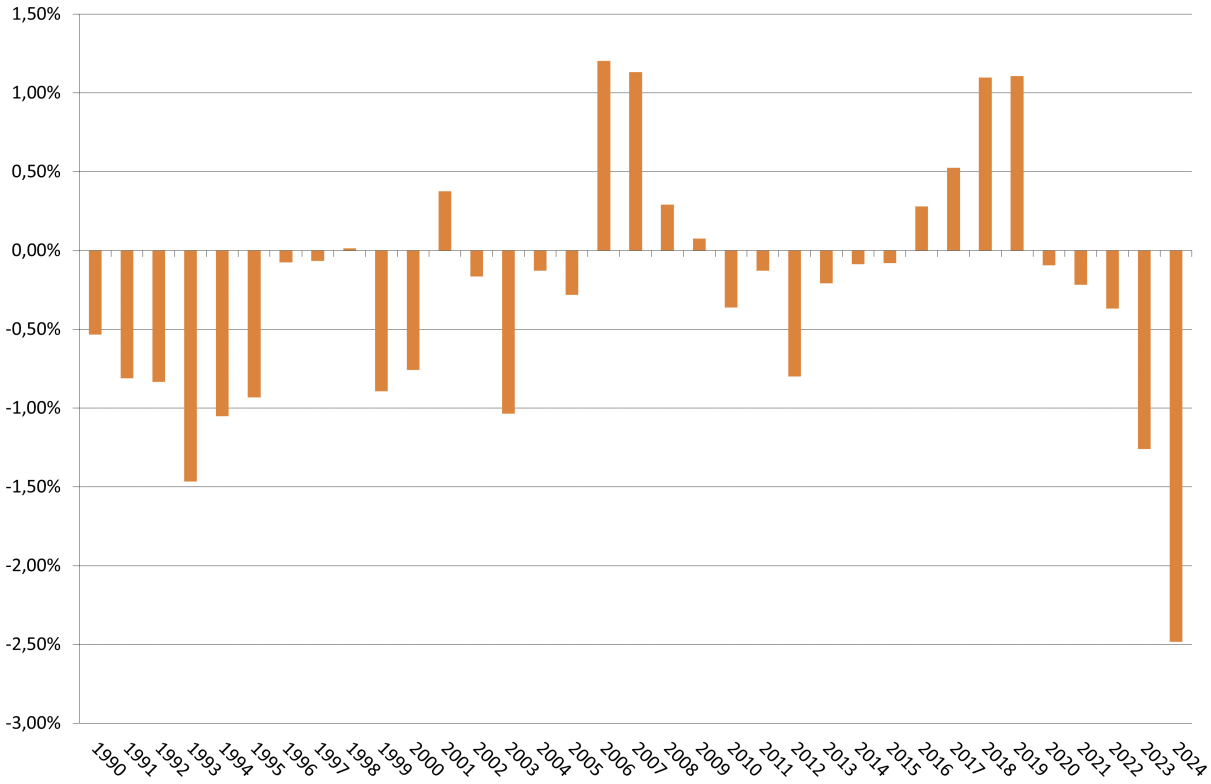
Table 474: Comparison of the CO_2 emissions determined using the Sectoral and Reference Approach (not including non-energy-related consumption), in kilotonnes

	1.AA	1.AB (excluding non-energy-related consumption)	1.AB (excluding non-energy-related consumption) minus 1.AA	
1990	988,122	982,842	-5,280	-0.53%
1995	878,998	870,796	-8,202	-0.93%
2000	835,868	829,528	-6,340	-0.76%
2005	810,812	808,525	-2,286	-0.28%
2010	778,760	775,950	-2,810	-0.36%
2015	749,820	749,216	-604	-0.08%
2016	749,860	751,962	2,102	0.28%
2017	734,193	738,048	3,855	0.53%
2018	706,154	713,903	7,748	1.10%
2019	660,039	667,345	7,307	1.11%
2020	599,889	599,323	-566	-0.09%
2021	630,554	629,185	-1,369	-0.22%
2022	625,032	622,729	-2,303	-0.37%
2023	550,118	543,193	-6,925	-1.26%

	1.AA	1.AB (excluding non-energy-related consumption)	1.AB (excluding non-energy-related consumption) minus 1.AA	
2024	531,526	518,329	-13,197	-2.48%

Source: ETF Reporting Tool

Figure 120: Percentage discrepancies between the annual carbon dioxide emissions calculated using the Reference Approach and the Sectoral Approaches



Source: own illustration, German Environment Agency

The following table contains the calorific values for 2024 derived from fuel-specific domestic consumption, including non-energy-related use (= *apparent consumption*) according to JAQ.

Table 475: Calorific values derived for the respective domestic consumption, in [MJ/kg]

Fuel/fuel group		Calorific value
Crude oil		42.505
Gasoline		42.281
Jet fuel and other kerosene		42.800
Diesel and light heating oil		43.000
Heavy fuel oil		40.343
LPG		43.074
Naphtha		44.000
Bitumen		39.011
Lubricants		41.818
Petroleum coke		32.000
Other petroleum products	*Additive*	37.661

Fuel/fuel group		Calorific value
	Paraffin wax	43.325
	Test gasoline (rubbing alcohol)	43.200
	Other oil products	39.501
Anthracite coal		29.700
Coke coal		29.000
(Other) hard coal		28.284
Crude lignite		8.988
Lignite briquettes		21.774
Meta-lignite (“hard lignite”)		31.400
Coke		28.650
Natural gas (incl. mine gas)		34.863

Annex 4 QA/QC plan

Information about the QC/QA plan is provided in Chapter 1.2.2.3.1.5.

Annex 5 Additional information to be included in the NID submission (where relevant) or other useful reference information

Annex 5.1 Additional information on inventory preparation and the National System

Annex 5.1.1 Definitions in the "National System" principles paper on emissions reporting

In the "National System" principles paper on emissions reporting, the state secretaries of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), Federal Ministry of the Interior (BMI), Federal Ministry of Defence (BMVg), Federal Ministry of Finance (BMF), Federal Ministry for Economic Affairs and Energy (BMWi); Federal Ministry of Transport, Building and Urban Affairs (BMVBS) and Federal Ministry of Food and Agriculture (BMEL) defined responsibilities for the various relevant source and sink categories and the necessary financing for 2008. The agreement reads as follows:

BMUB, BMI, BMVg, BMF, BMWi, BMVBS, BMEL Berlin, 5 June 2007

Definitions in the "National System" principles paper on emissions reporting

The state secretaries of the ministries concerned have determined as follows, by common consent, with regard to the issue of the "National System" for emissions reporting pursuant to Art. 5(1) Kyoto Protocol:

1. *The German Environment Agency, Section I 4.6 [107] "Emissions Situation", is the responsible "Single national entity" (national coordination agency) for reporting pursuant to the UN Framework Convention on Climate Change and the Kyoto Protocol. A country's Single National Entity is responsible for preparing the country's national inventory, working for continual improvement of the inventory, supporting those persons involved in the national system and preparing decisions of the Coordinating Committee.*

2. *A Coordinating Committee, representing all affected ministries, has been established to deal with all questions arising in the framework of the National System and to be responsible for official discussion and approval of the inventories and the reports required pursuant to Articles 5, 7 and 8 of the Kyoto Protocol. The Committee shall support all processes in this framework and, in particular, it shall clarify any uncertainties – for example, in connection with definition of individual emission factors.*

   In particular, the Committee shall define key source and sink categories and the minimum requirements for quality control and quality assurance for data collection and processing and for the annual quality control and quality assurance plan.

   As necessary, the Committee may specify the methods to be used for calculating emissions in the various categories and for calculating storage in sink categories. The Committee is chaired by the BMU. The Committee shall meet whenever at least one ministry sees a need for such a meeting. Subordinate authorities and other institutions involved in inventory preparation may be included in meetings as necessary.

3. *For preparation of the national inventory, such data shall be used for calculations of emissions and reductions as required pursuant to the provisions of Art. 3 (1) of decision 280/2004/EC and of Art. 2 (1) of the Ground rules for calculating emissions in source categories and storage in sink categories. Inventories shall be prepared on an annual basis. In addition, quality assurance in accordance with the*

[107] Author's remark: currently, I 2.6.

requirements of Art. 12 of the rules shall be carried out. Furthermore, reliable documentation and archiving shall be required.

Existing data transfer arrangements, such as those made on the basis of voluntary agreements or legal provisions, should not be fundamentally changed; they should only be completed and improved as necessary in order to provide a reliable database. For this reason, the aforementioned responsibilities do not necessarily include data collection and forwarding. With regard to division of responsibilities between BMU/UBA, BMVBS and BMWI, we refer in particular to Annex 1.

The responsibilities for ensuring proper data delivery to the Single National Entity and for quality control, documentation and data archiving shall be distributed as follows among the various relevant ministries:

a) For category 1 (Energy) – with the exception of categories 1.A.3 (Transport) and 1.A.5a (Energy: Other), where emissions sources of the German Federal Armed Forces (Bundeswehr) are concerned – the Federal Ministry of Economics and Technology (BMWi) has responsibility.

b) For categories 2 (Production processes) and 3 (Use of solvents and other products), the Federal Ministry of Economics and Technology (BMWi) has responsibility.

c) For category 1.A.3 (Transport), the Federal Ministry of Transport, Building and Urban Affairs (BMVBS) has responsibility.

d) For category 1.A.5a (Energy: Other), where emissions sources of the German Federal Armed Forces (Bundeswehr) are concerned – the Federal Ministry of Defence (BMVg) has responsibility. Where data are subject to secrecy provisions, the German Environment Agency shall take the relevant secrecy requirements into account.

e) For source and sink categories 4 (Agriculture) and 5 (Land use, land-use changes and forestry), the Federal Ministry of Food and Agriculture (BMEL) has responsibility.

f) For category 6 (Waste) and category 7, and well as for issues related to greenhouse gas emissions from biomass combustion, the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) has responsibility.

g) The Federal Ministry of Food and Agriculture (BMEL) is also responsible for preparing tables in the standardised reporting format pursuant to Art. 2 (2) letter a of Decision 2005/166/EC (implementation rules) in source and sink categories 4 and 5.

In addition, the relevant authorities, as determined by the statistics regulations, are responsible for tasks related to official statistics, including data delivery, quality assurance and data documentation and archiving. Cooperation between a) the statistical offices of the Federal Government and the federal states and b) the agencies concerned with reporting is coordinated through the Federal Statistical Office. In the process, secrecy requirements pertaining to statistics shall be observed.

4. *The responsible ministries shall clarify, at short notice, how proper data provision is to be permanently assured to the extent such clarification has not already been completed. In particular, this requirement shall apply to agreements, ordinances or laws needed for the institutionalisation of the National System. In general, for purposes of emissions reporting, voluntary agreements with associations and/or individual companies shall have the same status as legal provisions. In addition, as agreed in the coordination discussion on 12 September 2006, the German Environment Agency and the Federal Statistical Office shall determine what data can be provided, for reporting purposes, from the official statistical system, as well as what additional data should be collected through the official statistical system. The various relevant ministries, the German Environment Agency and the Federal Statistical Office shall send their proposals to the Federal Environment Ministry by 15 July 2007.*

5. *By 31 July 2007, the Federal Environment Ministry shall invite participating ministries to coordinate the proposals and to establish a schedule for implementing the required instruments. The responsible*

ministries and the Federal Government shall arrange for the establishment of the required instruments as quickly as possible.

6. *Where additional funding is required to perform the responsibilities mentioned under 3., such funding shall be provided from the proceeds from the sale of AAUs, in expansion of the state secretaries' agreement of 22 December 2006 on Article 3.4 of the Kyoto Protocol.*

   To this end, a budget item for relevant income shall be established within Individual Plan 16 (Einzelplan 16) as of the 2008 fiscal year. Following review by the Federal Ministry of Finance (BMF), the additional requirements requiring financing shall be listed as expenditures within the ministries' individual budgets. The ministries' additional requirements in this regard must be submitted to the BMF by 6 June 2007.

   Should additional budget funding be required in coming years, in addition to the additional requirements determined in connection with the 2008 budget, then suitable relevant amounts of additional AAUs shall be sold in subsequent years.

[…]

Annex: Division of responsibilities between BMU/UBA, BMVBS and BMWI

The BMU, BMVBS and BMWi have agreed that the existing emissions reporting structures are to be retained and that the German Environment Agency (UBA) shall continue to perform its existing tasks with regard to the categories 1, 1.A.3, 2 and 3. The BMVBS and the BMWi shall ensure that any gaps in the data for those categories for which they are responsible are closed.

The details:

BMWi:

With regard to category 1: The inventories in this area shall be prepared by the German Environment Agency on a basis that shall include energy data provided by the agency contracted by the BMWi for preparation of energy balances, as well as on the basis of additional relevant statistics and association information.

With regard to category 2: The inventories in this area shall be produced by the German Environment Agency on the basis of data that shall include data from statistics of the manufacturing sector (Produzierendes Gewerbe – ProdGewStatG) and from communications of relevant associations/individual companies.

With regard to category 3: The inventories in this area shall be produced by the German Environment Agency on the basis of data that shall include data from statistics of the manufacturing sector (Produzierendes Gewerbe – ProdGewStatG), from foreign trade statistics and from communications of relevant associations/individual companies.

Existing requirements for further optimisation shall be clarified, in the short term, by BMWi, BMU and UBA, working in coordination. Where data optimisation may be necessary as a result of changes to existing surveys based on the Environmental Statistics Act (UStatG) or on the 13th Ordinance on the Implementation of the Federal Immission Control Act (13. BimSchV), the BMU shall be responsible. The German Environment Agency shall assume responsibility for recording and archiving data received by the German Environment Agency.

BMVBS:

Emissions for category 1.A.3 (Transport) shall be calculated by the German Environment Agency using the TREMOD model. The BMVBS shall provide data/calculations as needed to close data gaps and determine emissions for international air transport or shall ensure that such data/calculations are provided by third parties. At present, emissions from ship transport may be calculated from Energy Balance data using default emission factors. The German Environment Agency shall assume responsibility for recording and archiving data received by the German Environment Agency.

Annex 5.1.2 Additional information about the Quality System of Emissions Inventories

Annex 5.1.2.1 Minimum requirements for a quality control and assurance system

As described above in the main section, the requirements for the quality control and quality assurance system (QC/QA system) and for quality control and quality assurance measures are defined primarily by Chapter 8 of the *IPCC Good Practice Guidance*.

From those provisions, the German Environment Agency has derived its own "General minimum requirements for quality control and quality assurance related to greenhouse gas emissions reporting" ("Allgemeine Mindestanforderungen an die Qualitätskontrolle und Qualitätssicherung bei der Treibhausgasemissionsberichterstattung"; last revision: November 2007). These are described below.

Annex 5.1.2.1.1 Introduction

Representatives of the ministries participating in the coordinating committee for the National System of Emissions Inventories define the general minimum requirements, which are described in this document, for quality control and quality assurance (QC/QA) in reporting on greenhouse gas emissions. They thus form the basis for the collection, processing, transfer and reporting of all data used for GHG reporting.

These minimum QC/QA requirements must be complied with on all levels of inventory preparation. In many cases, existing processes and systems, such as the quality standards for public statistics, can be used as a basis. Annex 1 of this document describes, by way of example, implementation of the minimum QC/QA requirements and the QC/QA system in the German Environment Agency. All participating institutions are required to submit suitable descriptions of their implementation of these minimum requirements so that they can be published with the inventory report as part of 2009 reporting. On request, the German Environment Agency supports participating ministries in preparing QC/QA systems in their relevant areas of responsibility.

Annex 5.1.2.1.2 System for quality control and quality assurance

The rules (Commission Decision 2005/166/EC) implementing Decision 280/2004/EC require national greenhouse gas inventories to conform to the QC/QA requirements of the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC Good Practice Guidance) and the IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC Good Practice Guidance for LULUCF).

The IPCC Good Practice Guidance specifies that QC/QA systems must be introduced, with the aim of enhancing transparency, consistency, comparability, completeness and accuracy of national emissions inventories and, especially, that such inventories must fulfil requirements for "good inventory practice". A QC/QA system comprises the following:

- An agency responsible for coordinating QC/QA activities
- Development and implementation of a QC/QA plan
- General QC procedures
- Category-specific QC procedures
- QA procedures and

- Reporting procedures
- Documentation and archiving procedures

QC/QA measures can conflict with requirements for punctuality and cost-effectiveness. The available time, staffing and financial resources should thus be taken into account in any QC/QA system development. It is good practice to set higher requirements for the data quality of the key categories. For other categories, not all category-specific QC procedures have to be implemented. In addition, not all measures have to be carried out on an annual basis; for example, data collection methods have to be reviewed only once in detail. Thereafter, it suffices to carry out periodic controls to determine whether the conditions for applying the methodology continue to be met. Another criterion for the requirements for QC/QA measures is the uncertainty of a specification. In order to reduce an inventory's overall uncertainty, those categories that have high levels of uncertainty should be reviewed in detail.

Annex 5.1.2.1.3 Agency responsible for coordinating QC/QA activities

As the Single National Entity (national coordination agency), the German Environment Agency is responsible for the QC/QA system for the national greenhouse gas inventory. In this function, it has established the position of coordinator for the Quality System for Emissions Inventories (QSE). It is good practice for all companies and organisations involved in inventory preparation to appoint a QC/QA coordinator and notify the QSE coordinator.

A QC/QA coordinator has responsibility for ensuring that a relevant QC/QA system is developed and implemented. Implementation should be suitably institutionalised – for example, by means of an in-house directive or association agreement.

In order to ensure that the Single National Entity can efficiently carry out its supporting tasks, the persons responsible for the following additional functions should be announced (by name) to the QSE coordinator:

Responsible expert (Fachverantwortlicher) – Person responsible for data collection, data entry and calculation, in accordance with the prescribed methods, as well as for implementation of quality control measures and preparation of the text contribution for the National Inventory Report.

Quality control manager (Qualitätskontrollverantwortlicher) – Person responsible for checking and approving data and report sections (the QC/QA coordinator may also perform this function).

Annex 5.1.2.1.4 QC/QA plan

The purpose of the QC/QA plan is to ensure that QC/QA measures are properly organised and executed. It includes a description of all required QC/QA measures and a schedule for implementation of these measures. The QC/QA plan also defines the primary emphases of these measures. The criteria for selection of categories for detailed review include the following:

- The category's relevance (key category yes/no, uncertainties high/low)
- The time of the last detailed QC/QA measure for the source category and the results
- Changes in methods or the underlying data
- Results of the annual inventory review under the UN Framework Convention on Climate Change
- Available resources for carrying out QC/QA measures

It is good practice to establish a QC/QA plan and then review and update it each year after the latest inventory has been prepared.

On the basis of the results of annual inventory review and the QC/QA measures of which it is aware, the Single National Entity prepares an improvement plan for the entire inventory. On this basis, it then derives proposals for a binding inventory plan for the next report year. These proposals are then submitted to the coordinating committee for approval. The QC/QA coordinator, working in cooperation with the QSE coordinator in the Single National Entity, defines the procedures, scheduling and scope for inclusion of his institution's QC/QA measures in the inventory plan for the overall inventory.

Annex 5.1.2.1.5 General quality control

Pursuant to the definition in the IPCC (Chapter 8.1 *Good Practice Guidance*), quality control (QC) comprises a system of routine technical activities to measure and control the quality of the inventory as it is being developed.

The QC system is designed to:

- Provide routine and consistent checks to ensure data integrity, correctness and completeness
- Identify and address errors and omissions
- Document and archive inventory material and record all QC activities

Table 8.1 of the *IPCC Good Practice Guidance* includes a complete list of general QC procedures. Requirements for general Tier 1 QC procedures can be derived from the requirements outlined in Chapter 8.6 of the *IPCC Good Practice Guidance*. Typical general quality control measures when determining the activity data include checking data for transmission errors, checking for completeness, checking formulae used to aggregate the data, and performing plausibility checks using external data sources and previous calculations. Suppliers of emissions calculations have to carry out additional QC measures – for example, checking the formulae used to calculate the emissions.

Required quality controls should be recorded in checklists. The lists should include at least the QC measures carried out, the results of the QC, any corrections made and the name of the person(s) responsible for the measures. Annex 2 of this document includes a sample checklist of the German Environment Agency.

Not all quality controls have to be carried out on an annual basis; some may be implemented at longer regular intervals. This applies especially to aspects of data collection that do not change from year to year. Requirements related to the frequency and completeness of QC measures are more stringent for key categories than for other categories. It should be ensured that all categories undergo detailed quality control at least periodically.

Annex 5.1.2.1.6 Category-specific quality control

In addition to Tier 1 procedures, particularly relevant categories (e.g. key categories) should always be subject to Tier 2 quality control when determining activity data, emissions and uncertainties, bearing in mind resource constraints (cf. Chapter 8.7 *Good Practice Guidance*). The chapters of the *IPCC Good Practice Guidance* that pertain to the various individual categories (Chapter 1-5) include additional information about category-specific QC measures. These guidelines must be observed in preparation of any QC/QA plan. :

When using aggregated activity data from secondary sources, it is good practice to evaluate the quality control measures used to compile the secondary sources. If the level of these measures is sufficient, it is enough to simply mention this in the documentation. Where secondary sources do not fulfil minimum requirements pertaining to quality control, suitable QC/QA checks should be carried out by the institution that uses the data. Results of subsequent QC/QA checks should be taken into account when determining the uncertainties of the activity data. In addition, wherever possible, a range of different sources should be compared for the purposes of determining data quality.

When using facility-specific activity data, it is good practice to review the methodology and QC/QA standards applied to data collection. If they do not meet minimum requirements, the use of the data should be reconsidered and the uncertainties adjusted as necessary.

With regard to emissions data, it is good practice to review the emission factors that have been used. This includes using national emission factors for key categories and reviewing the validity of IPCC default factors under the applicable national circumstances. If emissions are determined by direct measurement, it is good practice to review the measurement methods and quality standards used. Emission data and emission factors should be verified using data from previous years and independent sources, and any deviations explained.

Quality control for uncertainties includes checking to determine whether calculations are free of errors and whether documentation to reproduce the results is adequate. When using estimates provided by, the qualifications and estimation methods of the experts should be reviewed and documented.

Annex 5.1.2.1.7 Quality assurance procedures

While the primary aim of quality control is to ensure that methods are correctly applied, the primary purpose of quality assurance is to examine the methodology as such and improve it as necessary.

Pursuant to the relevant IPCC definition (Chapter 8.1 *Good Practice Guidance*), quality assurance (QA) measures are based on *"a planned system of review procedures conducted by personnel not directly involved in the inventory compilation/development process. Reviews, preferably by independent third parties, should be performed upon a finalised inventory following the implementation of QC procedures. Reviews:*

- verify that data quality criteria were met,
- ensure that the inventory represents the best possible estimates of emissions and sinks given the current state of scientific knowledge and data available, and
- support the effectiveness of the QC programme."

The required instrument for quality assurance is peer review. While the use of audits is recommended, audits are not required.

Annex 5.1.2.1.8 Reporting procedures

The Single National Entity is responsible for initiating and coordinating reporting and carrying out relevant overall organisation. Provision of data and reports by third parties must conform to applicable requirements pertaining to the scope, form and scheduling of/for such provision.

Annex 5.1.2.1.9 Documentation and archiving

As a general requirement, all data and information used for inventory calculation must be documented (i.e. recorded) and archived for each report year. The documentation aims to provide a complete and transparent overview of the emissions calculation. The general documentation and archiving requirements for the entire process of preparation of greenhouse gas inventories are described in Chapter 8.10.1 of the *IPCC Good Practice Guidance*.

Data providers are required to keep records of the following information about the data they supply to the German Environment Agency for the inventory calculations:

Data providers:

- Publication/source of the activity data with detailed references to the relevant Table numbers and names and pages in the original sources;
- Survey contents (definitions of the surveyed characteristics, delimitations, survey units) and survey methodology;
- The legal foundations and ordinances on which surveys are based;
- Chronological and spatial comparability with previous year data, and any changes in definitions, scopes of validity, cut-off points, sources of activity data or data collection methods;
- Any revision of previously published data;
- The accuracy or quantitative error of activity data, methods used to estimate errors and the names of experts who have carried out error estimation.
- Secrecy and data protection: suitable notification with regard to any individual data items that are considered secret.

These materials should be provided to the German Environment Agency on an annual basis together with the data; they are centrally archived by the German Environment Agency.

Quality control

The records kept in the context of quality control should include the names of the persons responsible for managing and carrying out relevant actions, the types of quality control carried out, the dates the quality control measures were carried out, the results and the corrections and modifications triggered by quality control measures. In each case, documentation and archiving of the quality control measures are carried out internally by the institution supplying the data. A general description of regularly carried out quality control measures is provided to the German Environment Agency for the purposes of the national inventory report and inventory review.

Providers of emissions calculations

For providers of emissions calculations, the minimum requirements for documentation also include the following:

- Description of the calculation methodology and the reasons the methods were selected;
- Assumptions and criteria related to selection of activity data and emission factors;
- Documentation for emission factors and their sources with detailed references to the relevant numbers and pages in the original sources;

- Calculation models;
- Calculation files, calculation software.

Points 1-4 are documented and archived along with descriptions provided for the national inventory report. Separate documentation for calculation models must be provided, in accordance with general scientific practice, and along with internal documentation in the form of manuals or guides. Data suppliers are responsible for documenting and archiving calculation files or calculation software internally. These materials should be provided to the German Environment Agency as necessary in the framework of inventory review.

Quality assurance

In addition to carrying out quality control measures, providers of emissions calculations are obligated to carry out quality assurance. The records kept in the context of quality control should include the names of the persons responsible for managing and carrying out relevant actions, the types of quality control carried out, the dates the quality control measures were carried out, the results and the corrections and modifications triggered by quality control measures. In addition, records should be kept of category-specific quality controls.

Documentation and archiving of quality assurance is carried out internally by the institution supplying the data, as well as through a summary of the assurance measures in the national inventory report.

Confidential data/secrecy

In general, confidential data must be designated as such when they are provided to ensure that the proper precautions are taken when they are used.

As part of the inventory review, there is a general obligation to disclose confidential data if this is deemed necessary by the inventory reviewers for reasons of transparency and traceability of the emission calculations. The extent to which this actually affects the disclosure of individual details should be clarified in each individual case with the institution providing the data.

Annex 5.1.2.1.10 Annex 1: Minimum requirements for quality control and quality assurance in emissions reporting in the German Environment Agency

Annex 5.1.2.1.10.1 Introduction

The general minimum requirements, as approved by the coordinating committee for the National System of Emissions Inventories, for quality control and quality assurance (QC/QA) in reporting on greenhouse gas emissions apply to all participants. These requirements are the basis for collecting, processing, transfer and reporting of/on all data that support reporting on greenhouse gas emissions. They are thus binding for all working groups involved in the German Environment Agency in the fulfilment of this reporting task.

Annex 5.1.2.1.10.2 System for quality control and quality assurance

In addition to the general minimum requirements, approved by the coordinating committee for the National System of Emissions Inventories, pertaining to quality control and quality assurance (QC/QA) in reporting on greenhouse-gas emissions, the specific provisions of in-house directive (Hausanordnung) No. 11/2005 also apply at the German Environment Agency. Pursuant to that directive, the procedure defined in the QSE manual is binding for all German Environment Agency personnel involved in emissions reporting (Rules of procedure of the German Environment Agency (Geschäftsordnung des Umweltbundesamtes), Volume II, Numeral XV).

The in-house directive fully implements the requirements of Chapter 8 of the IPCC *Good Practice Guidance*. Suitable specific instruments have been established by the German Environment Agency to ensure effective identification and the execution of measures for continual inventory improvement (improvement plan and inventory plan; cf. Annex 5.1.2.1.10.5). This resulted in the development of the Quality System for Emissions Inventories (QSE) that implemented the points mentioned in Annex 5.1.2.1.2.

Annex 5.1.2.1.10.3 Agency responsible for coordinating QC/QA activities in the German Environment Agency

Pursuant to in-house directive No. 11/2005, section FG V 1.6, "*Emissions Situation*" is the "Single National Entity" (SNE) within the German Environment Agency. In the German Environment Agency's organisational diagram, the SNE is thus included in the German Environment Agency's group of "focal points" and liaison offices for international organisations. In addition, this assignment of responsibility was confirmed by the relevant ministries through a state secretaries' resolution of 5 June 2007.

The roles and responsibilities of the Single National Entity and the specialised departments participating in emissions reporting are described in Chapter 3.2, "Roles and responsibilities" of the QSE manual. The Single National Entity is responsible for updating and managing the QSE manual and its appendices and annexes with the involvement of the contact persons designated by the specialist departments. The version of the QSE manual and the applicable documents published on the Single National Entity's intranet site is binding.

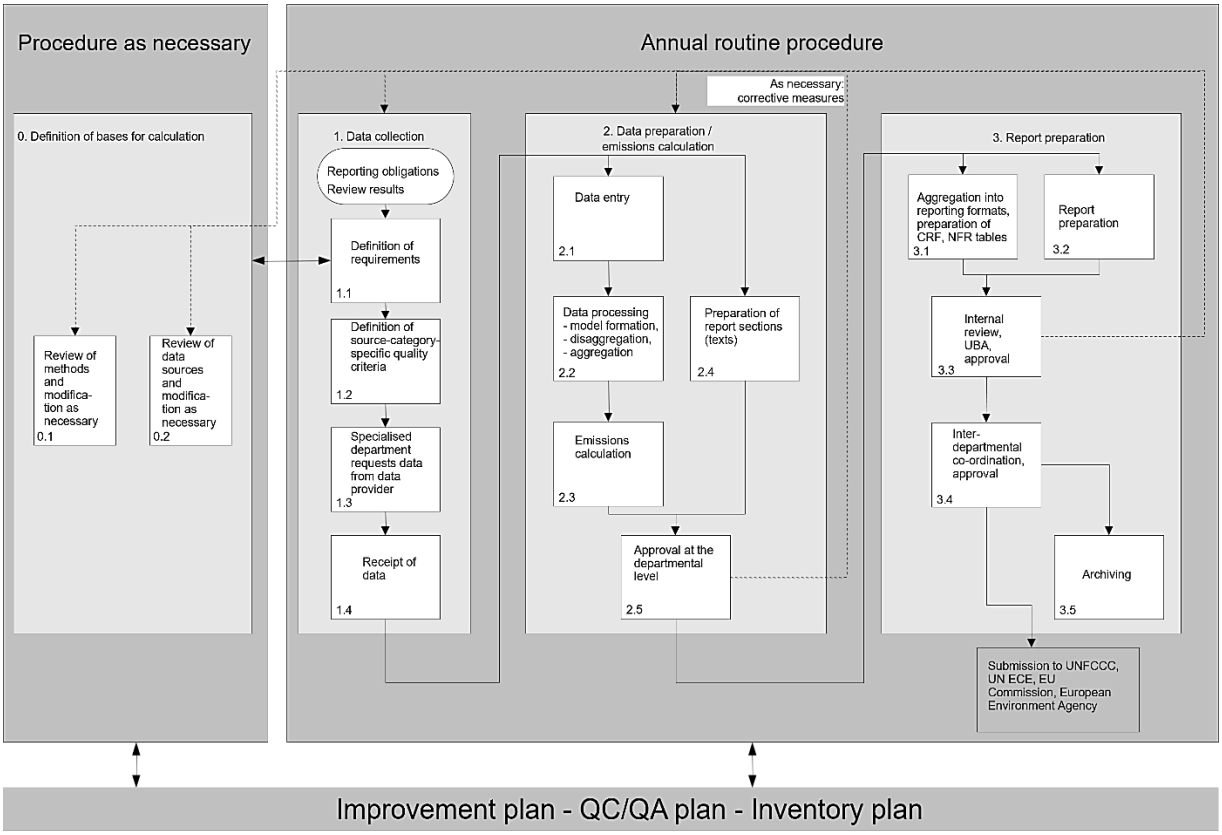
Annex 5.1.2.1.10.4 Reporting procedures

In many cases, complex activities comprise numerous different, but related and cumulative, activities (processes) that lead to the production of a single product. For successful management of these processes, it is important to be aware of these existing or future processes and to describe them in a logical, realistic manner (activities, dependencies, responsibilities, competences, etc.) and to link them together.

In practice, workflows of complex processes cannot be integrated into the hierarchical, traditional structures of companies and institutions without inconsistencies. The required processes are often diametrically opposed to these structures, since they cross different organisational units. Organising related work processes around product creation requires moving away from rigid hierarchical structures and redefining work processes with the aim of improvement.

Emissions reporting was therefore initially described as a process involving several interrelated activities that ultimately result in a product (NIR and inventories) (cf. Figure 121). Additional information is provided in the QSE manual, Chapter 4.3.

Figure 121: Overview of the overall emissions-reporting process



Source: own illustration, German Environment Agency

The activities carried out within the main and sub-processes shown were assigned appropriate responsibilities via a role concept, which implements/executes these processes. For example, many employees work in different work units and source groups, but essentially perform the same activities there. This led to the development of a certain group of persons (with a specific role – for example, responsible experts). This person must be subordinate to another group of people (role) who ensure that the requirements that the first group must observe and fulfil in their work have also been met (for example, specialised contact persons). In addition, a QSE coordinator was appointed, in accordance with the relevant requirements of the IPCC (cf. Annex 5.1.2.1.2), to ensure that the system is further developed.

Overall, a comprehensive role concept was developed that addresses the many different requirements applying to the German Environment Agency in its task as Single National Entity. The roles involved include the following:

1. **Responsible expert at the operational level (FV)**
   a. Main responsibilities: data collection, data entry, calculations with prescribed methods, execution of QC measures, preparation of the NIR text
2. **Quality control manager (QKV)**
   a. Is the superior of the FV
   b. Main responsibilities: checking and approving data and report sections
3. **Specialised contact person (FAP)**
   a. Member of the Single National Entity's staff
   b. Main responsibilities: providing category-specific support for involved experts (inventory work and report preparation) and quality control/quality assurance in the relevant categories in the NIR and CSE.

4. **Report coordinator (NIRK)**
   a. Member of the Single National Entity's staff
   b. Main responsibilities: coordination of textual contributions, creation of the NIR from individual submissions, comprehensive quality control and quality assurance for the NIR
5. **ZSE coordinator (ZSEK)**
   a. Member of the Single National Entity's staff
   b. Main responsibilities: maintenance of databases, emissions calculation and aggregation, overarching QC and QA for data entry and inventory calculation
6. **QSE coordinator (QSEK)**
   a. Member of the Single National Entity's staff
   b. Main responsibilities: maintenance and refinement of the QSE (system, checklists, improvement plan, inventory plan, QC/QA plan and QSE manual)
7. **NaSE coordinator (NaSEK)**
   a. Member of the Single National Entity's staff
   b. on-time reporting in line with requirements, involvement of national institutions, establishment/documentation of legal agreements

As a rule, each of the above-described roles will have tasks in several different main and sub-processes of emissions reporting.

Annex 5.1.2.1.10.5 QC plan, QA plan and inventory plan

To ensure that all potential improvements identified during the course of inventory work are systematically implemented, it is essential to first compile them in a coordinated manner. All information necessary for systematic further use (origin of the potential improvement, category, responsibility, priority, etc.) must be provided for the identified areas for improvement. Planning and arrangements for implementing identified potential improvements (required actions/corrective measures, deadlines, etc.) should then be made on the basis of this information.

In the interest of proper management and documentation under the NaSE and the QSE (cf. Figure 122), procedures have been defined for processing identified potential improvements for their systematic management and further use. The overall aim is to answer the central question of WHO should do WHAT, HOW, WHEN and WHY:

WHO?: Specifies the reference to the role concept: a certain person xy is responsible – for example, in the role of responsible expert (FV)

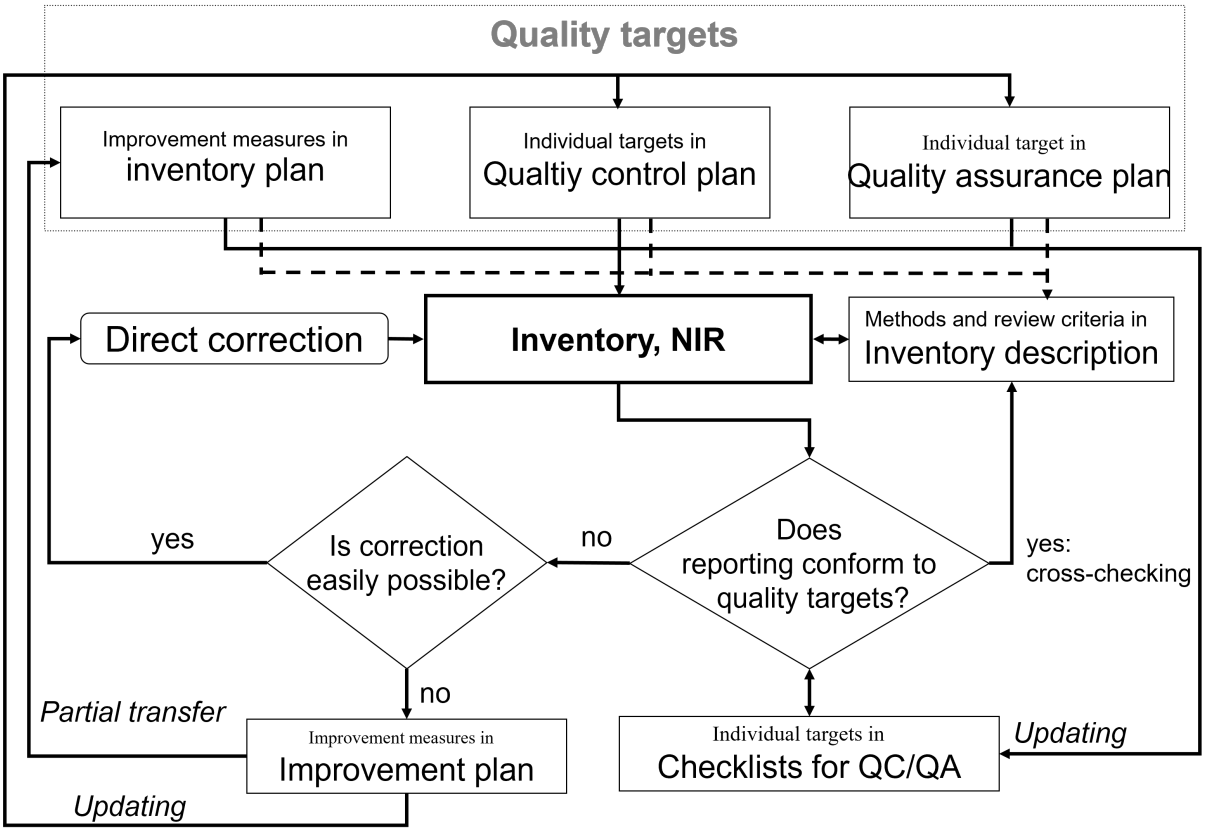
WHAT?: Specifies the reference to the object that is to be improved – for example, the CO_2 calculation in category xy needs to be improved

HOW? Specifies the reference to the aim that is to be achieved – for example, a certain improvement, pursuant to the inventory plan or checklist.

WHEN?: Specifies the reference to the time by which the improvement must be completed pursuant to the inventory plan

WHY?: Specifies the reference to the origin of the necessary action – for example, based on a recommendation from the UNFCCC review process

Figure 122: Management and documentation under the NaSE and the QSE



Source: own illustration, German Environment Agency

The quality objectives were taken from the general quality objectives of the *IPCC Good Practice Guidance* (transparency, consistency, accuracy, comparability, completeness). In addition, individual operational objectives for quality control and quality assurance were derived for each category by comparing the requirements of the *IPCC Good Practice Guidance*, the results of independent inventory reviews (UNFCCC and EU) and the actual inventory.

An improvement plan compiles all areas for improvement and any complaints arising from the results of the independent inventory checks and records them along with possible corrective measures. The Single National Entity categorises and prioritises the corrective measures and then, in consultation with the relevant responsible experts, integrates them as necessary in the inventory plan. There, they are linked to deadlines and responsibilities. As an annex to the NIR, the inventory plan undergoes a coordination and approval process at the German Environment Agency and in the coordinating committee. It is thus a binding set of specifications for improvements to be carried out in future.

In the interest of transparent, effective control and execution of inventory improvement measures, such measures, in accordance with the *IPCC Good Practice Guidance* (Chapter 8.5) are defined role-specifically, as well as category-specifically as necessary, in the quality control plan/quality assurance plan (QC/QA plan). The QC plan refers exclusively to the quality control objectives for the inventory. In the QA plan, quality assurance objectives may be focused on the inventory, the reporting process or the QSE itself. Furthermore, the quality assurance plan includes scheduling of quality assurance measures to be performed by external third parties.

The checklists for quality control and quality assurance list all individual objectives in the emissions reporting process, in accordance with the quality control and quality assurance plans.

The checklists are made available to all parties responsible for quality control and quality assurance and are intended to make it easier to monitor progress towards individual objectives. The checklists are used to document execution of measures for quality control and quality assurance. Where individual objectives are not achieved and direct correction is not possible, an entry must be made in the improvement plan (see above).

Annex 5.1.2.1.10.6 Procedures for general and category-specific quality control

Based on the requirements of the IPCC Good Practice Guidance, the German Environment Agency has developed a checklist concept that formulates the quality requirements as specific objectives. Every effort should be made to achieve these objectives. Progress towards the objectives is entered and documented in the checklists. The possible entries include “yes” (objective was achieved), “not relevant” (objective as formulated does not correspond to the specific situation for the category in question; this answer is rarely possible as an answer) and “no” (it was not possible to achieve the objective).

Each checklist includes a general section that reflects all Tier 1 QC requirements from IPCC Good Practice Guidance and is carried out for each report. In addition, each checklist contains a category-specific section (Tier 2) that provides concrete objectives for the area of key categories.

Checklists are provided only for the first five roles within the role concept. Where different roles are responsible for different main and sub-processes of emissions reporting (cf. Annex 5.1.2.1.10.4), checklists also refer primarily to several different main and sub-processes of emissions reporting. They thus represent a cross-section of emissions reporting. The checklists of the responsible experts (FV) and the specialised contact persons (FAP) include a basic common set of objectives. Since the specialised contact persons are responsible for reviewing the work of the responsible experts, this can best be ensured if both are required to pursue the same objectives.

Annex 5.1.2.1.10.7 Quality assurance procedures

The role concept itself ensures that procedures are designed in such a way that quality assurance is always supported by the dual control principle as a minimum. The specialised contact persons are tasked with ensuring that quality of the emissions calculations and textual contributions of the responsible experts.

In the section on “Expert Peer Review”, the IPCC makes it clear that the (above-described) formal procedure selected by the German Environment Agency can complement, but not replace, expert peer review (Good Practice Guidance; Chapter 8.8). To meet the justified need to involve external experts while taking into account the available resources, detailed reviews are carried out by external third parties as part of research projects and expert reports for specific issues. In general, the two sides involved (i.e. responsible expert and specialised contact person) jointly manage the process of commissioning third parties. In addition, a workshop on the National System was established, which is held on an irregular basis. For these workshops, national experts are invited to come to the German Environment Agency for discussion with German Environment Agency experts (responsible experts) on current inventory issues related to selected categories.

No audits have been carried out in the German Environment Agency to date, and none are planned at present. According to the Good Practice Guidance, audits are not absolutely required.

Annex 5.1.2.1.10.8 Documentation and archiving

Standardised documentation and archiving procedures are to be used in preparation of German greenhouse gas inventories. At the same time, it is important to differentiate between the central

documentation and archiving carried out by the Single National Entity and the non-central documentation and archiving carried out by the specialised departments of the German Environment Agency and other institutions.

The documentation procedures for data and contextual information vary according to requirements and overlap in some areas, with some redundancy and some information varying in the level of detail provided. Consistency must be ensured for both on a regular basis.

To ensure that all of the German Environment Agency's working units use basically consistent procedures, the specifications applying to the instruments used in such procedures – including both general specifications and specifications developed especially for emissions reporting – must be complied with. For the purposes of documentation, the German Environment Agency has access to the instruments described in Table 476. The specified documentation requirements must be met in each case. Where no special specifications apply, the provisions from the "General minimum requirements for quality control and quality assurance in reporting on greenhouse gas emissions" ("Allgemeine Mindestanforderungen an die Qualitätskontrolle und Qualitätssicherung bei der Treibhausgasemissionsberichterstattung") apply.

Table 476: Documentation instruments at the German Environment Agency

Instrument	**Requirements**
Publicly available	
National inventory (CRF tables, CRF Reporter)	Annex 2, QSE manual: instructions for carrying out recalculations in the CRF tables
National Inventory Report	Annex 3, QSE manual: specifications for preparing report sections in the context of the National System
Publication	Rules of procedure of the German Environment Agency: Point 6.2 Publications
Published manuals, guides	For IT descriptions: procedural model of the German Environment Agency; otherwise: no special specifications
Centralised and internally available at the Single National Entity	
CSE database	Annex 5, QSE manual: specifications for data documentation within the CSE
Inventory description	Annex 4, QSE manual: requirements for documentation (record-keeping) and archiving
Decentralised, and internally available	
Records of the central registry	Rules of procedure of the German Environment Agency: Point 4.2.10 Handling of files
Reference files	No special specifications
Internal manuals, guides	For IT descriptions: procedural model of the German Environment Agency; otherwise: no special specifications

An integrated documentation concept defines what key content should be stored in the aforementioned documentation instruments. It also defines how a suitable referencing system is to be used to ensure consistency and transparency across all such instruments (cf. Annex 4, QSE manual).

Annex 5.1.2.1.11 Annex 2: Example of a general checklist for the role of responsible expert

The example presented below (last revision: CHKL 2010) includes only the relevant requirements. Detailed information has been removed in the interest of clarity.

Table 477: General checklist for responsible experts

Process No.	Sub-process description	Individual objective	Optional objective
Main process: 0. Definition of bases for calculation			
0.1	Review of methods and modification as necessary	The calculation method is in conformance with current key category analysis.	
0.1	Review of methods and modification as necessary	The calculation method was selected according to the IPCC Good Practice Guidance decision tree and is consistent with it.	Deviations from the decision tree in the IPCC Good Practice Guidance are explained and transparently documented.
0.1	Review of methods and modification as necessary	The calculation method was selected taking into account the requirements from the inventory plan.	Deviations from the inventory plan are explained and transparently documented.
0.1	Review of methods and modification as necessary	The selected calculation method can be applied to the entire time series as of 1990 or is already being consistently applied.	In the event of a change in methodology in the time series, recalculation pursuant to the QSE manual (Annex 2) and the creation of transparent documentation are ensured.
0.1	Review of methods and modification as necessary	Deviations from the objectives required in 0.1.01-0.1.04 are explained and transparently documented.	
0.2	Review of data sources and modification as necessary	Have new data sources been used?	
0.2	Review of data sources and modification as necessary	The data source(s) is/are/will be available in the long term (for example, on the basis of legal provisions, long-term agreements [> 3 years], etc.).	
0.2	Review of data sources and modification as necessary	One/several complete time series as of 1990 are available in the data source(s).	Gaps in the data available for time series as of 1990 are explained and transparently documented.
0.2	Review of data sources and modification as necessary	One/several complete time series as of 1990 are available in the data source(s).	A suitable process (interpolation/extrapolation) was chosen for dealing with data gaps in conformance with the IPCC Good Practice Guidance (Chap. 7.3.2.2), and the process is transparently documented. Note: Continued use of the same value is not extrapolation!
0.2	Review of data sources and modification as necessary	One/several complete time series as of 1990 are available in the data source(s).	After data gaps are closed, a time series recalculation was carried out as necessary pursuant to QSE manual (Annex 2) and is transparently documented in the NIR and CRF.

Process No.	Sub-process description	Individual objective	Optional objective
0.2	Review of data sources and modification as necessary	The data source(s) completely cover(s) the category.	The incomplete coverage is addressed in an extrapolation and has been taken into account in the uncertainties calculation. All steps are transparently documented.
0.2	Review of data sources and modification as necessary	Uncertainties information (amount and distribution) is available for the data source(s).	
0.2	Review of data sources and modification as necessary	EF and AR are consistent in their source group allocation.	In the case of discrepancies between the EF and AD, other data sources can establish agreement between the two values. Alternatively, the lack of consistency is taken into account in an extrapolation and in the uncertainties calculation, and the entire process is transparently documented.
0.2	Review of data sources and modification as necessary	The procedures for calculating output data are transparently described.	
0.2	Review of data sources and modification as necessary	The data source(s) has/have been selected taking into account the requirements from the inventory plan.	Any discrepancies are explained and transparently documented.
0.2	Review of data sources and modification as necessary	The assumptions and criteria that were used to select the respective data source(s) are transparently documented.	
0.2	Review of data sources and modification as necessary	The data provider has carried out routine quality checks of the data source(s). For individual projects, one-time quality checks have been carried out. These checks are transparently documented.	
0.2	Review of data sources and modification as necessary	When using one/more new data source(s), a recalculation pursuant to the QSE manual (Annex 2) has been carried out on the basis of this/these other data source(s).	
0.2	Review of data sources and modification as necessary	When using IPCC default EFs, how the EFs have been reviewed in relation to national circumstances and are applicable to Germany. The result of this review is transparently documented.	For IPCC default values that do not align with national circumstances, the deviations have been taken into account and documented in the uncertainties.
0.2	Review of data sources and modification as necessary	When EFs other than the IPCC default EF are used, this is explained and transparently documented. Note: Other EFs may only be used if they enable country-specific emissions to be calculated more accurately.	
0.2	Review of data sources and modification as necessary	The AD used have been compared with other data sources (for example, EU-ETS, IEA, EPER, etc.), and the result is transparently documented.	

Process No.	Sub-process description	Individual objective	Optional objective
Main process: 1. Data collection			
1.1	Definition of requirements	The data requirements take into account the information from the inventory plan and the inventory reviews (for example, S&A Report, Centralised Review).	
1.3	The relevant specialised department requests the data from the data supplier(s)	The requirements for QC and data formats have been communicated to the data suppliers and/or contractors, and this communication is documented. Note: Where data suppliers are involved through NaSE agreements, this objective has been achieved.	The data supplier (for example, an association) carries out its own routine quality checks and the results are documented.
1.4	Receipt of data	The data supplier or contractor has carried out and documented the required quality checks.	The data supplier (for example, an association) carries out its own routine quality checks and the results are documented.
1.4	Receipt of data	The received data are complete without any gaps.	All data gaps in the time series as of 1990 have been closed in accordance with the IPCC Good Practice Guidance by extrapolation/interpolation (Section 7.3.2.2) and are transparently documented and explained. Note: Continued use of the same value is not extrapolation
1.4	Receipt of data	The data received are consistent with the previous year's data, and they are clearly described.	Any marked discrepancies with the previous year's data are transparently explained and documented.
1.4	Receipt of data	The data received is of the same order of magnitude as other data sources (such as ETS data, IEA, EPER, etc.). The result of the review is documented.	The reasons for any discrepancies are transparently explained and documented.
1.4	Receipt of data	The methods/assumptions on which the uncertainties were determined are transparently documented.	If it was not possible to derive any assumptions, an expert estimate has been carried out as an alternative and the expert's qualifications are transparently documented.
1.4	Receipt of data	The uncertainty calculations are complete and plausible.	
Main process: 2. Data preparation/emissions calculation			
2.1	Data entry (preferably into the CSE)	All of the EFs have been entered into the CSE.	
2.1	Data entry (preferably into the CSE)	The documentation for the EF data source(s) is complete and conforms to the requirements of the QSE manual (Annexes 3, 4 and 5).	
2.1	Data entry (preferably into the CSE)	Development of the EFs within the time series is plausible and, in the event of anomalies (e.g. changes in order of magnitude), is transparently explained and documented.	Implausible EFs have been corrected.

Process No.	Sub-process description	Individual objective	Optional objective
2.1	Data entry (preferably into the CSE)	All of the AD have been entered into the CSE.	
2.1	Data entry (preferably into the CSE)	The documentation for the AR data source(s) is complete and conforms to the requirements of the QSE manual (Annexes 3, 4 and 5).	
2.1	Data entry (preferably into the CSE)	Development of the AD within the time series is plausible and, in the event of anomalies (e.g. changes in order of magnitude), is transparently explained and documented.	Implausible discrepancies have been corrected.
2.1	Data entry (preferably into the CSE)	After the data is entered into the CSE, the accuracy of the figures, units and conversion factors is checked and confirmed.	
2.1	Data entry (preferably into the CSE)	All of the uncertainties have been entered into the CSE and documented in line with the requirements of the QSE manual (Annexes 3, 4 and 5).	
2.2	Data preparation (model formation, disaggregation, aggregation)	The inventory description includes an adequate description of the models with regard to organisation, structure, calculation procedures, assumptions, etc.	
2.3	Emissions calculation	The current inventory calculations have been checked against calculations from previous reports.	In the event of significant changes or noticeable deviations from the expected trend, the calculation and input data were reviewed and any remaining discrepancies are transparently explained and documented.
2.3	Emissions calculation	The results of emissions calculation for current/previous reports have been checked against other data sources for Germany, especially ETS data, and found to be comparable. The result is transparently documented.	If no comparison is possible or no comparison has been made, this has been clearly and transparently explained.
2.3	Emissions calculation	The national Implied EF (cf. S&A Report I) from the previous report is comparable with the Implied EFs of other countries (same order of magnitude).	Extreme Implied EFs are clearly and transparently explained and documented in the NIR or reference made to an existing explanation.
2.4	Preparation of report sections (texts)	The category has been completely and transparently described for the NIR in accordance with the required six subchapters for the NIR (“Category description”, “Methodological issues”, etc.).	
2.5	Approval by the relevant experts	The values of AD, EF and ED and their uncertainties are up to date in the NIR and congruent with the values in the CSE.	
2.5	Approval by the relevant experts	Documentation of the origins of the AD, EF and ED data and their uncertainties in the NIR are up to date and congruent with the values in the CSE.	Missing or incomplete documentation of the data origin is clearly explained and transparently documented.

Annex 5.1.3 The database system for emissions – Central System of Emissions

Since 1998, the German Environment Agency has maintained and managed an IT tool for inventory preparation: the Central System of Emissions (CSE), an integrated national database. The CSE implements the diverse requirements for emissions calculation and reporting and automates key work steps. It supports inventory planning and reporting (for example, by carrying out emissions calculations and recalculations and relevant error analysis); inventory management (for example, by archiving and annual data evaluation); and quality management at the data level (cf. UBA 2003a, Projekthandbuch Decor (Decor project handbook)). The CSE makes it possible to fulfil the key requirements for transparency, consistency, completeness, comparability and accuracy at the data level.

Data documentation plays a central role in the CSE. The CSE stores information such as who is responsible for handling specific tasks; data sources and calculation procedures; and uncertainties in time-series values. The time and originator of changes are also documented. The system has a history management function that archives deleted values and can restore them if necessary. This makes it possible to trace back and reconstruct data, and it enables third parties to carry out independent reviews. The system also provides mechanisms that support quality assurance at the data level (e.g. components for recording uncertainties and checking plausibility). Transparency is ensured primarily by the fact that data is collected in the same structure in which it is available, and because all data is processed in and transferred to a report format in the CSE itself and are therefore traceable. To this end, the CSE manages detailed technology-specific activity data and emission factors, which are aggregated using calculation rules (calculation methods) to produce category-specific values for the reporting formats. Aggregation of individual CSE time series for the CRF report lines, for example, is described in Annex 3 and Chapters 3 – in each case for the individual categories. In addition to aggregation and model formation for calculations, the CSE also supports scenario and forecast calculations and the reference approach.

The Central Emissions System also organises data exchange within the national system, i.e. within the UBA and with third parties. In addition to direct entry, aggregated values are imported from existing databases using a standard interface (e.g. TREMOD for traffic data or GAS-EM for agricultural data). Ideally, inventory data should be entered into the CSE directly by the relevant responsible experts or imported, by the CSE administrator using the import interface. This applies to in-house employees of the German Environment Agency as well as to external parties involved in the National System.

Annex 5.1.4 Verification of the German Greenhouse Gas Inventory

Annex 5.1.4.1 Introduction

Four independent set of data were used. They were selected amongst the criteria given in the 2019 refinements of the IPCC guidelines for verification (IPCC, 2019). Here the IPCC lists several data sources that may serve as independent verification datasets. The most prominent dataset amongst the options listed under 6.10.1 of the 2019 refinements are the Emission Database for Global Atmospheric Research (EDGAR) of the JRC (Crippa et al., 2025). We chose this dataset for verification as it is widely used amongst the atmospheric research community and is for example used in the compilation of the Copernicus Atmospheric Monitoring Service data products for methane (Seegers et al., 2020) and CO_2 (Chevallier, 2020). EDGAR is also compiled by data sources (EC, 2025) that are listed in the IPCC refinements under 6.10.1, therefore, EDGAR represents a prime synergetic dataset that has to be included in any verification work.

Another important source of data that is explicitly mentioned is data from inverse modelling, discussed in the IPCC refinements in chapter 6.10.2. Under 6.10.2.5 CAMS data is explicitly mentioned as a potential source of verification data. Therefore, the CAMS global inversion data from the Copernicus Atmospheric Datastore is used for verification, which is available for N_2O (Thompson, 2021), CO_2 (Chevallier, 2020) and CH_4 (Seegers et al., 2020).

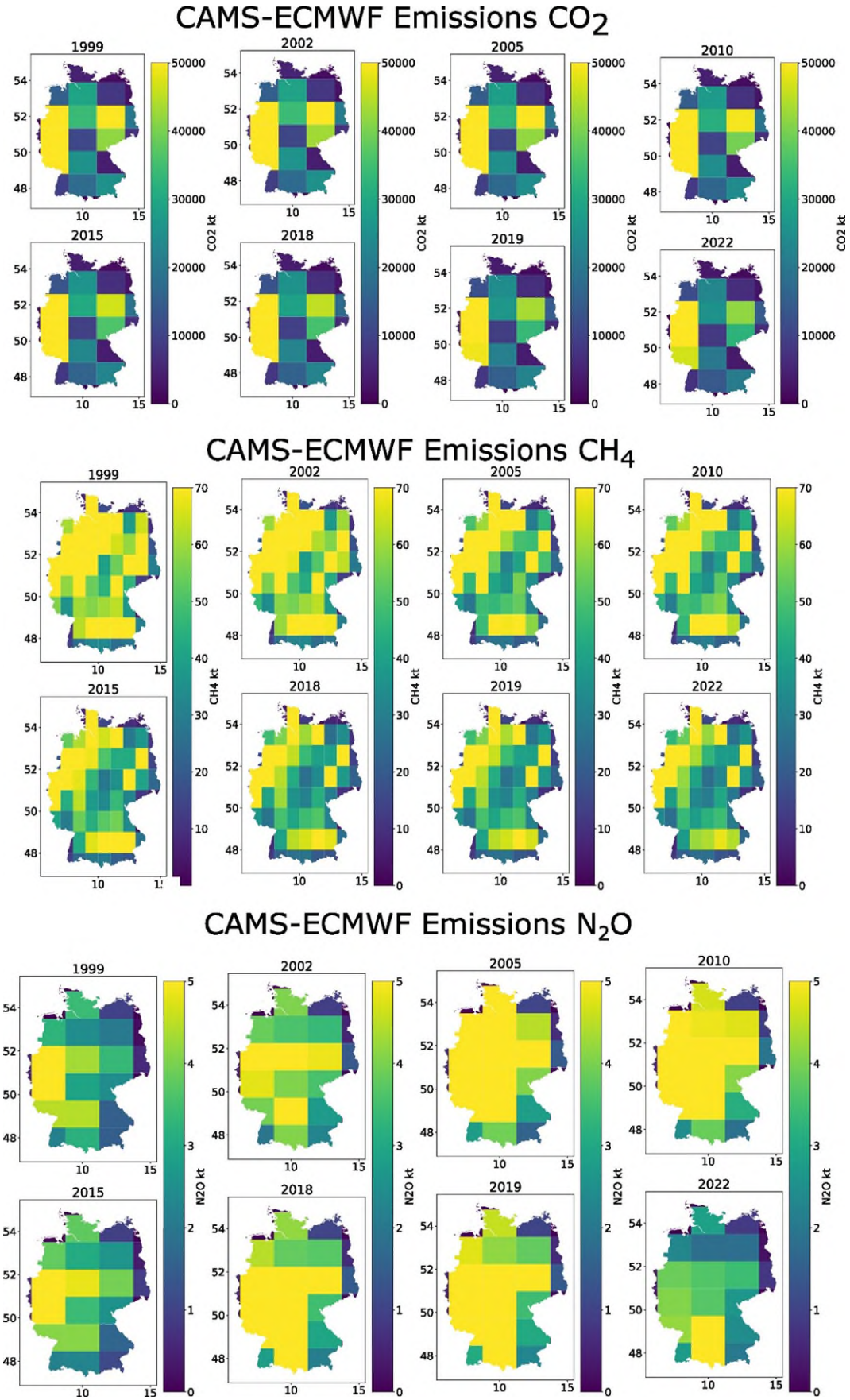
The last two independent sources of data that will be used for verification are not explicitly listed by the IPCC 2019 refinements (IPCC, 2019). These are the database of the Pollution Release and Transfer Register (PRTR) (Umweltbundesamt, 2025) and the data from the European Emission Trade System (ETS), provided by the European Environment Agency (EEA, 2025). Details of the German PRTR data as well as the database may be found under: https://thru.de/thrude/. Details with respect to the ETS data may be found in the European topic center report compiled by (Graichen, Cludius and Gores, 2019). These four diverse and independent datasets are ideal for a verification of the German inventory according to the IPCC Refinements of 2019 (Romano et al., 2019). Data for all of the three major Green House Gases (GHG) N_2O, CH_4 and CO_2 for all the sectors (including LULUCF/AFOLU) were compared with the four datasets in order to verify the temporal trends in diagrams and by standard mathematical similarity operators such as the Pearson and Spearman-Rank correlations, which are widely used to compute similarity between two mathematical vectors.

The main aim of this chapter is to offer qualitative and semi-quantitative comparisons of the national totals for the three major GHGs methane, nitrous-oxide and CO_2 to independent sources of GHG data. The specific focus is set on the verification of temporal trends in the yearly national totals of the three above named GHGs in kt of CO_2 equivalent. Direct sectoral comparisons has not been considered as the verification data exhibit very different levels of disaggregation (from none, as in case of the CAMS data product, up until very detailed, as in case of EDGAR).

Methods and Materials

The four sets of data each require their own analysis tools that have been developed for this verification work. Whilst the EDGAR database is available for modelling activities in yearly gridded format, it is also available as tabulated document presenting only the national totals. The PRTR database, in the form of an sql-database file offers all the national reported data on large point sources, whilst the CAMS data is available in monthly slices in netcdf-Format. The ETS data is available as a csv file for download hosted at the EEA.

Figure 123: Time slice emission data for Germany from the CAMS data store



Source: own illustration, German Environment Agency

Annex 5.1.4.1.1 The EDGAR Inventory

The EDGAR Inventory Data and its methodology for previous versions of the EDGAR GHG Database has been described in detail in (Crippa et al., 2025). An update of this report is currently in preparation. EDGAR strives to support all countries of the world with emission inventory data. In the process EDGAR is compiled in a consistent, homogeneous and transparent manner (Crippa et al., 2025). This is of high benefit for e.g. all developing countries, who do not yet have consistent inventory data. In addition, the gridded emission data of EDGAR is highly appreciated in the inverse modelling community, who rely on globally consistent gridded emission data for their model runs. Calculation of the CAMS CO2 and CH4 inversion optimised data product require the usage of EDGAR data as stated in (Seegers et al., 2020) and (Chevallier, 2020). The yearly national total data from the tabulated EDGAR files (Crippa et al., 2025) will be used in the following for the here presented verification work for CO_2, N2O and CH4.

Annex 5.1.4.1.2 The CAMS Global Inversion-Optimised Greenhouse Gas Data

The CAMS global inversion optimized GHG data is a compilation of data, which are produced by three different processing chains. The CH_4 production chain is described in (Seegers et al., 2020). Data processing for the compilation of the N_2O data is detailed in (Thompson, 2021), whilst (Chevallier, 2020), describes the data for the CO_2 product. Figure 123 shows the data from the three processing chains, clipped to the extent of Germany. The spatial resolution of the data differs from 2.5° longitude x 1.27° latitude (Thompson, 2021) to 1° longitude x 1° latitude for the methane data product (Seegers et al., 2020). For the verification of the data three different inversion runs can be selected from the application programming interface of CAMS. These are based either on no additional input (time series from 1990 till 2023), surface air samples (time series 1979-2023), spaceborne data (time series from 2015 onwards), or a combination of surface air samples (time series 1979-2023) and surface data (time series from 1990 to 2023). The longest time series option (surface air sample) was chosen, for the data comparison work presented here to enable the longest trend comparison possible for CO_2, whilst the 1990-2023 data was used for methane. Please note that the CAMS time series data for N_2O only starts from 1996 onwards whilst the comparisons for CO_2 use the full timespan from 1990 till 2023 and 1990-2022 CH_4.

The Pollution Release and Transfer Register (The PRTR) database is offered as an SQL-Database file at the domain thru.de by the Umweltbundesamt in Germany. It is comprised of reported data for large emission sources in Germany. The PRTR reporting is based on the European Union Regulation No 166/2006 on the establishment of a PRTR register. To access the PRTR database and extract annual data for the three GHGs a modified Python script was used, which is based on the PRTR reporting tool (Hausmann et al., 2021). Figure 124 shows the data of the PRTR point sources reported in the PRTR database file to illustrate points of high point-source emission activity. Currently the database offers PRTR data from 2007 till 2023.

Annex 5.1.4.2 The European Emission Trade Data

The ETS database is hosted by the EEA (EEA/EuTL, 2025), which also provides a webtool for the display, download and analysis of the data. The data lists the different sectors, which are part of the ETS system, with their respective CO_2 emission equivalents. More details on the database and an in-depth analysis can be found in (Graichen et al., 2019).

Annex 5.1.4.2.1 Analysis

The analysis of the data requires an overlapping time period with the GHG totals of Germanys national inventory from previous reporting years (2023) CRF tables. Therefore, the time period

from 1990-2022/23 was considered as the timeframe for the comparisons considering the temporal coverage of the three comparison data sets. The available data was, where applicable (the CAMS and the PRTR data), plotted for a visual comparison shown in Figure 123 and Figure 124 to visually identify potential spatial patterns and to highlight the spatial density or sparsity of the data in question. The Pearson and the Spearman-Rank correlation were computed for the individual temporal verification datasets to the national inventory data in the overlapping time periods visible in Figure 125. These two mathematical similarity measures were computed, in order to quantify the similarity between the temporal trends visible in Figure 125, for trend verification purposes. The results are shown in Table 472.

The EDGAR Inventory

EDGAR data was extracted from the national totals spread-sheets, offered as download from the JRC (EC, 2025). The national totals for Germany were converted to kt CO_2 equivalent for a better comparison of the data to the national inventory, in case of the comparison to the EU-ETS data, AR5 GWP were used in this case. For an individual Comparison of the gases CO_2, N_2O and CH_4 were compared separately in their own individual mass fractions. Figure 125 shows the EDGAR data in orange, whilst the national inventory data is plotted as thick blue line.

Annex 5.1.4.2.2 The CAMS Global Inversion-Optimised Greenhouse Gas Data

The CAMS inversion optimized GHG data was aggregated to the spatial scale of Germany using a spatial vector data file symbolizing the country area of Germany (Patterson & Kelso, 2022), which was intersected with the CAMS data, enabling the cropping of the data pixels. Then the equal earth projection (Šavrič et al., 2019) was used to calculate the area of each cell in-order to convert the CAMS flux data to mass per pixel and month. These were then summed up for all twelve months of the respective year to yield the total for the respective gas and year. The data is shown as green line in Figure 125.

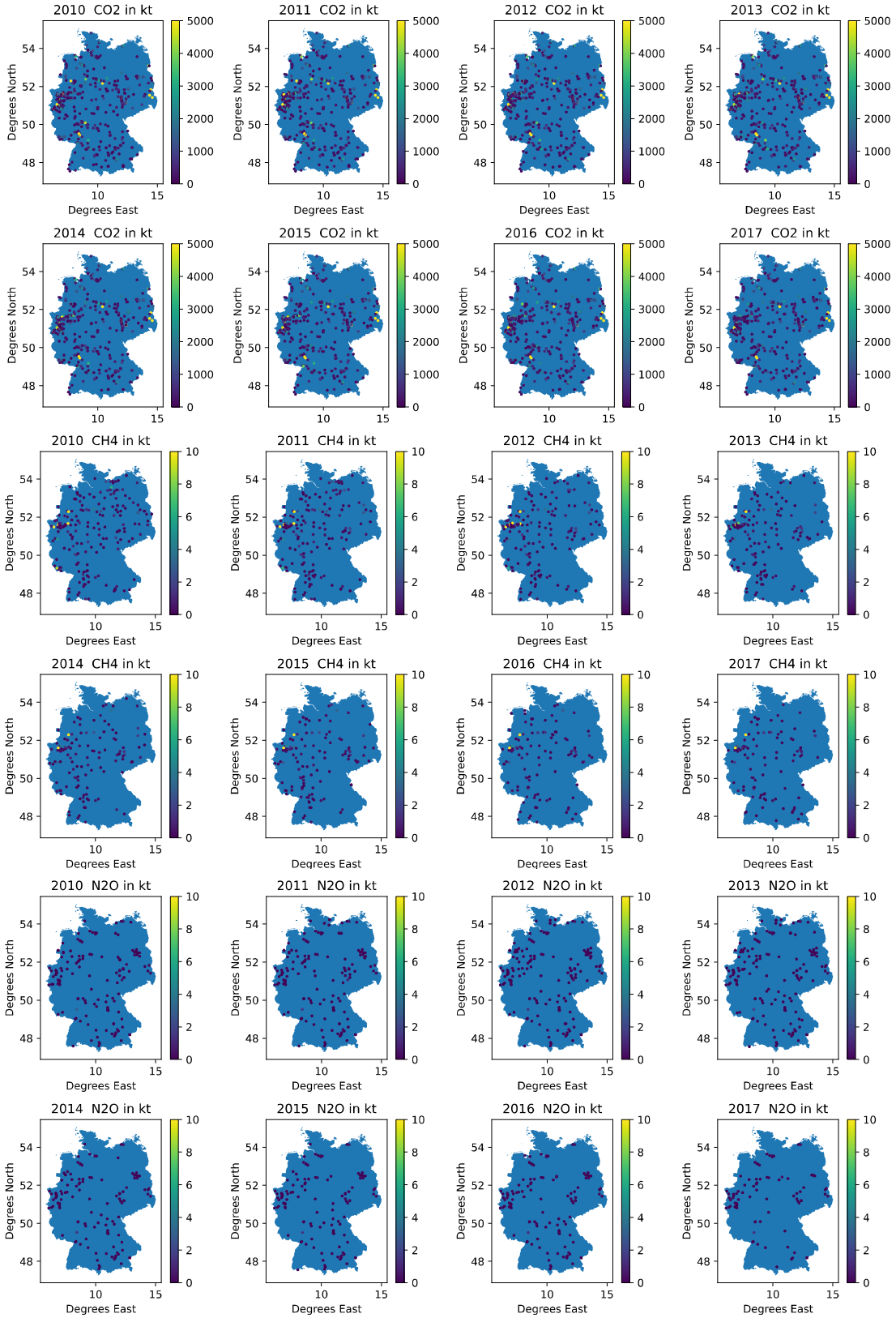
Annex 5.1.4.2.3 The Pollution Release and Transfer Register

The PRTR database was queried for data reported from large point-sources. These data contain the longitude and latitude coordinates of each point source, which offers the possibility of spatially displaying the data, as shown in Figure 124 for visualisation. The yearly sums, plotted as red line in Figure 125, were directly extracted from the database file.

Annex 5.1.4.2.4 The European Emission Trade System

The data of the ETS system, hosted by the EEA (EEA, 2025), are filtered for the total verified Emissions of all sectors and plotted against the sum of N_2O and CO_2 of all the other datasets as shown in the leftmost bottom diagram of Figure 125. As data from the ETS system does not cover methane the ETS data is only compared to the sum of the respective gases CO_2 equivalent in Table 472.

Figure 124: Time slice emission data for Germany from the EPRTR database



Source: own illustration, German Environment Agency

Annex 5.1.4.3 Results and Discussion

The trend data in Figure 125 shows very different patterns for each of the three GHGs, which is also visible in Table 472. Overall the EDGAR data shows the highest trend similarity to the national GHG total, with correlation scores above 0.9 with the PRTR data, whilst the CAMS data shows large similarity to the national CH_4 total only in case of CH_4 and CO_2. The biggest disagreement is between the CAMS N_2O trend and the national totals for N_2O with rather small correlation values for the Pearson correlation and the Spearman Rank correlation.

Table 478: Correlation scores for the three datasets to the German inventory totals

CO_2	PRTR	CAMS	EDGAR	ETS
Pearson	0.988	0.994	0.99	NaN
Spearman-Rank	0.986	0.997	0.99	NaN
CH_4	PRTR	CAMS	EDGAR	ETS
Pearson	0.983	0.977	0.992	NaN
Spearman-Rank	0.993	0.985	0.999	NaN
N_2O	PRTR	CAMS	EDGAR	ETS
Pearson	0.941	0.135	0.97	NaN
Spearman-Rank	0.87	-0.064	0.917	NaN
CO_2 and N_2O	PRTR	CAMS	EDGAR	ETS
Pearson	NaN	NaN	NaN	0.91
Spearman-Rank	NaN	NaN	NaN	0.84

Annex 5.1.4.3.1 The EDGAR Inventory

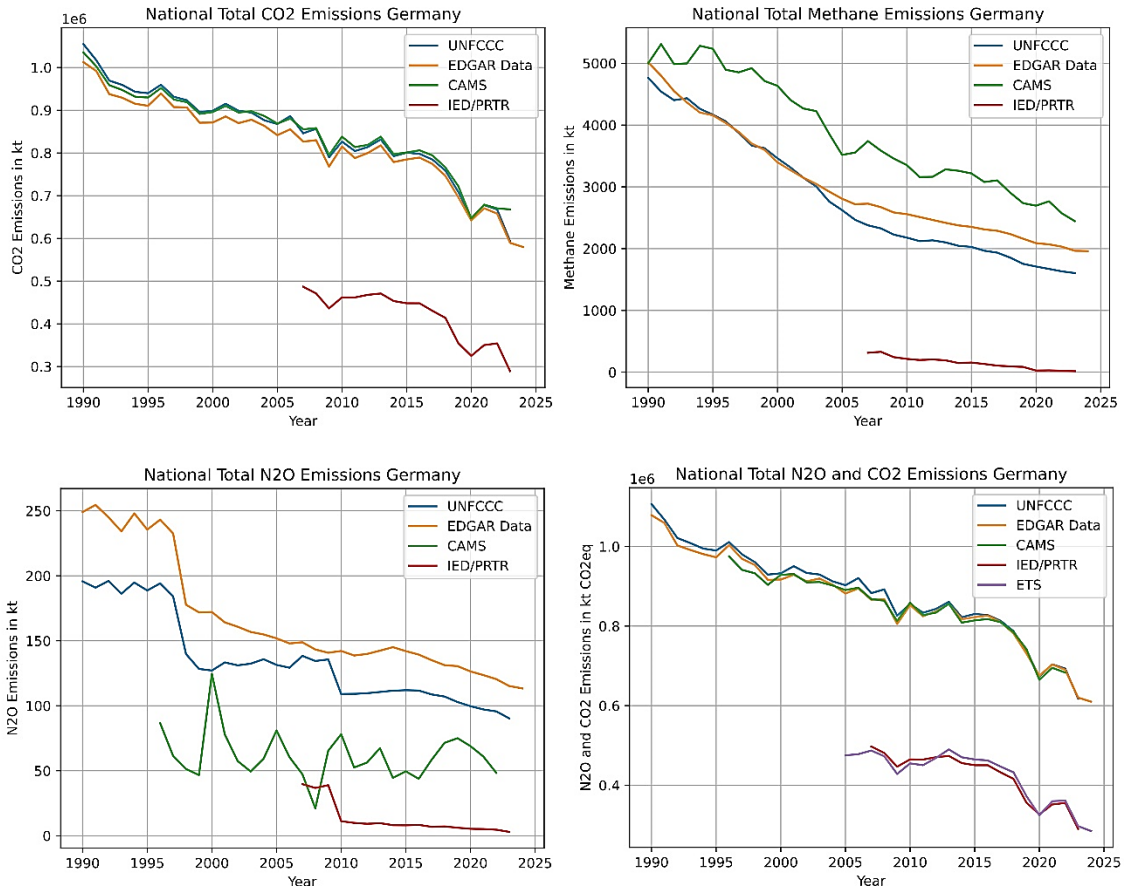
The EDGAR inventory usually is in good agreement with the national inventory data with high correlation values to the national inventory totals, as shown in Table 472 and as visible by the orange line, which is always in close agreement with the reported national totals (blue line) in Figure 125. Overall, the EDGAR data shows slightly higher emission values, which is to be expected if different data sources are used to compile a worldwide consistent emission database. The lower values in the CO_2 data with respect to the 2024 reported CRF might also be caused by methodological differences.

Annex 5.1.4.3.2 The CAMS Global Inversion-Optimised Greenhouse Gas Data

The CAMS inversion optimised datasets shows no correlation for N_2O, with the trends shown in the green curve of Figure 125 not matching the general trend of the inventory data in blue or the EDGAR data in orange. In addition, temporal gradients are starkly amplified in the CAMS N_2O data, if compared to the inventory data. An example is the dip during the financial crisis in Europe around 2008. The trend between the bottom-up inventories and CAMS data is in good agreement for CO_2 and CH_4 as shown in Figure 125, with correlation scores higher than 0.9. Here the bottom-up inventories show an almost exactly the similar trend as the CAMS data, especially in case of the CO_2 CAMS data. This is remarkable considering the coarse spatial resolution of the CAMS data product and the research that is carried out to further refine CO_2 data modelling for inventory verification. Currently there are several big research projects underway to offer a consistent CO_2 monitoring system at a finer spatial and temporal resolution. Good examples are the European projects COCO2 and CORSO, which will offer high quality CO_2 monitoring data over Europe. Methane data from CAMS, as shown in Figure 125, shows a good agreement of the trend

to the inventory data, as also visible by the high correlation scores in Table 472. The green curve in Figure 125 is, however, offset against the methane emission data from the other sources. This trend may only be explained by a closer examination and comparison of different model results, which will likely be offered by global and European research initiatives, such as the World Emission Project, or the current EU projects (Avengers, EYE-Clima and Paris). N_2O data from CAMS show a strong oscillation, if compared to the national inventory and EDGAR data. Therefore, almost no correlation can be seen in Table 472 to the other data sets. A reconciliation between national inventories and this modelling results should be attempted in the aforementioned research projects. Remarkable is the large dip around 2008, which shows a strong contrast in the data if compared to the bottom-up inventories.

Figure 125: Trend plots for CO_2, CH_4 and N_2O emission totals 1990-2021



Source: own illustration, German Environment Agency

Annex 5.1.4.3.3 The Pollution Release and Transfer Register

The PRTR data matches the trends of the reported national GHG gases quite well, as highlighted in Table 472. Here we see quite consistent correlation scores for methane and nitrous oxides. The low correlation values for CO_2 are due to an increase in CO_2 emissions in the PRTR data, compared to the overall decline of CO_2 in the national totals. The strong decline in the nitrous oxides of the national totals is mirrored by the PRTR data, showing the stop of N_2O emissions from large point sources represented by the PRTR database.

Annex 5.1.5 The European Emission Trade System

The data from the ETS verified totals for Germany fits quite well to the overall trends in the inventory data with correlation scores around 0.8/0.9 for the spearman-rank and pearson correlations as shown in Table 472. This shows that the temporal trend of the combined N_2O and CO_2 emissions of Germany's national inventory is in agreement with the external ETS data.

Annex 5.1.6 Past and present verification activities of greenhouse gas emissions in national and international projects

In the following text, all emission data in CO_2 equivalents are still calculated with the greenhouse gas potentials (GWP) of the Fourth IPCC Assessment Report (IPCC AR4).

Annex 5.1.6.1 Introduction

Multidisciplinary scientific projects are usually set up as temporal research initiatives with clearly set goals and tasks for the participating members. They develop tools and data within a project frame of 3 to 4 years and are discontinued after their completion. This places certain constraints on the development and usage of the developed data and tools for inventory agencies:

1. It is necessary to have a fixed set of coordinating personnel within the inventory agencies to use the results and tools for emission reporting.
2. Inventory staff needs to be actively involved in the design and development of these tools and sets of data.
3. The inventory team members should act as a scientific relay between the emission inventory world and e.g. the modelling community and the atmospheric science community in order to express their specific verification needs to improve the emission inventory or identify problematic source categories.

This can be done at the country and specific level with source-specific bottom-up data research projects, which yield emission factors and activity data for very specific single sources. The bigger picture (sector-wide goals, LULUCF/AFOLU or modelling of national totals for stakeholders), however, require the involvement of larger expert groups from various fields of academic research. This was established for the first time in for GHG research in Europe with the VERIFY project (https://verify.lsce.ipsl.fr/). The aim of the verify project was to assemble European inventory agencies such as RVIM (Netherlands), ISPRA and CMCC (Italy), UBA (Germany) and CITEPA (France) to collaborate with academic partners in order to establish a "common language" between inventory agencies and a large consortium of climate research specialists in order to answer to the 2019 IPCC refinements[108] on QA/QC and verification, which suggest just such a collaboration.

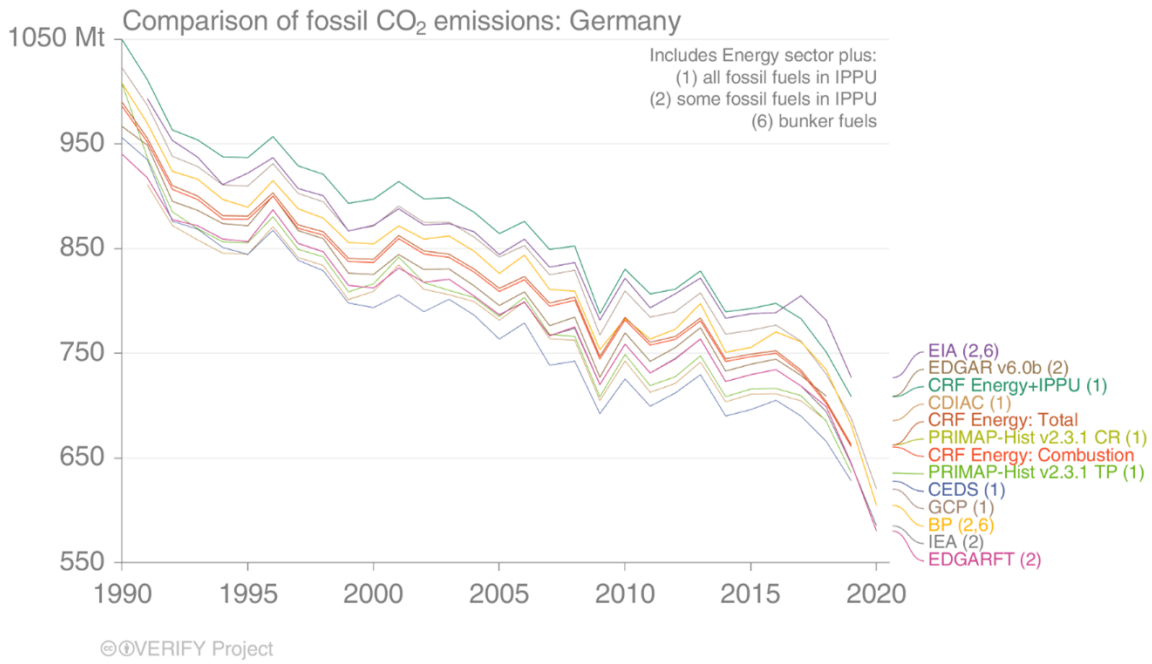
The nature of the project offers only a temporal limited set of data in the form of the report data below, which has been part of the VERIFY project, which has ended. All plots presented below are available from the following VERIFY resource page as fact sheets: http://webportals.ipsl.jussieu.fr/VERIFY/FactSheets/. Detailed reports on the methodology used in the production of the data may be found here: https://verify.lsce.ipsl.fr/index.php/repository/key-reports-verify.

108 Romano, D. et al. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories — IPCC General Guidance and Reporting. https://www.ipcc.ch/report/2019-refinement-to-the-2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/ (2019).

Annex 5.1.6.2 Fossil Fuel CO_2 data

The fossil fuel CO_2 comparison data from the VERIFY project has been published by (Petrescu et al., 2021). Figure V1 shows the UNFCCC fossil fuel data, labelled as CRF encompassing different sectors, compared to other sets of data. An in-depth description of the other individual sets of data may be found in (Petrescu et al., 2021), or in (Minx et al., 2021), which deliver an in-depth analysis of the features of different sets of data. Figure 126 shows that the reported greenhouse gas data is well in the envelope of the other independent bottom-up set of data, which shows that the trend as well as the overall magnitude of the reported emissions totals in Germany are in agreement with these external sets of data. An interesting aspect of these bottom-up inventories is their direct link to the economy, where it is possible to see e.g. the economic crisis in 2008-2009 as well as the Eurozone crisis around 2012. The steep decline in 2020 is also remarkable.

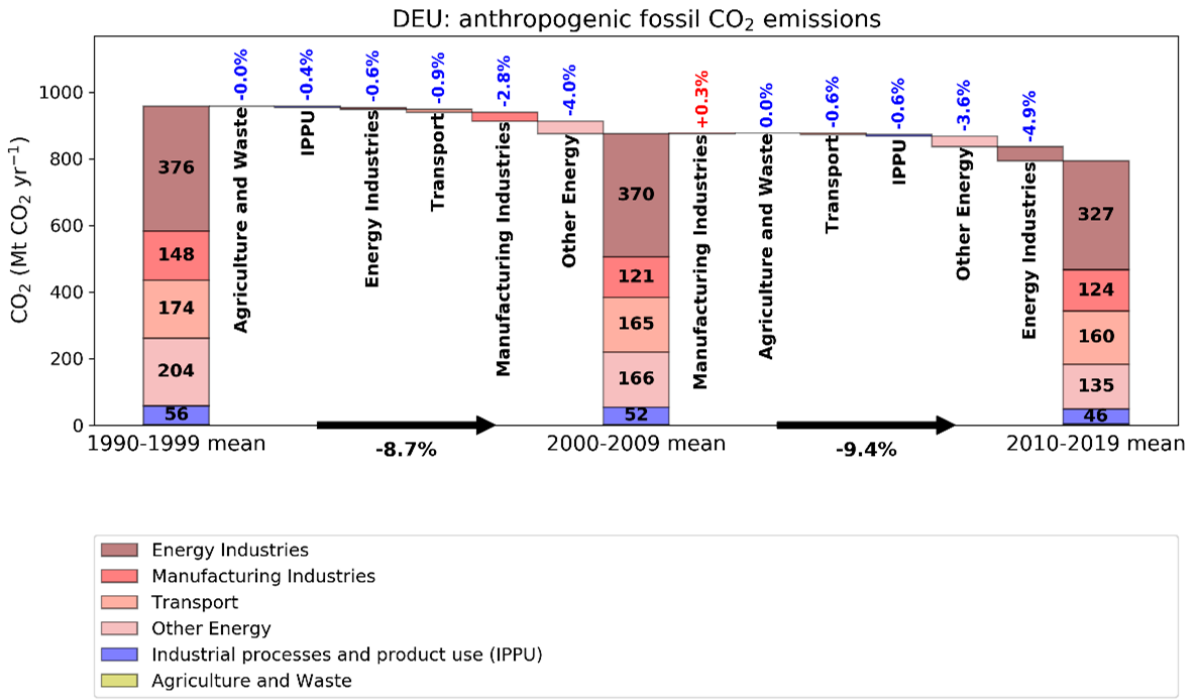
Figure 126: Fossil CO_2 emissions for Germany from bottom-up inventories, CRF depicts the reported emissions to the UNFCCC. The trend as well as the order of magnitude are in good agreement between the different sets of data.



Source: own illustration, German Environment Agency

Figure 127 from (Petrescu et al., 2021). shows the mean of the CO_2 data in the three decades (1990-1999, 2000-2009, 2010-2019) across individual sectors as well as the corresponding trend in each sector. Here we see that the energy related sectors contributed to a large extent to the reduction across the decades, whilst e.g. the transport sector decreased in CO_2 emissions by only a small portion. The large drop in the manufacturing industries may have been caused by closure of large manufacturing plants in the 1990s due to a restructuring of the industry which took part in Germany at that time. The growth in the 2000s in emissions in that sector shows the economic upsurge in this specific sector.

Figure 127: Fossil CO_2 emissions for Germany as mean over the three respective decades. Energy related emissions in Germany have dropped quite significantly between the decades, whilst transport related emissions decreased slower.

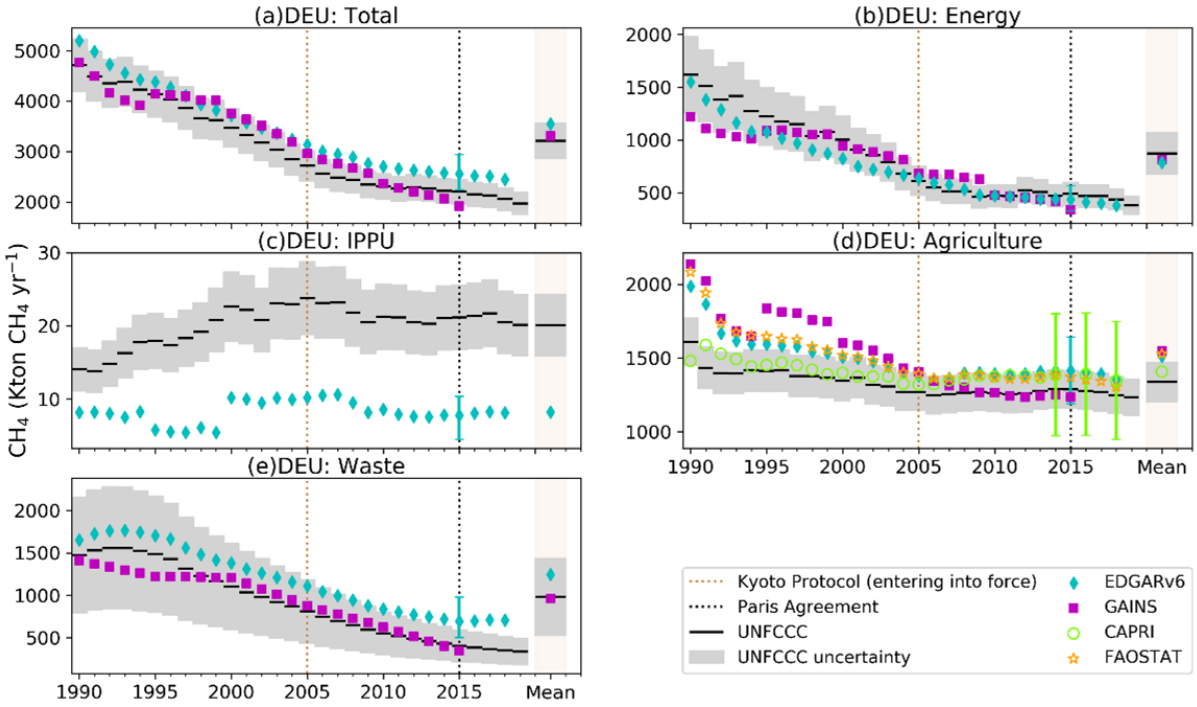


Source: own illustration, German Environment Agency

Annex 5.1.6.3 Methane

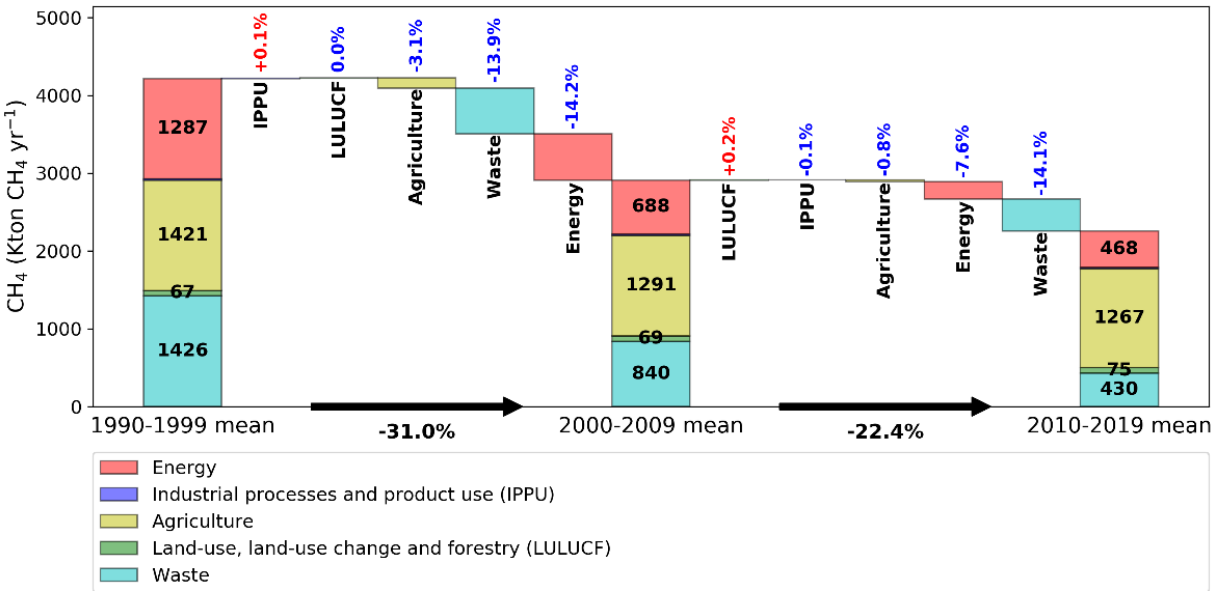
The data presented here is part of VERIFYs methane data which has also been published by (Petrescu et al., 2021). Figure 128 shows anthropogenic methane in different sectors, compared to different bottom-up datasets. We see that the CH_4 total is in good agreement with the other bottom-up set of data, together with the energy, waste and agricultural sectors. Only the IPPU sector deviates slightly, which may be caused by methodological differences in the EDGAR data. Figure 129 shows the mean CH_4 emissions over the three decades (1990-1999, 2000-2009, 2010-2019) across individual sectors as well as the corresponding trend in each sector. We see that the energy and the waste sector have contributed substantially to the methane emission reductions, whilst agricultural emissions decreased only slowly. Figure 130 shows methane data from global inversions and from the GOSAT satellite. We see that the error bar for both methods is larger than from the reported UNFCCC emissions. However, both methods verify the trend of the reported UNFCCC data and envelope the reported UNFCCC methane data. Data from VERIFY for countries with lesser days of cloud cover, e.g. in southern Europe, show even better results for the top-down methane data, with smaller error bars, due to the higher availability of data from spaceborne sensors (Petrescu et al., 2021).

Figure 128: Anthropogenic CH_4 data for the reported UNFCCC data as well as selected bottom-up datasets



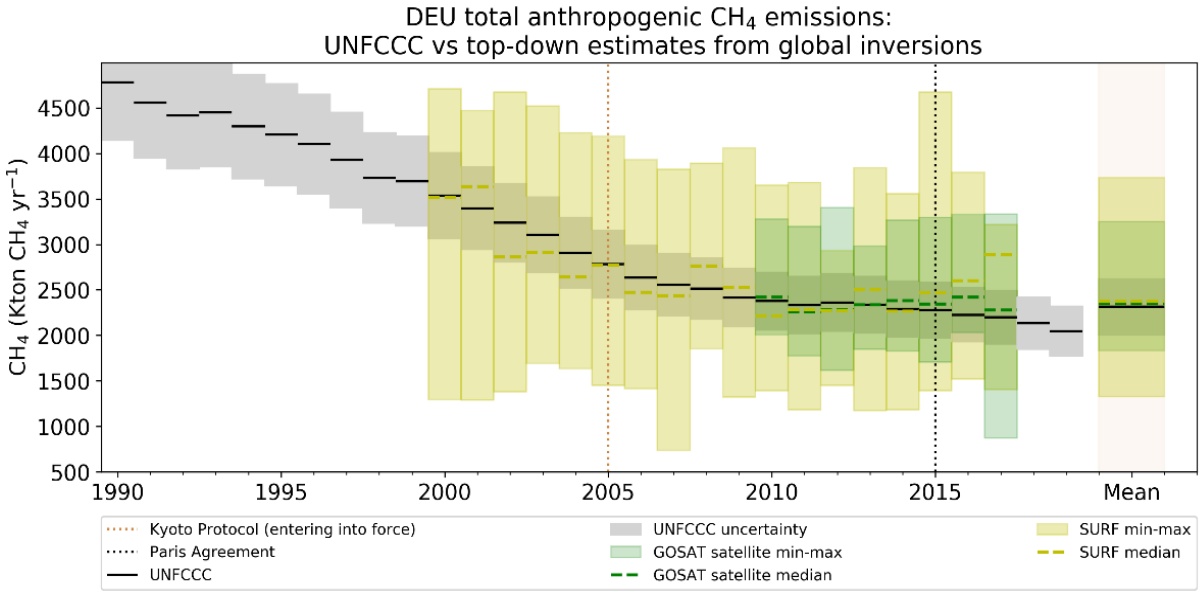
Source: own illustration, German Environment Agency

Figure 129: Trends in anthropogenic CH_4 data for the reported UNFCCC data over three decades



Source: own illustration, German Environment Agency

Figure 130: Top down anthropogenic CH_4 emissions from the GOSAT satellite as well as from global inversions

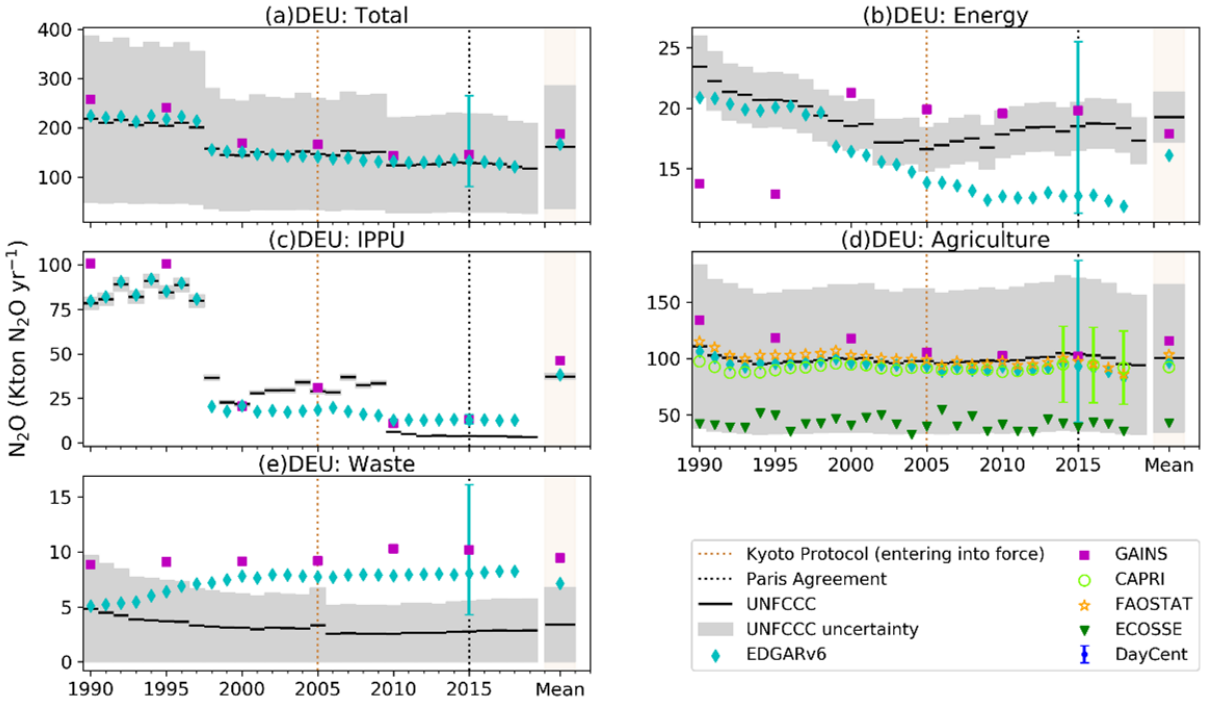


Source: own illustration, German Environment Agency

Annex 5.1.6.4 N_2O

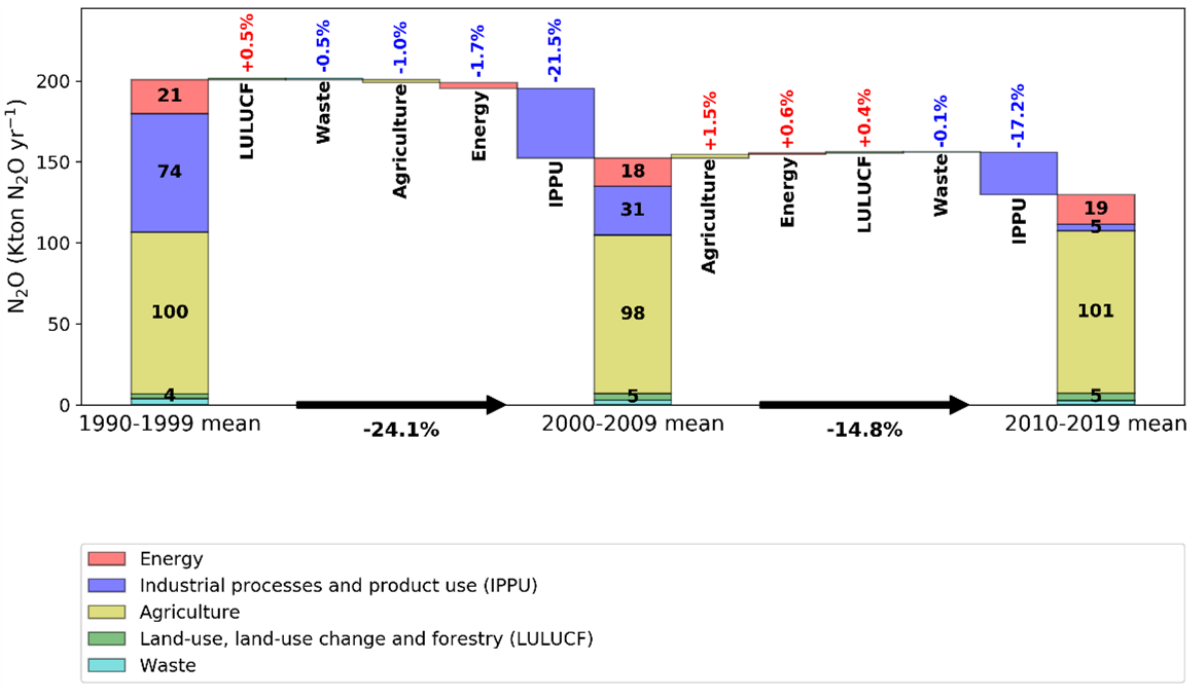
The N_2O data is also described in (Petrescu et al., 2021). Figure 131 shows the N_2O trend in the different sectors compared to the UNFCCC data. The trend as well as the magnitude of the N_2O data in the individual sectors fit quite well, given the large error bars in the different sectors, such as the agricultural and waste sector. The three decadal plot of Figure 132 shows that the largest cuts in emissions have been achieved by the IPPU sector, whilst energy, LULUCF and agriculture have seen a slight increase of N_2O in the last two decades.

Figure 131: Anthropogenic N_2O data for the reported UNFCCC data as well as selected bottom-up datasets



Source: own illustration, German Environment Agency

Figure 132: Trends in N_2O data for the reported UNFCCC data over three decades

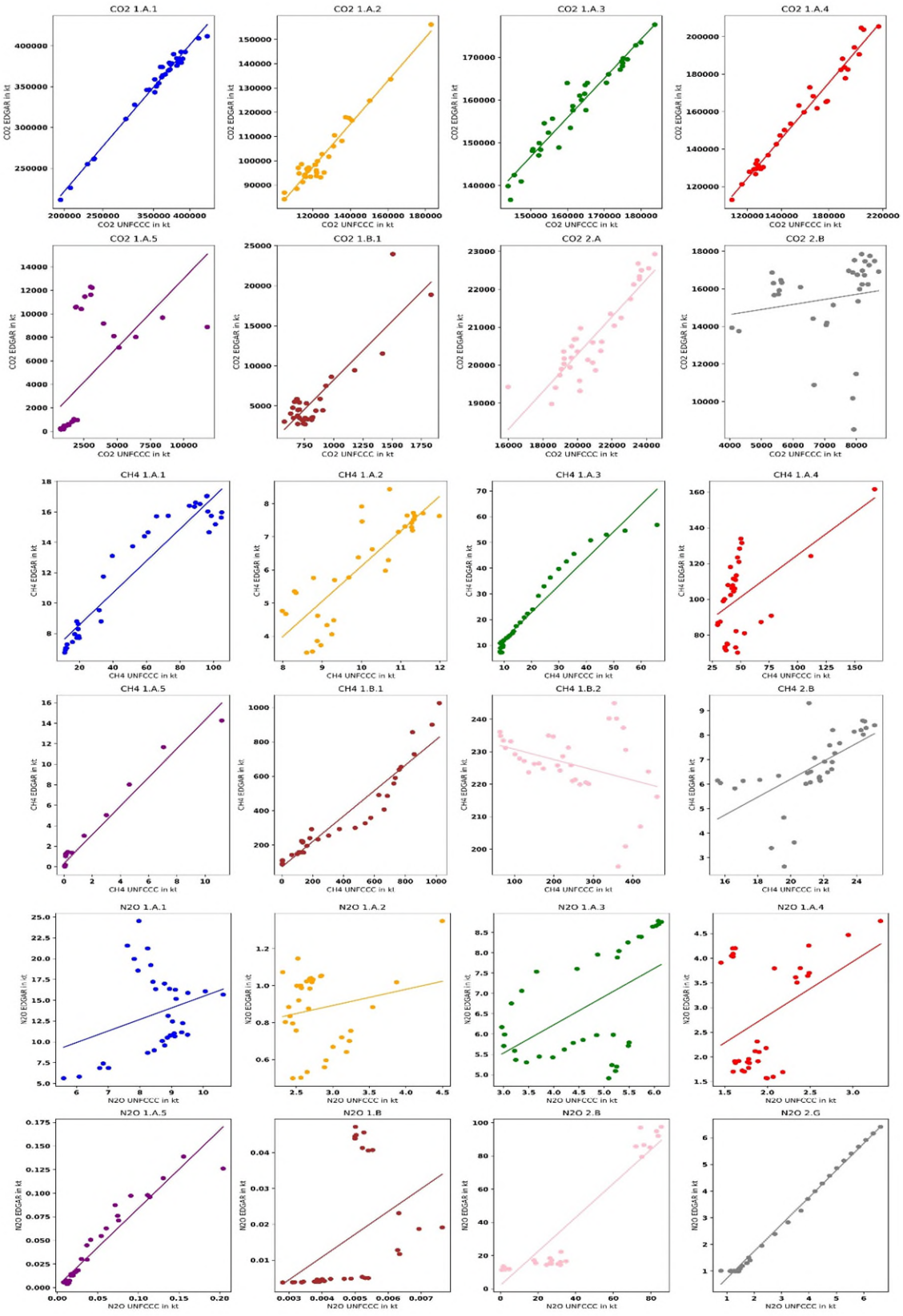


Source: own illustration, German Environment Agency

Annex 5.1.7 Detailed sector time-series analysis

Time series analysis of the Emission Database for Global Atmospheric Research (EDGAR) in greater sector detail is shown in figure 133. EDGAR is one of the key sets of data which has been recommended by the IPCC 2019 refinements on QA/QC & verification for GHG reporting by (IPCC, 2019). The data by (Crippa et al., 2022) of version 8 may be retrieved from the EDGAR project page: https://edgar.jrc.ec.europa.eu/report_2023#intro. It is available as separate excel or ".csv" files from the JRC. All sector data for the three gases shown in Figure 133 illustrate that the trend between the EDGAR 8.0 data and the inventory data is very similar, as shown by the other, more, coarser sectoral VERIFY analysis above. The major emitting sectors are also in the same order of magnitude in the EDGAR 8.0 and the UNFCCC data. This shows that there is a high correlation between the two sets of data for all the three major greenhouse gases. Smaller deviations between the two sets of data may be due to country specific differences in the reporting (higher tier reporting in the national UNFCCC data due to an improved level of dis-aggregation and more complex models vs. more generic approaches) in case of EDGAR. The differences in the national sectoral data and the sectoral EDGAR data are more apparent in Table 474. For CO_2 sectors 1.A.5, 2.B and 2.D significantly lower correlation values can be observed between the two data sets. This shows that that the Edgar data deviates significantly in the industry sectors 2B and 2D, due to different methodologies. Even higher deviations can be observed for methane in the sectors 1.A.4 and 1.B.2. The largest deviations may be found for N2O in the sectors 1.A.2, 1.A.4 and 1.B.

Figure 133: Sector comparison of reported trend data with EDGAR 8.0 data for Germany for the three major greenhouse gases (CO_2, CH_4 and N_2O) the line represents a least squares linear fit of the data



Source: own illustration, German Environment Agency

Table 479: Sectoral correlation scores between Edgar 8.0 and Germanys 2023 sectoral CRF data

CO_2		
Sector	**Pearson**	**Spearman**
1.A.1	0.992	0.9642
1.A.2	0.9723	0.799
1.A.3	0.9686	0.973
1.A.4	0.9864	0.977
1.A.5	0.587	0.889
1.B.1	0.881	0.361
2.A	0.895	0.836
2.B	0.159	0.512
2.C	0.797	0.714
2.D	0.677	0.41
CH_4		
Sector	**Pearson**	**Spearman**
1.A.1	0.951	0.893
1.A.2	0.8541	0.818
1.A.3	0.968	0.961
1.A.4	0.549	0.476
1.A.5	0.982	0.867
1.B.1	0.953	0.987
1.B.2	-0.356	-0.373
2.B	0.616	0.814
2.C	0.802	0.717
N_2O		
sector	**Pearson**	**Spearman**
1.A.1	0.304	0.15
1.A.2	0.19	-0.02
1.A.3	0.542	0.531
1.A.4	0.4144	0.086
1.A.5	0.958	0.942
1.B	0.424	0.802
2.B	0.9414	0.899
2.G	0.9974	0.91

Annex 5.2 Additional information about greenhouse gas trends

Here we provide the detailed tables on the trend discussion presented in Chapters ES.2 and 2.

Table 480: Development of emissions in Germany, by greenhouse gas, in kilotonnes of CO_2 equivalents [kt CO_2-eq.]

GHG emissions/removals	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
CO_2 emissions (without LULUCF)	1,054,796	1,016,930	969,465	959,385	943,227	939,933	959,689	931,507	923,498	895,441	898,974	915,254	898,833	899,538	883,451
Net CO_2 emissions/removals	1,081,618	982,470	946,420	918,884	922,548	926,712	929,776	914,224	899,780	875,424	897,408	882,469	883,287	902,516	887,461
CH_4 (without LULUCF)	133,690	127,417	123,512	124,408	119,596	116,975	113,908	108,703	102,921	101,719	97,140	93,016	88,315	84,315	77,523
CH_4 (with LULUCF)	142,141	135,052	130,615	134,338	127,966	125,095	121,499	116,145	113,339	109,660	105,250	102,506	98,206	90,956	85,794
N_2O (without LULUCF)	52,317	50,155	52,618	49,679	52,541	50,473	51,385	49,133	37,625	34,134	34,177	35,351	36,016	33,663	36,264
N_2O (with LULUCF)	53,539	51,395	53,870	50,834	53,731	51,656	52,598	50,349	38,758	35,327	35,363	36,486	37,133	34,909	37,436
F gases, total	12,325	11,891	12,383	15,010	15,450	16,023	15,218	15,440	15,939	14,244	12,707	13,461	13,494	13,023	13,439
GHG emissions without LULUCF	1,253,128	1,206,392	1,157,977	1,148,483	1,130,814	1,123,404	1,140,200	1,104,783	1,079,983	1,045,538	1,042,998	1,057,082	1,036,658	1,030,539	1,010,676
GHG emissions/removals, with LULUCF	1,289,623	1,180,808	1,143,288	1,119,066	1,119,695	1,119,487	1,119,090	1,096,157	1,067,817	1,034,655	1,050,728	1,034,922	1,032,120	1,041,403	1,024,130
GHG emissions/removals	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
CO_2 emissions (without LULUCF)	866,910	884,925	845,672	851,006	789,245	829,787	805,771	814,787	834,504	794,688	798,771	800,432	788,561	758,195	709,773
Net CO_2 emissions/removals	869,065	895,737	857,007	840,172	783,503	831,511	806,763	803,705	829,932	799,293	796,508	803,345	792,053	808,986	742,430
CH_4 (without LULUCF)	73,593	69,191	66,651	65,239	62,376	60,995	59,397	59,734	58,788	57,265	56,674	54,945	54,089	51,836	49,006
CH_4 (with LULUCF)	81,554	76,353	76,039	72,712	69,783	69,454	67,724	67,476	66,711	64,862	64,371	62,333	63,333	58,099	56,367
N_2O (without LULUCF)	34,837	34,349	37,531	35,045	35,633	28,785	28,560	28,295	29,124	29,067	28,544	29,077	29,133	26,573	26,513
N_2O (with LULUCF)	36,012	35,561	38,665	36,251	36,784	29,913	29,690	29,432	30,244	30,242	29,698	30,193	30,173	27,704	27,599
F gases, total	13,608	13,533	13,657	13,636	14,031	13,683	13,888	14,129	14,195	14,213	14,617	14,576	14,497	13,531	12,708
GHG emissions without LULUCF	988,947	1,001,999	963,511	964,925	901,285	933,250	907,615	916,945	936,610	895,232	898,606	899,030	886,280	850,135	798,001
GHG emissions/removals, with LULUCF	1,000,238	1,021,185	985,369	962,771	904,101	944,562	918,064	914,742	941,082	908,609	905,194	910,446	900,056	908,320	839,104
GHG emissions/removals	**2020**	**2021**	**2022**	**2023**	**2024**										
CO_2 emissions (without LULUCF)	646,683	679,946	670,017	591,373	573,925										
Net CO_2 emissions/removals	686,158	715,588	719,867	654,005	622,132										
CH_4 (without LULUCF)	47,775	46,671	45,584	44,931	44,120										
CH_4 (with LULUCF)	54,866	54,966	52,262	54,602	52,660										
N_2O (without LULUCF)	25,349	25,656	24,095	24,240	22,857										
N_2O (with LULUCF)	26,429	26,668	25,166	25,207	23,949										
F gases, total	11,165	10,499	9,571	9,035	8,867										
GHG emissions without LULUCF	730,972	762,773	749,266	669,578	649,770										
GHG emissions/removals, with LULUCF	778,619	807,721	806,865	742,849	707,608										

Table 481: Development of emissions in Germany, by category, in kilotonnes of CO_2 equivalents [kt CO_2-eq.]

GHG emissions/removals, by source and sink categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1. Energy	1,044,283	1,007,351	958,923	949,668	926,927	922,715	943,143	911,252	901,294	876,376	872,684	892,304	875,936	871,724	852,464
2. Industrial processes	93,216	89,549	89,529	90,792	96,316	94,745	92,862	93,448	80,994	73,414	76,592	73,067	71,521	74,145	75,911
3. Agriculture	74,078	66,396	65,835	64,612	65,239	64,880	64,925	64,118	64,261	64,301	64,150	64,143	63,353	60,608	60,812
4. LULUCF	36,495	-25,584	-14,689	-29,417	-11,119	-3,917	-21,109	-8,625	-12,166	-10,883	7,730	-22,160	-4,538	10,864	13,454
CO_2	26,822	-34,459	-23,045	-40,502	-20,679	-13,220	-29,913	-17,283	-23,717	-20,017	-1,566	-32,785	-15,546	2,977	4,010
N_2O & CH_4	9,673	8,875	8,355	11,085	9,560	9,303	8,804	8,658	11,551	9,134	9,296	10,625	11,008	7,886	9,444
5. Waste	41,550	43,096	43,691	43,411	42,332	41,065	39,270	35,964	33,433	31,447	29,572	27,569	25,848	24,062	21,489
GHG emissions/removals, by source and sink categories	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
1. Energy	835,758	851,450	810,157	818,205	763,434	799,058	773,097	785,887	804,967	763,159	768,670	767,800	751,784	722,043	673,699
2. Industrial processes	72,752	73,058	76,226	72,060	64,086	61,850	63,278	60,491	60,399	60,700	59,880	61,452	65,281	62,235	59,062
3. Agriculture	60,606	59,732	60,892	59,821	60,319	60,150	59,930	60,084	61,557	62,310	61,612	61,874	61,689	58,725	58,634
4. LULUCF	11,290	19,186	21,858	-2,155	2,816	11,312	10,449	-2,203	4,471	13,377	6,589	11,416	13,776	58,185	41,103
CO_2	2,155	10,812	11,335	-10,835	-5,742	1,724	992	-11,082	-4,573	4,605	-2,262	2,913	3,492	50,791	32,656
N_2O & CH_4	9,136	8,374	10,523	8,680	8,558	9,588	9,456	8,879	9,044	8,772	8,851	8,503	10,284	7,394	8,447
5. Waste	19,831	17,758	16,237	14,839	13,445	12,192	11,309	10,483	9,688	9,062	8,443	7,904	7,526	7,131	6,606
GHG emissions/removals, by source and sink categories	**2020**	**2021**	**2022**	**2023**	**2024**										
1. Energy	612,720	643,676	637,851	561,904	543,295										
2. Industrial processes	54,933	56,827	51,446	47,022	47,889										
3. Agriculture	57,201	56,360	54,320	55,203	53,308										
4. LULUCF	47,646	44,949	57,599	73,271	57,839										
CO_2	39,475	35,642	49,850	62,632	48,207										
N_2O & CH_4	8,171	9,307	7,749	10,638	9,632										
5. Waste	6,118	5,909	5,650	5,449	5,277										

Table 482: Contributions to emissions trends in Germany, by greenhouse gas and category, in percent [%]

Shares of greenhouse gases*	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
CO_2 emissions*	84.2	84.3	83.7	83.5	83.4	83.7	84.2	84.3	85.5	85.6	86.2	86.6	86.7	87.3	87.4	87.7	88.3	87.8	88.2	87.6
CH_4*	10.7	10.6	10.7	10.8	10.6	10.4	10.0	9.8	9.5	9.7	9.3	8.8	8.5	8.2	7.7	7.4	6.9	6.9	6.8	6.9
N_2O*	4.2	4.2	4.5	4.3	4.6	4.5	4.5	4.4	3.5	3.3	3.3	3.3	3.5	3.3	3.6	3.5	3.4	3.9	3.6	4.0
F gases, total	1.0	1.0	1.1	1.3	1.4	1.4	1.3	1.4	1.5	1.4	1.2	1.3	1.3	1.3	1.3	1.4	1.4	1.4	1.4	1.6
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Shares of greenhouse gases*	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**					
CO_2 emissions*	88.9	88.8	88.9	89.1	88.8	88.9	89.0	89.0	89.2	88.9	88.5	89.1	89.4	88.3	88.3					
CH_4*	6.5	6.5	6.5	6.3	6.4	6.3	6.1	6.1	6.1	6.1	6.5	6.1	6.1	6.7	6.8					
N_2O*	3.1	3.1	3.1	3.1	3.2	3.2	3.2	3.3	3.1	3.3	3.5	3.4	3.2	3.6	3.5					
F gases, total	1.5	1.5	1.5	1.5	1.6	1.6	1.6	1.6	1.6	1.6	1.5	1.4	1.3	1.3	1.4					
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	101					
Shares of categories*	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
1. Energy	83.3	83.5	82.8	82.7	82.0	82.1	82.7	82.5	83.5	83.8	83.7	84.4	84.5	84.6	84.3	84.5	85.0	84.1	84.8	84.7
2. Industrial processes	7.4	7.4	7.7	7.9	8.5	8.4	8.1	8.5	7.5	7.0	7.3	6.9	6.9	7.2	7.5	7.4	7.3	7.9	7.5	7.1
4. Agriculture	5.9	5.5	5.7	5.6	5.8	5.8	5.7	5.8	6.0	6.2	6.2	6.1	6.1	5.9	6.0	6.1	6.0	6.3	6.2	6.7
5. Waste	3.3	3.6	3.8	3.8	3.7	3.7	3.4	3.3	3.1	3.0	2.8	2.6	2.5	2.3	2.1	2.0	1.8	1.7	1.5	1.5
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Shares of categories*	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**					
1. Energy	85.6	85.2	85.7	85.9	85.2	85.5	85.4	84.8	84.9	84.4	83.8	84.4	85.1	83.9	83.6					
2. Industrial processes	6.6	7.0	6.6	6.4	6.8	6.7	6.8	7.4	7.3	7.4	7.5	7.5	6.9	7.0	7.4					
4. Agriculture	6.4	6.6	6.6	6.6	7.0	6.9	6.9	7.0	6.9	7.3	7.8	7.4	7.2	8.2	8.2					
5. Waste	1.3	1.2	1.1	1.0	1.0	0.9	0.9	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8					
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100					

* Not including emissions from Land Use, Land Use Change and Forestry (LULUCF).

Table 483: Emissions of direct and indirect greenhouse gases and SO_2 in Germany since 1990

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
CO_2 emissions (without LULUCF)	1,054,796	1,016,930	969,465	959,385	943,227	939,933	959,689	931,507	923,498	895,441	898,974	915,254	898,833	899,538	883,451
Net CO_2 emissions/removals	1,081,618	982,470	946,420	918,884	922,548	926,712	929,776	914,224	899,780	875,424	897,408	882,469	883,287	902,516	887,461
CH_4 (without LULUCF)	4,775	4,551	4,411	4,443	4,271	4,178	4,068	3,882	3,676	3,633	3,469	3,322	3,154	3,011	2,769
CH_4 (with LULUCF)	5,076	4,823	4,665	4,798	4,570	4,468	4,339	4,148	4,048	3,916	3,759	3,661	3,507	3,248	3,064
N_2O (without LULUCF)	197	189	199	187	198	190	194	185	142	129	129	133	136	127	137
N_2O (with LULUCF)	202	194	203	192	203	195	198	190	146	133	133	138	140	132	141
F gases, total (CO_2 equivalent)	12,325	11,891	12,383	15,010	15,450	16,023	15,218	15,440	15,939	14,244	12,707	13,461	13,494	13,023	13,439
NO_X	2,850	2,622	2,466	2,363	2,233	2,173	2,090	2,014	1,984	1,948	1,871	1,816	1,757	1,714	1,670
SO_2	5,461	3,965	3,237	2,902	2,416	1,743	1,476	1,226	978	798	643	622	559	528	486
NMVOC	3,942	3,419	3,095	2,905	2,493	2,361	2,262	2,202	2,144	1,980	1,813	1,719	1,626	1,548	1,543
CO	13,319	11,048	9,532	8,623	7,590	7,187	6,615	6,368	5,852	5,435	5,096	4,898	4,597	4,256	4,048
	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
CO_2 emissions (without LULUCF)	866,910	884,925	845,672	851,006	789,245	829,787	805,771	814,787	834,504	794,688	798,771	800,432	788,561	758,195	709,773
Net CO_2 emissions/removals	869,065	895,737	857,007	840,172	783,503	831,511	806,763	803,705	829,932	799,293	796,508	803,345	792,053	808,986	742,430
CH_4 (without LULUCF)	2,628	2,471	2,380	2,330	2,228	2,178	2,121	2,133	2,100	2,045	2,024	1,962	1,932	1,851	1,750
CH_4 (with LULUCF)	2,913	2,727	2,716	2,597	2,492	2,481	2,419	2,410	2,383	2,316	2,299	2,226	2,262	2,075	2,013
N_2O (without LULUCF)	131	130	142	132	134	109	108	107	110	110	108	110	110	100	100
N_2O (with LULUCF)	136	134	146	137	139	113	112	111	114	114	112	114	114	105	104
F gases, total (CO_2 equivalent)	13,608	13,533	13,657	13,636	14,031	13,683	13,888	14,129	14,195	14,213	14,617	14,576	14,497	13,531	12,708
NO_X	1,634	1,681	1,593	1,543	1,452	1,468	1,445	1,447	1,448	1,406	1,381	1,343	1,286	1,201	1,115
SO_2	468	470	447	444	389	397	374	371	361	337	341	316	307	294	258
NMVOC	1,497	1,500	1,428	1,366	1,247	1,367	1,273	1,259	1,213	1,174	1,140	1,134	1,137	1,091	1,062
CO	3,825	3,827	3,702	3,661	3,128	3,461	3,333	3,246	3,224	3,058	3,033	2,923	2,938	2,838	2,751
	2020	**2021**	**2022**	**2023**	**2024**										
CO_2 emissions (without LULUCF)	646,683	679,946	670,017	591,373	573,925										
Net CO_2 emissions/removals	686,158	715,588	719,867	654,005	622,132										
CH_4 (without LULUCF)	1,706	1,667	1,628	1,605	1,576										
CH_4 (with LULUCF)	1,960	1,963	1,866	1,950	1,881										
N_2O (without LULUCF)	96	97	91	91	86										
N_2O (with LULUCF)	100	101	95	95	90										
F gases, total (CO_2 equivalent)	11,165	10,499	9,571	9,035	8,867										
NO_X	983	969	928	841	809										
SO_2	239	249	247	210	199										

NMVOC	1,032	1,052	1,044	968	953											
CO	2,428	2,551	2,507	2,340	2,322											

Table 484: Changes in emissions of direct and indirect GHGs and SO_2 in Germany since 1990/1995

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
CO_2 emissions (without LULUCF)		-3.6	-8.1	-9.0	-10.6	-10.9	-9.0	-11.7	-12.4	-15.1	-14.8	-13.2	-14.8	-14.7	-16.2
Net CO_2 emissions/removals		-9.2	-12.5	-15.0	-14.7	-14.3	-14.0	-15.5	-16.8	-19.1	-17.0	-18.4	-18.3	-16.6	-18.0
CH_4 (without LULUCF)		-4.7	-7.6	-6.9	-10.5	-12.5	-14.8	-18.7	-23.0	-23.9	-27.3	-30.4	-33.9	-36.9	-42.0
N_2O (without LULUCF)		-4.1	0.6	-5.0	0.4	-3.5	-1.8	-6.1	-28.1	-34.8	-34.7	-32.4	-31.2	-35.7	-30.7
F gases, total		0.0	0.0	0.0	0.0	0.0	-5.0	-3.6	-0.5	-11.1	-20.7	-16.0	-15.8	-18.7	-16.1
Total emissions, without LULUCF		-3.7	-7.6	-8.4	-9.8	-10.4	-9.0	-11.8	-13.8	-16.6	-16.8	-15.6	-17.3	-17.8	-19.3
Total emissions/removals, with LULUCF		-8.4	-11.3	-13.2	-13.2	-13.2	-13.2	-15.0	-17.2	-19.8	-18.5	-19.8	-20.0	-19.2	-20.6
Total emissions, without LULUCF, with respect to base year*		-4.0	-7.9	-8.6	-10.0	-10.6	-9.3	-12.1	-14.1	-16.8	-17.0	-15.9	-17.5	-18.0	-19.6
NO_X		-8.0	-13.5	-17.1	-21.6	-23.7	-26.7	-29.3	-30.4	-31.6	-34.3	-36.3	-38.3	-39.9	-41.4
SO_2		-27.4	-40.7	-46.9	-55.8	-68.1	-73.0	-77.6	-82.1	-85.4	-88.2	-88.6	-89.8	-90.3	-91.1
NMVOC		-13.3	-21.5	-26.3	-36.8	-40.1	-42.6	-44.1	-45.6	-49.8	-54.0	-56.4	-58.7	-60.7	-60.8
CO		-17.1	-28.4	-35.3	-43.0	-46.0	-50.3	-52.2	-56.1	-59.2	-61.7	-63.2	-65.5	-68.0	-69.6
	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
CO_2 emissions (without LULUCF)	-17.8	-16.1	-19.8	-19.3	-25.2	-21.3	-23.6	-22.8	-20.9	-24.7	-24.3	-24.1	-25.2	-28.1	-32.7
Net CO_2 emissions/removals	-19.7	-17.2	-20.8	-22.3	-27.6	-23.1	-25.4	-25.7	-23.3	-26.1	-26.4	-25.7	-26.8	-25.2	-31.4
CH_4 (without LULUCF)	-45.0	-48.2	-50.1	-51.2	-53.3	-54.4	-55.6	-55.3	-56.0	-57.2	-57.6	-58.9	-59.5	-61.2	-63.3
N_2O (without LULUCF)	-33.4	-34.3	-28.3	-33.0	-31.9	-45.0	-45.4	-45.9	-44.3	-44.4	-45.4	-44.4	-44.3	-49.2	-49.3
F gases, total	-15.1	-15.5	-14.8	-14.9	-12.4	-14.6	-13.3	-11.8	-11.4	-11.3	-8.8	-9.0	-9.5	-15.6	-20.7
Total emissions, without LULUCF	-21.1	-20.0	-23.1	-23.0	-28.1	-25.5	-27.6	-26.8	-25.3	-28.6	-28.3	-28.3	-29.3	-32.2	-36.3
Total emissions/removals, with LULUCF	-22.4	-20.8	-23.6	-25.3	-29.9	-26.8	-28.8	-29.1	-27.0	-29.5	-29.8	-29.4	-30.2	-29.6	-34.9
Total emissions, without LULUCF, with respect to base year*	-21.3	-20.3	-23.3	-23.2	-28.3	-25.7	-27.8	-27.0	-25.5	-28.8	-28.5	-28.5	-29.5	-32.4	-36.5
NO_X	-42.6	-41.0	-44.1	-45.8	-49.0	-48.5	-49.3	-49.2	-49.2	-50.7	-51.5	-52.9	-54.9	-57.8	-60.9
SO_2	-91.4	-91.4	-91.8	-91.9	-92.9	-92.7	-93.1	-93.2	-93.4	-93.8	-93.8	-94.2	-94.4	-94.6	-95.3
NMVOC	-62.0	-62.0	-63.8	-65.3	-68.4	-65.3	-67.7	-68.0	-69.2	-70.2	-71.1	-71.2	-71.2	-72.3	-73.0
CO	-71.3	-71.3	-72.2	-72.5	-76.5	-74.0	-75.0	-75.6	-75.8	-77.0	-77.2	-78.1	-77.9	-78.7	-79.3
	2020	**2021**	**2022**	**2023**	**2024**										
CO_2 emissions (without LULUCF)	-38.7	-35.5	-36.5	-43.9	-45.6										
Net CO_2 emissions/removals	-36.6	-33.8	-33.4	-39.5	-42.5										
CH_4 (without LULUCF)	-64.3	-65.1	-65.9	-66.4	-67.0										
N_2O (without LULUCF)	-51.5	-51.0	-53.9	-53.7	-56.3										
F gases, total	-30.3	-34.5	-40.3	-43.6	-44.7										
Total emissions, without LULUCF	-41.7	-39.1	-40.2	-46.6	-48.1										

Total emissions/removals, with LULUCF	-39.6	-37.4	-37.4	-42.4	-45.1											
Total emissions, without LULUCF, with respect to base year*	-41.8	-39.3	-40.4	-46.7	-48.3											
NO_X	-65.5	-66.0	-67.4	-70.5	-71.6											
SO_2	-95.6	-95.4	-95.5	-96.1	-96.4											
NMVOC	-73.8	-73.3	-73.5	-75.4	-75.8											
CO	-81.8	-80.8	-81.2	-82.4	-82.6											

* The base year for CO_2, CH_4 & N_2O is 1990; the base year for HFC, PFC, SF_6 & NF_3 is 1995

Table 485: Changes in emissions of direct and indirect GHGs and SO_2 in Germany since the respective previous year, in percent [%]

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
CO_2 emissions (without LULUCF)		-3.6	-4.7	-1.0	-1.7	-0.3	2.1	-2.9	-0.9	-3.0	0.4	1.8	-1.8	0.1	-1.8
Net CO_2 emissions/removals		-9.2	-3.7	-2.9	0.4	0.5	0.3	-1.7	-1.6	-2.7	2.5	-1.7	0.1	2.2	-1.7
CH_4 (without LULUCF)		-4.7	-3.1	0.7	-3.9	-2.2	-2.6	-4.6	-5.3	-1.2	-4.5	-4.2	-5.1	-4.5	-8.1
N_2O (without LULUCF)		-4.1	4.9	-5.6	5.8	-3.9	1.8	-4.4	-23.4	-9.3	0.1	3.4	1.9	-6.5	7.7
F gases, total							-5.0	1.5	3.2	-10.6	-10.8	5.9	0.2	-3.5	3.2
Total emissions, without LULUCF		-3.7	-4.0	-0.8	-1.5	-0.7	1.5	-3.1	-2.2	-3.2	-0.2	1.4	-1.9	-0.6	-1.9
Total emissions/removals, with LULUCF		-8.4	-3.2	-2.1	0.1	0.0	0.0	-2.0	-2.6	-3.1	1.6	-1.5	-0.3	0.9	-1.7
NO_X		-8.0	-5.9	-4.2	-5.5	-2.7	-3.9	-3.6	-1.5	-1.8	-4.0	-2.9	-3.2	-2.5	-2.5
SO_2		-27.4	-18.4	-10.3	-16.7	-27.9	-15.3	-17.0	-20.2	-18.4	-19.4	-3.2	-10.1	-5.5	-8.0
NMVOC		-13.3	-9.5	-6.1	-14.2	-5.3	-4.2	-2.7	-2.6	-7.6	-8.5	-5.2	-5.4	-4.8	-0.3
CO		-17.1	-13.7	-9.5	-12.0	-5.3	-8.0	-3.7	-8.1	-7.1	-6.2	-3.9	-6.1	-7.4	-4.9
	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
CO_2 emissions (without LULUCF)	-1.9	2.1	-4.4	0.6	-7.3	5.1	-2.9	1.1	2.4	-4.8	0.5	0.2	-1.5	-3.9	-6.4
Net CO_2 emissions/removals	-2.1	3.1	-4.3	-2.0	-6.7	6.1	-3.0	-0.4	3.3	-3.7	-0.3	0.9	-1.4	2.1	-8.2
CH_4 (without LULUCF)	-5.1	-6.0	-3.7	-2.1	-4.4	-2.2	-2.6	0.6	-1.6	-2.6	-1.0	-3.1	-1.6	-4.2	-5.5
N_2O (without LULUCF)	-3.9	-1.4	9.3	-6.6	1.7	-19.2	-0.8	-0.9	2.9	-0.2	-1.8	1.9	0.2	-8.8	-0.2
F gases, total	1.3	-0.5	0.9	-0.2	2.9	-2.5	1.5	1.7	0.5	0.1	2.8	-0.3	-0.5	-6.7	-6.1
Total emissions, without LULUCF	-2.1	1.3	-3.8	0.1	-6.6	3.5	-2.7	1.0	2.1	-4.4	0.4	0.0	-1.4	-4.1	-6.1
Total emissions/removals, with LULUCF	-2.3	2.1	-3.5	-2.3	-6.1	4.5	-2.8	-0.4	2.9	-3.5	-0.4	0.6	-1.1	0.9	-7.6
NO_X	-2.2	+2.8	-5.2	-3.1	-5.9	+1.1	-1.6	+0.1	+0.1	-2.9	-1.8	-2.7	-4.3	-6.6	-7.2
SO_2	-3.8	0.4	-4.9	-0.7	-12.3	2.1	-5.8	-0.8	-2.7	-6.8	1.2	-7.2	-2.8	-4.5	-12.2
NMVOC	-3.0	0.2	-4.8	-4.4	-8.7	9.5	-6.9	-1.1	-3.7	-3.2	-2.9	-0.5	0.3	-4.1	-2.6
CO	-5.5	+0.1	-3.3	-1.1	-14.6	+10.6	-3.7	-2.6	-0.7	-5.1	-0.8	-3.6	+0.5	-3.4	-3.0
	2020	**2021**	**2022**	**2023**	**2024**										
CO_2 emissions (without LULUCF)	-8.9	5.1	-1.5	-11.7	-3.0										
Net CO_2 emissions/removals	-7.6	4.3	0.6	-9.1	-4.9										
CH_4 (without LULUCF)	-2.5	-2.3	-2.3	-1.4	-1.8										
N_2O (without LULUCF)	-4.4	1.2	-6.1	0.6	-5.7										

F gases, total	-12.1	-6.0	-8.8	-5.6	-1.9
Total emissions, without LULUCF	-8.4	4.4	-1.8	-10.6	-3.0
Total emissions/removals, with LULUCF	-7.2	3.7	-0.1	-7.9	-4.7
NO_X	-11.8	-1.5	-4.2	-9.4	-3.8
SO_2	-7.3	4.2	-0.9	-14.8	-5.3
NMVOC	-2.8	1.9	-0.7	-7.3	-1.6
CO	-11.8	+5.1	-1.7	-6.7	-0.8

Table 486: Changes in emissions in Germany by category since 1990/since the respective previous year, in percent [%]

with respect to 1990	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1. Energy		-3.5%	-8.2%	-9.1%	-11.2%	-11.6%	-9.7%	-12.7%	-13.7%	-16.1%	-16.4%	-14.6%	-16.1%	-16.5%	-18.4%	-20.0%	-18.5%	-22.4%	-21.6%	-26.9%
2. Industrial processes		-3.9%	-4.0%	-2.6%	3.3%	1.6%	-0.4%	0.2%	-13.1%	-21.2%	-17.8%	-21.6%	-23.3%	-20.5%	-18.6%	-22.0%	-21.6%	-18.2%	-22.7%	-31.3%
3. Agriculture		-10.4%	-11.1%	-12.8%	-11.9%	-12.4%	-12.4%	-13.4%	-13.3%	-13.2%	-13.4%	-13.4%	-14.5%	-18.2%	-17.9%	-18.2%	-19.4%	-17.8%	-19.2%	-18.6%
5. Waste		3.7%	5.2%	4.5%	1.9%	-1.2%	-5.5%	-13.4%	-19.5%	-24.3%	-28.8%	-33.6%	-37.8%	-42.1%	-48.3%	-52.3%	-57.3%	-60.9%	-64.3%	-67.6%
with respect to 1990	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**					
1. Energy	-23.5%	-26.0%	-24.7%	-22.9%	-26.9%	-26.4%	-26.5%	-28.0%	-30.9%	-35.5%	-41.3%	-38.4%	-38.9%	-46.2%	-48.0%					
2. Industrial processes	-33.6%	-32.1%	-35.1%	-35.2%	-34.9%	-35.8%	-34.1%	-30.0%	-33.2%	-36.6%	-41.1%	-39.0%	-44.8%	-49.6%	-48.6%					
3. Agriculture	-18.8%	-19.1%	-18.9%	-16.9%	-15.9%	-16.8%	-16.5%	-16.7%	-20.7%	-20.8%	-22.8%	-23.9%	-26.7%	-25.5%	-28.0%					
5. Waste	-70.7%	-72.8%	-74.8%	-76.7%	-78.2%	-79.7%	-81.0%	-81.9%	-82.8%	-84.1%	-85.3%	-85.8%	-86.4%	-86.9%	-87.3%					
with respect to the previous year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
1. Energy		-3.5%	-4.8%	-1.0%	-2.4%	-0.5%	2.2%	-3.4%	-1.1%	-2.8%	-0.4%	2.2%	-1.8%	-0.5%	-2.2%	-2.0%	1.9%	-4.8%	1.0%	-6.7%
2. Industrial processes		-3.9%	0.0%	1.4%	6.1%	-1.6%	-2.0%	0.6%	-13.3%	-9.4%	4.3%	-4.6%	-2.1%	3.7%	2.4%	-4.2%	0.4%	4.3%	-5.5%	-11.1%
3. Agriculture		-10.4%	-0.8%	-1.9%	1.0%	-0.6%	0.1%	-1.2%	0.2%	0.1%	-0.2%	0.0%	-1.2%	-4.3%	0.3%	-0.3%	-1.4%	1.9%	-1.8%	0.8%
5. Waste		3.7%	1.4%	-0.6%	-2.5%	-3.0%	-4.4%	-8.4%	-7.0%	-5.9%	-6.0%	-6.8%	-6.2%	-6.9%	-10.7%	-7.7%	-10.5%	-8.6%	-8.6%	-9.4%
with respect to the previous year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**					
1. Energy	4.7%	-3.2%	1.7%	2.4%	-5.2%	0.7%	-0.1%	-2.1%	-4.0%	-6.7%	-9.1%	5.1%	-0.9%	-11.9%	-3.3%					
2. Industrial processes	-3.5%	2.3%	-4.4%	-0.2%	0.5%	-1.4%	2.6%	6.2%	-4.7%	-5.1%	-7.0%	3.4%	-9.5%	-8.6%	1.8%					
3. Agriculture	-0.3%	-0.4%	0.3%	2.5%	1.2%	-1.1%	0.4%	-0.3%	-4.8%	-0.2%	-2.4%	-1.5%	-3.6%	1.6%	-3.4%					
5. Waste	-9.3%	-7.2%	-7.3%	-7.6%	-6.5%	-6.8%	-6.4%	-4.8%	-5.2%	-7.4%	-7.4%	-3.4%	-4.4%	-3.5%	-3.2%					

Annex 5.3 Recalculations: detailed analysis on the basis of CRT Table 8

Reference is made here to the CRF tables published in parallel with this report.

However, due to space limitations and to avoid redundancies, the specific table contents are generally not incorporated into the NID.

Annex 6 Detailed explanation of the methods and data for calculating CO_2 emissions from combustion of fuels

Annex 6.1 The Energy Balance for the Federal Republic of Germany

The basis for determining the energy-related emissions is the Energy Balance of the Federal Republic of Germany, which is prepared by the Working Group on Energy Balances (AG Energiebilanzen – AGEB) on behalf of the Federal Ministry for Economic Affairs and Energy (BMWE). The most important data source for the Energy Balance is the Federal Statistical Office (Statistisches Bundesamt). The Federal Statistical Office surveys used to prepare the Energy Balances of the Federal Republic of Germany are listed in Table 484. Data on renewable energy sources are determined by the Working Group on Renewable Energy Statistics (Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat) under the leadership of the German Environment Agency (UBA) and directly adopted by the Working Group on Energy Balances (AGEB) for the Energy Balances. The data involved include provisional data on renewable energy sources, which are incorporated into the estimated Energy Balance and the evaluation tables.

Additional data, supplementing those provided by the aforementioned data sources, are provided by associations of the German energy industry and by German research institutes. The final Energy Balance includes data from the following associations: Nuclear Technology Germany (KernD), the Federal German association of lignite-producing companies and their affiliated organisations (DEBRIV), the Federal German association of the energy and water-resources industries (bdew), the Gesamtverband Steinkohle association of the German hard-coal-mining industry (GVSt) and the Fuels and Energy industry association (en2x). In the Federal Republic of Germany, energy statistics are published by numerous other agencies, and their statistics can differ in terms of their presentation, scope, methodology and aggregation.

The complete Energy Balances for the years since 1990 are available on the AGEB website (AGEB, 2025b).

The AGEB's website presents a foreword for the Energy Balances (AGEB, 2015) that describes the structure of the Energy Balance.

The overall responsibility for preparation of Energy Balances lies with the AGEB.

In recent years, German experts on energy statistics have expended considerable efforts to minimise the differences between the provisional and final Energy Balances. In 2020, the Federal Statistical Office obtained the EU grant "improvement of timeliness of energy statistics" from EUROSTAT. In the framework of a dedicated project, this funding is expected to enable the Federal Statistical Office to provide data for year x-1 to the AGEB as early as August of the relevant year. The project was launched in 2020 and includes the statistical offices of the German federal states, which are responsible for the concrete surveys involved. Key surveys for the preparation of the Energy Balance and the emissions inventories were prioritised in terms of timing, enabling the Federal Statistical Office to extrapolate a complete data set for 2019 in July 2020 based on the data collected by the cut-off date using imputation methods. In July 2021, these methods were used in routine operations for the first time. In October 2021, quality assurance for the methods was carried out by comparing the extrapolated results with the final 2020 survey data. In the 2022 survey year, the resulting methodological improvements made it possible to prepare a considerably improved provisional Energy Balance, now based, for the first time, on extrapolations – the 2021 provisional Energy Balance. The participating institutions coordinated their scheduling for the relevant data flow so carefully that a number of process

steps were carried out in the shortest possible time, and the relevant data were made available for inventory preparation in report year 2023.

Annex 6.2 Structure of the Energy Balances

Energy balances provide an overview of the production, conversion and use of energy sources/fuels in a defined area in the form of a matrix. In the Energy Balance of the Federal Republic of Germany, energy flows are shown for a total of 30 energy sources/fuels (groups). The production balance shows

- domestic production,
- imports,
- removals from stocks,
- exports,
- international marine bunkers, and
- additions to stocks,

of energy resources, and it summarises them under primary energy consumption. The primary Energy Balance provides the basis for calculations under the IPCC reference procedure (Plinke & Schonert, 2000). The usage balance provides a key basis for preparation of emissions inventories. The usage balance can also be used for determination of primary energy consumption. It comprises:

- the transformation balance
- flaring and line losses
- non-energy-related consumption, and
- final energy consumption.

Data on non-energy-related consumption, broken down by industrial sectors, are regularly provided to the German Environment Agency in an additional table included with the Energy Balance for Germany.

Differences between the production and usage balances are compensated for in the item "Statistical differences".

The transformation balance, which is part of the usage balance, shows what energy resources are converted, or transformed, into other, "secondary" resources. The conversion output shows the results of this transformation. Energy transformation can involve conversions of substances – such as the conversion of crude oil (conversion input) into petroleum products (conversion output) – or conversions of energy – such as combustion of hard coal (conversion input) – in power stations, for production of electrical energy (conversion output). The energy consumption in the transformation sector shows how much energy was needed for operation of the conversion systems (the transformation sector's own consumption). The transformation balance is divided into a total of 12 different sectors.

Non-energy-related consumption, as a component of the consumption balance, is shown as a total, without allocation to industrial sectors. Data on non-energy-related consumption, broken

down by industrial sectors, are regularly provided to the German Environment Agency in an additional table included with the Energy Balance for Germany. It describes which energy resources are used as raw materials (e.g. in the chemicals industry, conversion of energy resources into plastics).

The description of final energy consumption (by energy sources/fuels) shows the potential scope of energy consumption in the final consumption sectors. (The energy that is ultimately required (such as for work, lighting, space heat and process heat) has to be differentiated from final energy consumption and is not listed in the EB (AGEB, 2019). The breakdown covers the areas of industry – subdivided into 14 sectors – transport, households, commercial use, trade, services and other consumers (including agriculture).

The energy flow in the Energy Balances is shown for 30 energy sources/fuels. These energy resources can be allocated to the following main groups:

- hard coal,
- lignite,
- petroleum (including LPG and refinery gas),
- gases (coke oven and blast furnace gas, natural gas and mine gas, and excluding landfill gas and the gases in the previous category),
- renewable energies (including renewable waste and, as of 2013, sewage sludge),
- electrical power and other energy sources/fuels (non-renewable waste, waste heat).

Detailed information about the transformation balance, non-energy-related consumption, final energy consumption and the energy sources/fuels groups is provided in the NIR (UBA et al., 2023). Reference is also made here to the brochure ("Energy in Figures – Work and Achievements of the AG Energiebilanzen" (AGEB, 2019)), which contains further information and background details on Germany's energy balance.

Energy Balances for Germany as a whole are available for the years as of 1990 (AGEB, 2003) waste, waste heat). As of the year 2000, the energy resource structure in the area of renewable energies/waste was changed: hydroelectric, wind power systems and photovoltaic systems were combined, and waste/biomass was divided into renewable and non-renewable shares. Since 2003, non-renewable waste and waste heat are also listed under final energy consumption within the Energy Balance.

In the Energy Balance, fuels/energy sources are listed in natural units, including tonnes (t) for solid and liquid fuels, cubic metres (m^3) for gases (except for natural gas), kilowatt hours (kWh) for electrical power and natural gas, and joules (J) for waste, renewable energy sources, nuclear power and district heating. To make it easier to compare and add up the data, all values are converted into joules (J) using the right conversion factors. Unlike gas statistics, the energy balance refers to all gases in terms of their calorific value H_i – and not of their gross calorific value, H_s. This data are submitted to the Federal Environment Agency together with the provisional energy balance.

To meet the need for emissions reporting to be as up to date as possible, the following procedure is carried out on an annual basis as of 2022 for purposes of inventory preparation: at the end of August, the Working Group on Energy Balances (AGEB) provides the German Environment Agency with a complete provisional Energy Balance, based on extrapolated statistics of the Federal Statistical Office, for the year x-1. The AGEB then delivers the final Energy Balance to the

German Environment Agency as scheduled in the following February (then for the year x-2). Publication then takes place around April.

Annex 6.3 Methodological issues: Energy-related activity data

The inventories for air pollutants and greenhouse gases compiled by the German Environment Agency are based on the energy balances for Germany compiled by the Working Group on Energy Balances (AGEB). The data required for emissions calculation can be read directly from Energy Balance lines 11, 12, 15, 16, 40, 60, 65 and 68. For natural gas and light heating oil, EB line 14 is also used in the calculation.

In a few cases, the special requirements for emissions calculation and the need to assure the completeness of data necessitate a departure from the above-described system, and additional data have to be added:

- The emissions-relevant fuel inputs for lignite drying have to be subtracted from EB line 10. An exact description of category 1.A.1.c is provided in Chapter 3.2.6.2.
- Natural gas inputs in compressors for the years 1995-2002 were taken directly from the Energy Balance (EB line 33). For the years 1990-1994 and for the period as of 2003, the values have to be calculated outside of the Energy Balance. The methods are described in the NIR 2022's (UBA et al., 2022) Chapter for category 1.A.3.e.
- Since the quantities of waste incinerated are not recorded in full in the Energy Balance for systematic reasons or with a focus on energy production, waste statistics must also be used to supplement the data in this case. Relevant explanations are provided in Chapter for category 1.A.1.a and in the Chapter for category 1.A.2.g Other (stationary).
- Firewood use in the categories *commercial and institutional* is not listed in the Energy Balances up to 2012 and must be added. The method is described in the chapter about category 1.A.4.

The use of reducing agents for the production of pig iron is reported in the energy balance partly as energy consumption in EB line 54 and partly as conversion input in EB line 17 (blast furnace gas equivalent). The use of blast furnace gas produced during pig iron production for energy generation is recorded in the corresponding energy balance lines 11, 12, 15, 33 and 54. To prevent double counting, the reducing agent inputs from blast furnaces, as listed in EB line 54, and the relevant blast furnace gas equivalent are not reported.

Annex 6.4 Uncertainties, time-series consistency and quality assurance in the Energy Balance

With the introduction of the Energy Statistics Act in 2003, the essential data basis for the energy balance improved relatively, but due to the dynamics in the energy sector, an amendment to the Energy Statistics Act soon became necessary. The currently valid amendment of the Act on Energy Statistics of 6 March 2017 (Federal Law Gazette (BGBl) I p. 392) introduces improvements in statistical coverage, updates the survey groups involved and adds a number of new aspects to be surveyed. The frequency of surveys has also shifted somewhat in favour of monthly surveys. The first survey covered the survey year 2018.

The data structures of the Energy Balance are adjusted on an ongoing basis to ensure that the best possible data are provided.

These changes are made at relatively large intervals and documented by the Working Group on Energy Balances (AGEB) in each case:

- Explanations on the updates to the energy balances 2003-2006[109]
- Comments on the changes in the energy balances from 2003 to 2007[110]
- Update to the energy balances 2003 to 2009[111]
- Methodological changes in the 2012 energy balance[112]
- Explanations on the energy balances (updated as of November 2015)[113]

In October 2021, the AGEB prepared a report on "Germany's Energy Balance – required revisions" ("Revisionsbedarf in der Energiebilanz Deutschland") as commissioned. When implementing the proposals in this report, the time series were updated for the first time in 2023. Further updates will be made every two years. The AGEB has provided UBA with an overview of the required revisions.

Annex 6.4.1 Quality report of the Working Group on Energy Balances (AGEB) regarding preparation of Energy Balances for the Federal Republic of Germany

Since 2012, the Working Group on Energy Balances (AGEB) has regularly submitted joint quality reports to the German Environment Agency (UBA) that document its quality assurance measures in preparation of Energy Balances. As part of the commissioned work on energy balances, from 2020 onwards energy balances are compiled and delivered in time series as a quality assurance measure, so that jumps in time series can be identified more easily than before when compiling data.

The following section presents the content of the current report with its original wording (indicated in a different font).

Annex 6.4.1.1 Context

Context

In the framework of greenhouse gas reporting, the National Coordination Committee for the National System of Emissions Inventories has established minimum requirements for quality control and quality assurance (QC/QA). Those requirements are to be fulfilled at all levels of inventory preparation. One of the most important data sets for determination of greenhouse gas emissions consists of the Energy Balances for the Federal Republic of Germany, which the Working Group on Energy Balances (AGEB) was commissioned to prepare. The EEFA research institute (Münster) and the Centre for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW; Stuttgart) support the AGEB in its work as subcontractors. All persons working on Energy Balances

[109] http://www.ag-energiebilanzen.de/#revision_der_eb_2003_bis_2006

[110] http://www.ag-energiebilanzen.de/#aktualisierungen_der_energiebilanzen_2003_bis

[111] http://www.ag-energiebilanzen.de/#revision_der_energiebilanzen_2003_bis_2009_05

[112] http://www.ag-energiebilanzen.de/#methodische_aenderungen_der_eb_2012

[113] http://www.ag-energiebilanzen.de/index.php?article_id=29&fileName=vorwort.pdf

are required to comply with minimum requirements for QC/QA in areas such as transparency, consistency, comparability, completeness and accuracy.

To document its data sources and quality assurance measures in preparation of Energy Balances, the Working Group on Energy Balances (AGEB) herewith submits its current quality report to the German Environment Agency (UBA). It focuses particularly on the 2022 Energy Balance.

1. Division of reponsibilities in the preparation of energy balances

The Energy Balances for Germany (also considering that the data for the energy balances is updated every two years) are generated centrally using a database (based at the Centre for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW)). The basic responsibilities for the various energy sources/fuels (Energy Environment Forecast and Analysis (EEFA) institute: hard coal, lignite, coking gas, blast furnace gas, basic oxygen furnace gas and mine gas; ZSW: petroleum and petroleum products, natural gas, petroleum gas and other fuels; office of the Working Group on Renewable Energy Statistics (Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat): renewable energies) have not been affected by the change. Also, in connection with its Energy Balance work, the EEFA research institute has coordinated the quarterly estimates of primary energy consumption for the Federal Republic of Germany and prepared estimates for the energy source "hard coal." The ZSW is responsible for "Other" energy sources. Figures on renewable energies are calculated and published on the basis of the relevant data in consultation with the office of the Working Group on Renewable Energy Statistics (GS AGEE-Stat).

In February of 2024, EEFA/ZSW prepared an "early-estimate" version of the 2023 Energy Balance (with data available as of 15 February 2024). The 2023 provisional Energy Balance was then submitted in May 2024. In September of the same year, a further 2024 provisional, "early-estimate" Energy Balance was prepared along with the evaluation tables. This Balance included data and estimates of the Federal Statistical Office, including data and estimates on development of final energy consumption by industry. In the normal process, data from official Mineral Oil Statistics (AMS) of the Federal Office for Economic Affairs and Export Control (BAFA) are integrated within the petroleum section of the Energy Balance, which is usually available for the previous year in the middle of the following year.

In February or spring of any given year, important official data sources, such as surveys on energy consumption in industrial sectors, are generally not yet available. Consequently, the data gaps have to be closed using estimates. It is therefore obvious that the estimated Energy Balances (or an early estimate version of the Balance) cannot fulfil the strict data quality requirements met by the final Energy Balance, which is published with a time lag of about one year.

2. Quality of the data sources used

The following data of the Federal Statistical Office are used in the preparation of the Energy Balances for the Federal Republic of Germany:

- *Annual survey (No. 060) of energy use by manufacturing, mining and quarrying companies,*
- *Monthly survey (No. 061E) of coal imports,*
- *Annual survey (No. 062) of heat and electricity generation from geothermal energy,*
- *Annual survey (No. 063) of production of biofuels,*
- *Annual survey (No. 064) of generation and use of heat and of heating-network operations,*

- *Monthly survey (No. 066K) of electricity and heat generation for the public supply,*
- *Monthly survey (No. 066N) on electricity feed-in and feed-out at grid operators,*
- *Annual survey (No 067) of electricity and heat generation by manufacturing, mining and quarrying companies,*
- *Monthly survey (No. 068) of the gas supply,*
- *Annual survey (No. 070) of electricity feed-in and electricity demand as recorded by electricity grid operators,*
- *Annual survey (No. 071) of supply of oil products,*
- *Annual survey (No. 073) of production, use and supply of sewage gas,*
- *Annual survey (No. 075) of supply of LP gas,*
- *Annual survey (No. 082) of gas sales and income in the gas supply sector,*
- *Annual survey (No. 083) of electricity sales and income in the electricity supply sector,*
- *Energiesteuerstatistik (energy taxation statistics), (Fachserie 14, Reihe 9.3).*

The data of the Federal Statistical Office are subject to official quality requirements. The quality reports of the Federal Statistical Office are available (in German) on the Internet:

https://www.destatis.de/DE/Methoden/Qualitaet/Qualitaetsberichte/Energie/einfuehrung.html [114]*, last accessed on 12 February 2025.*

In addition, data from the official mineral oil statistics (AMS) of the Federal Office of Economics and Export Control (BAFA) are used. Since this year, these have only been published as PDF files on the BAFA website, but are also prepared by BAFA in Excel format and sent to AGEB by email.

The AMS, which are published monthly and annually, are a closed, consistent system covering all petroleum production and consumption in Germany. The statistical basis for the AMS consists of the Integrated Mineral Oil Report (Integrierte Mineralölbericht – IM), which is prepared monthly on the basis of the Act on mineral oil data (Mineralöldatengesetz) with input from companies operating in Germany's petroleum market. The Federal Office for Economic Affairs and Export Control (BAFA) reports the production and consumption data, together with the relevant data of the Federal Statistical Office, to IEA and Eurostat, which publish internationally comparable energy balances. The calorific values for crude oil inputs and the petroleum products that are covered by these reports are cross-checked against the national Energy Balance. For the Energy Balance's section on petroleum, both AMS data and data of the Federal Statistical Office are used.

In addition to the available official data, association data are also used. Among the statistics provided by associations, the Statistik der Kohlenwirtschaft (coal industry statistics; since 2020, available only for lignite) play a special role. The data used for the Energy Balance include the following:

- *Data on extraction, production of lignite products, producers' own consumption and sales (form 5) as well as information from production reports,*

[114] The Federal Statistical Office publishes only quality reports in accordance with the new EnStatG 2017 on its website. Quality reports in accordance with the old EnStatG are no longer available online.

- *Data on domestic sales/use, broken down by federal states and consumer groups,*

The coal statistics data available in Germany have a semi-official status and are very precise and reliable. For more than 60 years, the Statistik der Kohlenwirtschaft coal sector statistics association has served as a liaison between coal sector companies and official producers of statistics. Official coal statistics in this area are based on surveys carried out by the Statistik der Kohlenwirtschaft association. A large part of the coal data is made publicly accessible on the website http://www.kohlenstatistik.de. The transparency this provides also attests to the reliability and accuracy of these data sources. The Act on Energy Statistics (Energiestatistikgesetz) has no separate paragraph about surveys on the domestic coal sector; its refers instead explicitly to the functioning system of coal statistics.

A considerable portion of the data used for preparation of the overall natural-gas balance (Erdgasbilanz) comes from official statistics. In addition, additional association data and model calculations are required in some areas to close data and information gaps in the official statistics programme.

For natural gas, associated gas:

- *Data on flaring losses are obtained using the implied calorific value given by the Federal association of the natural gas, oil and geothermal energy industry (BVEG, the former WEG oil and gas industry association). The 2019 Statistical Report (Statistischer Bericht 2019) (page 22) introduced a change in the breakdown of flaring losses into the categories "routine," "safety-relevant" and "non-routine."*
- *In early Balance years, data on natural gas consumption in the transport sector were derived by Zukunft Erdgas (formerly Erdgas mobil) from data provided by the German Association of Energy and Water Industries (BDEW). Energy tax statistics also supplied data for this sector. In the latest update, the data are derived using a model-based method working from the CNG and LNG sales in Germany.*
- *As a result of the change in the statistical report of the Federal association of the natural gas, oil and geothermal energy industry (BVEG), own consumption is now listed as process-related own consumption, i.e. including processing losses, measuring differences and flaring losses. For the purposes of the preparation of Energy Balances, the BVEG provided actual own-consumption figures for the years 2018-2020.*

The following additional sources are also used:

- *In the framework of monitoring under the CHP Act (Kraft-Wärme-Kopplungsgesetz), the Öko-Institut e.V. Institute for Applied Ecology estimates inputs of natural gas, and light fuel oil, for electricity and heat generation in compact gas-/oil-fired CHP systems that are not covered by official statistics.*

Detailed information on how the various data sources are used in preparation of the Energy Balance is provided by the "cookbook" ("Kochbuch"; it contains source information for specific entries in the Balance).

Beyond the quality of the available data, the multi-year availability of sources and a uniform and consistent presentation of time series play an important role in energy balance sheet preparation. Such aspects play a critically important role in ensuring that the procedures and methods used for the preparation of Energy Balances generate data that can be consistently integrated, without structural discontinuities, in the basic scheme for the Balances. Both the relevant official sources and the coal statistics data have a long tradition. Where breaks in time series cannot be avoided as

a result of reviews or changes in statistical foundations (for example in the Act on Energy Statistics), these breaks are documented in the sources used for preparation of Energy Balances. This ensures that methods are always properly adjusted.

3. Transparency of methods and procedures

The Act on Energy Statistics (Energiestatistikgesetz – (EnStatG) entered into force on 1 January 2003. That act consolidates official energy statistic from different legal frameworks, and adapts them to users' changed information requirements. Since the act's entry into force, the Federal Statistical Office has also collected and provided data for the areas heat market, combined heat/power generation (CHP) and renewable energy sources. As a result of the restructuring, the Federal Statistical Office, in addition to providing data on electricity and heat generation from combined heat/power generation (CHP), also provides data on all fuel inputs for CHP, for both the general public supply and industry (broken down by energy sources).

These changes in the available statistics have made it necessary to adjust the methods used for the Energy Balances – especially for their descriptions of industrial final energy consumption. The outlined expansion of the data available means that, from 2003 onwards, separate information will be available on fuel use for pure electricity production in industrial power generation.

Data on the distribution of fuel use between electricity and heat in combined heat and power generation in industry and in combined heat/power plants is not collected by the Federal Statistical Office, but is estimated by the Working Group on Energy Balances (AGEB) or by institutes commissioned by it. The "Finnish" method used for this purpose is based on Directive 2004/8/EC of the European Parliament and of the Council of 11 February 2004. This method is precisely defined mathematically and is explained in the forewords to the Energy Balances. Currently, it is also explained in the brochure "Energie in Zahlen – Arbeit und Leistungen der AG Energiebilanzen" ("Energy in figures – the work and services of the Working Group on Energy Balances"), p. 10, 11 f.

With regard to quality assurance, the Finnish method makes calculations for power/heat production for the public supply and for industry clear and transparent. The necessary assumptions, such as the reference efficiencies of non-CHP generation, are specified in the documentation on the energy balance. All this shows that, despite the use of sometimes complex methodological transformation steps, a high degree of transparency and clarity can be guaranteed in the results when preparing energy balances. As a result, all Energy Balance fields can always be traced back to their primary statistical foundations.

Primary data provided by official or association sources – regardless of the quality – only be used directly in a few areas of the energy balance without the use of methodological or statistical procedures for compiling the energy balance. Description of relevant complex energy flows using matrices that conform to the formal parameters and methodological specifications for the Energy Balances and on the basis of statistical raw data requires many transformation steps, recalculations and reallocations. What is more, in some (few) areas of the Energy Balance primary statistics are no longer available, and thus data gaps have to be closed through the use of formal estimation methods applied in accordance with the requirements of each relevant individual case[115].

[115] Outlook: The amended Act on Energy Statistics (Energiestatistikgesetz – (EnStatG) entered into force on 10 March 2017. The amended version of the act suitably addresses changed requirements for energy data at the national and international levels. In addition, it adapts energy statistics to the changed conditions in the energy sector. Furthermore, it closes a number of data gaps,

4. CHECKING AND VERIFICATION OF RESULTS

Measures for quality assurance and control cover the following areas:

- *Assurance of data quality/transparency of methods and procedures,*
- *Mechanisms for checking and critically reviewing the Energy Balances, measures that assure the Balances' correctness, completeness and consistency,*
- *Measures for documentation and archiving designed to ensure the Balances' clarity and reproducibility,*
- *Expert responsibility for the preparation of Energy Balances.*

Critical discussion, verification and checking of results take place on various levels:

- *The work is checked for plausibility on a reciprocal basis and using control variables (e.g. year-on-year changes, implicit calorific values, usage rates).*
- *The time series consistency is regularly verified. Where a time series shows implausible jumps that cannot be attributed to transfer or calculation errors, and this must be tied to developments in the underlying primary statistics, the problem is discussed constructively with the institution supplying the data (such as the Federal Statistical Office).*
- *The Energy Balances are cross-checked against the data provided to IEA/Eurostat.*
- *In addition, the AGEB member associations carry out supporting checks.*
- *Furthermore, data and results are discussed early on with responsible experts of the German Environment Agency.*
- *Statistical questions related to the Energy Balance are also discussed by the "Working Group on methods" ("Arbeitskreis Methodi" – AKM) based in the Federal Ministry for Economic Affairs and Climate Action (BMWK).*

With a view to effective prevention of errors in data calculation and estimation for the Energy Balances, the annual balances are prepared using standardised procedures. To that end, a broad range of instruments has been developed that automate proven estimation procedures and formal calculation method, within the context of Energy Balance preparation. This approach, which in some cases only requires the raw statistical data to be entered into the appropriate tools, largely eliminates calculation and transformation errors. The use of consistent, standardised methods also plays an important role in assuring time series consistency.

5. DOCUMENTATION AND ARCHIVING

The EEFA research institute and the Centre for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW) maintain detailed documentation on the annual Energy Balances. The documentation covers every Energy Balance entry, lists the statistical sources and surveys used and precisely describes the calculation methods and procedures used. The aim of the documentation is to ensure complete traceability both for our own purposes and for the Federal Ministry for Economic Affairs and Climate Action (BMWK) and the German Environment Agency (UBA). Furthermore, regular updating of the documentation contributes to data quality and helps to assure consistency in time series and methods.

All statistical data, calculation methods and estimation procedures used in preparation of Energy Balances for the Federal Republic of Germany are archived. The electronic data are stored on servers of the ZSW (AGEB database). For archiving of electronic content, the EEFA institute uses a

especially in the areas of renewable energies, combined heat/power generation (CHP) and heat generation. The amended EnStatG has been applied to monthly surveys in the period as of the reporting month January 2018.

range of computers and removable disk drives, as well as network-based server and cloud-computing solutions. Data back-ups are carried out both automatically and manually (at regular intervals).

6. QUALIFIED STAFF

The EEFA Research Institute and the ZSW have experienced staff with in-depth knowledge of statistics, economics and energy management at their disposal for the service project "Preparation of Energy Balances for the Federal Republic of Germany" ("Erstellen von Energiebilanzen für die Bundesrepublik Deutschland").

7. EXPLANATIONS ON THE CURRENTNESS AND AVAILABILITY OF DATA FOR THE PREPARATION OF THE ENERGY BALANCES

Official statistics

Since 2022 and in the framework of national inventory preparation, every August the Federal Statistical Office has collected/calculated additional data that enter into the Energy Balance of the previous year (in 2022, therefore, into the 2023 Energy Balance) and the Joint Annual Questionnaire. As a result, official data now become available much earlier than was previously the case. The "cookbook" on energy balance provides detailed information on which statistics from the Federal Statistical Office, BAFA, etc., were used.

Association statistics

In the final Energy Balance, gaps in the available official data are closed, at various points, with data provided by associations (see above).

Also, thanks to the quarterly estimates that the Working Group on Energy Balances carries out in cooperation with energy industry associations, current data and forecasts are available on an ongoing basis on the development of primary energy consumption in Germany.

Important preliminary data, which is also required for the final energy consumption of the estimated energy balances as of May and September, is provided by the BDEW, which publishes data on "The German energy market – facts and figures on the gas, electricity and district-heating sectors" ("Energiemarkt Deutschland – Zahlen und Fakten zur Gas-, Strom- und Fernwärmeversorgung") every summer. In addition, the estimated Energy Balance incorporates BDEW data on gross electricity generation. In addition, there are data of Statistik der Kohlenwirtschaft coal-industry statistics, and data of the Fuels&Energy industry association (Wirtschaftsverband Fuels&Energie – en2x, formerly Mineralölwirtschaftsverband e.V. Association of the German Petroleum Industry).

Ongoing early estimate of the German Energy Balance, beginning in February of the following year

The fact that the early estimate of the complete German Energy Balance for the previous year now becomes available as of 15 February of each year must be seen as a significant improvement, schedule-wise, in the availability of complete energy data. The early estimate of the Energy Balance is not based solely on the energy data that are available at the time it is produced; extensive portions of the early Balance (such as those covering final energy consumption) are also based on formal forecasting procedures (models). Details on the approach used in preparing the early estimate of the German Energy Balance are provided in the German Environment Agency's study "Pilotprojekt zur Frühschätzung der Energiebilanz 2020 und Vergleich zu späteren definierten Datenständen" ("Pilot project on the early estimate of the 2020 Energy Balance, and comparison

with later defined data inventories") (UBA-Texte 18/23) (available on the internet at: https://www.umweltbundesamt.de/publikationen/pilotprojekt-zur-fruehschaetzung-der-energiebilanz) and the UBA follow-up study "Further development of the model for early estimation of the energy balance" (UBA texts 167/2024, available online at: https://www.umweltbundesamt.de/publikationen/weiterentwicklung-des-modells-zur-fruehschaetzung-0).

The latest early estimate of the energy balance for the 2024 reporting year will be submitted to the German Environment Agency on 14 February 2025.

Other data

All renewable energies trends data that are used in the satellite balance are obtained from calculations of the Working Group on Renewable Energy Statistics (Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat).

Figures for electricity generation and fuel inputs in small CHP systems fired with natural gas (< 1 MW) were calculated with data the BHKW (compact combined heat-and-power (CHP) generating systems) database of the Öko-Institut e.V. Institute for Applied Ecology. The same data are used for reporting in the IEA/Eurostat context.

Data on the use of petroleum coke in metallurgical coking plants are provided for the Federal balance by the relevant German federal states, on the basis of an agreement between the Working Group on Energy Balances (AGEB) and the federal state working group on Energy Balances (Länderarbeitskreis Energiebilanzen).

Table 487: Federal Statistical Office surveys used in preparation of Energy Balances for the Federal Republic of Germany

Survey	*No.*	*Reporting period*	*Currentness*	*Basic scope*	*Content focus*
Annual survey of energy use by manufacturing, mining and quarrying companies	*060*	*Annually*	*End of the following year*	*All companies in the manufacturing, mining and quarrying sectors that have at least 20 employees*	*Relevant fuel quantities, including purchases, stocks, consumption and sales, broken down by fuel type and fuel energy content; relevant electricity quantities, including own generation and consumption; ... ; sales of electricity and heat, broken down by purchaser groups and exports; and quantities involved in both energy-related and non-energy-related use of fuels*
Survey on coal imports	*061E*	*Monthly, annually*	*Eight weeks after the end of the reporting period*	*All legal entities (in the following, "companies") that import coal and coal products into Germany; "imports" includes both imports for further distribution and imports for own use.*	*Imports of coal, broken down by countries, coal types, energy content and cross-border prices; quantities in stocks, broken down by coal types; coal sales, broken down by coal types and, within the coal types, by purchaser and consumer groups.*
Annual survey of heat and electricity generation from geothermal energy	*062*	*Annually*	*Nine weeks after the end of the reporting period*	*All operators of systems for use of deep geothermal energy*	*The types of systems involved and their performance; the quantities of heat and electricity generated, broken down by types of use; and the quantities of heat and electricity sold, broken down by purchaser groups.*
Annual survey of production of biofuels	*063*	*Annually*	*Nine weeks after the end of the reporting period*	*All operators of systems for the production of biofuels.*	*The types of systems involved and their performance; the quantities of biofuels used, broken down by type and by origin (including both domestic and international origin); the quantities of biofuels produced, broken down by type; the imported and exported quantities of biofuels, broken down by type; the quantities of biofuels sold, broken down by type*
Annual survey of generation and use of heat and of heating network operations	*064*	*Annually*	*Twelve weeks after the end of the reporting period*	*All operators of heating plants with installed rated capacity of 1 MWth, all operators of installations for grid-connected heat supply, including heat-driven CHP installations, and third parties that use such installations.*	*The quantities of heat generated and, in the case of heat-driven CHP plants, the quantities of electricity generated, broken down by types of fuels used; the quantities of heat purchased, broken down by supplier groups; the quantities of heat sold, broken down by purchaser groups; the relevant quantities of fuel stocks, broken down by energy content; the quantities of fuels used to generate heat and electricity, broken down by type and energy content; the quantities of heat and electricity used (own consumption); the installed thermal storage capacity; the quantities of network losses; the type and quantity of net rated electrical output installed and the type and quantity of net rated thermal output installed; in the case of heat networks, the heat carriers predominantly used; the total number of heat networks, and their total route length; the extent of heat network additions and removals; and the quantities of imported and exported heat.*
Monthly survey of electricity and heat generation	*066K*	*Monthly, annually*	*About 70 days after the end of the reporting month*	*All operators of plants for generation of electricity, including CHP plants, and in each case with a net rated electrical output of at least 1 megawatt (MW); and plants for storage of electricity, with an installed net rated electrical output of at least 1 megawatt or a storage capacity of at least 1 megawatt-hour. Such operators are considered electricity companies (EVU) pursuant to Art. 3 No.*	*In the case of operators of plants for electricity generation (with an output of at least 1 MW): the quantities of generated electricity or of generated electricity and heat, broken down by types of fuel used and processes used; the quantities sold, broken down by purchaser groups; the quantities of own consumption, broken down by electricity and heat in each case; the net nominal capacity of plants for generation of electricity or of electricity and heat; the efficiency of CHP plants, broken down by process types; the primary energy savings achieved by CHP plants, broken down by process types; the quantities of fuel stocks maintained for generation of electricity, or, in the case of CHP plants, for*

Survey	No.	Reporting period	Currentness	Basic scope	Content focus
				18 Energy Industry Act (Energiewirtschaftsgesetz – EnWG).	*generation of electricity and heat, in each case broken down by fuels and energy content; the quantities of fuels used to generate electricity, or, in the case of CHP plants, to generate electricity and heat, in each case broken down by fuels and energy content. In the case of operators of plants for storage of electricity (with output of at least 1 MW): the quantities of stored and delivered electricity, broken down by storage technology, and, in the case of pumped storage power plants, also broken down by generation from pumping operations and from natural inflow; the installed net nominal electricity capacity, and, in the case of pumped-storage power plants, also broken down by generation and pumping operations; the usable storage capacity.*
Monthly survey on electricity feed-in and feed-out at grid operators	*066 N*	*Monthly*	*About 70 days after the end of the reporting month*	*All electricity grid operators*	*Information on the following attributes is collected: By country, the number and net rated capacity of generation plants directly connected to the grid they operate, as well as the feed-in of electricity in physical quantities, broken down by energy source and, within each energy source, by plants with a net rated capacity of less than and greater than 1 MW electrical; imports and exports of electricity in physical quantities, broken down by country; the amount of grid losses; the amount of electricity consumed, broken down by purchaser group.*
Annual survey of electricity and heat generation by manufacturing, mining and quarrying companies,	*067*	*Annually*	*Nine weeks after the end of the reporting period*	*Operators of electricity generation plants for the operators' own supply, including plants for generation of electricity and heat in co-generation processes (CHP)*	*The quantities of generated electricity or of generated electricity and heat, broken down by types of fuel used and processes used; the quantities of own consumption, broken down by electricity and heat in each case; the net nominal capacity of plants; the efficiency of CHP plants, broken down by process types; the primary energy savings achieved by CHP plants, broken down by process types; the quantities of fuel stocks maintained for generation of electricity, or, in the case of CHP plants, for generation of electricity and heat, in each case broken down by fuels and energy content; and the quantities of fuels used to generate electricity, or, in the case of CHP plants, to generate electricity and heat.*
Monthly survey of gas supply	*068*	*Monthly Annually*	*Monthly, and promptly; the annual survey becomes available six weeks after the end of the reporting period*	*All operators of installations for production of natural gas, or for transport of natural gas and biogas via long-distance pipelines, and all operators of facilities for storage of natural gas*	*All operators of plants for natural gas production: the quantities of gas produced and the quantities of own consumption. All operators of systems for transport of natural gas and biogas via long-distance pipelines: the quantities of natural gas fed into the long-distance network; the quantities of biogas fed into the long-distance network; the quantities of gas withdrawn from the long-distance network; the physical quantities of imported and exported natural gas, broken down by neighbouring countries, and the quantities of own consumption. All operators of plants for storage of natural gas: the storage balance at the end of the month, the storage fill levels at the end of the month, and the quantities of own consumption*
Annual survey of electricity feed-in, and electricity demand, as recorded by electricity grid operators	*070*	*Annually*	*Twelve weeks after the end of the reporting period*	*All operators of electricity grids for the public supply*	*Special contract customers pursuant to Art. 2 (3) No. 1 of the Concession Fees Ordinance (Konzessionsabgabenverordnung) with billed user charges; the quantities of network/grid withdrawals of electricity for end customers, and of grid feed-in of electricity, broken down by fuels and sites; the number and installed net nominal capacity of generation plants that are directly connected to the grid operated by the operator*

Survey	*No.*	*Reporting period*	*Currentness*	*Basic scope*	*Content focus*
Annual survey of deliveries of petroleum products	*071*	*Annually*	*Nine weeks after the end of the reporting period*	*All companies supplying fuel oil or aviation fuel to end-users*	*The following characteristics apply for the survey programme for the annual petroleum products survey: on a federal state basis, the volume of the oil products sold, broken down by products and purchaser groups.*
Annual survey of production, use and supply of sewage gas	*073*	*Annually*	*Eight weeks after the end of the reporting period*	*All operators of installations that produce sewage gas or that use sewage sludge to generate electricity and heat*	*The quantities of produced sewage gas, and the quantities of sewage sludge used to generate electricity and heat, broken down by energy content; the quantities of sewage gas used, broken down by types of use; the quantities of sewage gas sold, broken down by purchaser groups; the quantities of sewage gas/sewage sludge-based electricity and heat generated and sold; and the installed net nominal electrical capacity and net nominal thermal capacity of plants for generation of electricity and heat*
Annual survey of deliveries of LP gas	*075*	*Annually*	*Eight weeks after the end of the reporting period*	*All legal entities (in the following, "companies") that sell at least 100 tonnes of LP gas to end users per year.*	*On a federal state basis, the quantities of LP gas sold broken down by purchaser groups*
Annual survey of gas sales and income in the gas supply sector	*082*	*Annually*	*Eight weeks after the end of the reporting period*	*All operators of systems in the gas supply sector*	*In the case of gas producers: the quantities of gas extracted or produced; the quantities of gas sold, broken down by purchaser groups; the proceeds from the sale of gas, broken down by purchaser groups; imports and exports of natural gas, broken down by contractual quantities, and by countries of origin and destination; the quantities of flared gas; the quantities of own consumption and of other losses. In the case of operators of long-distance networks: the quantities of gas fed into the grid; the physical quantities of natural gas imports and exports, broken down by neighbouring countries; the quantities of own consumption; the quantities of other losses. In the case of operators of gas storage facilities: the number, types, working gas volumes and maximum withdrawal rates of the storage facilities; the cumulative quantities of fed-in gas as of the end of the year, and the cumulative quantities of withdrawn gas as of the end of the year; the quantities of own consumption and of other losses. In the case of operators of distribution networks: the quantities of gas fed into the gas distribution network; the quantities of own consumption and of other losses. In the case of gas suppliers and gas wholesalers: the imports and exports of natural gas, broken down by contractual quantities, and by countries of origin and destination; the quantities of gas sold, broken down by purchaser groups; the proceeds from the sale of gas, broken down by purchaser groups*
Annual survey of electricity sales and income in the electricity supply sector	*083*	*Annually*	*Nine weeks after the end of the reporting period*	*All electricity supply companies including electricity traders*	*The survey programme of the annual survey of electricity sales and revenues in electricity supply includes the following characteristics: the volume of the electricity sold, broken down by purchaser groups; the revenues from the sale of electricity, broken down by purchaser groups and the revenues from the sale of electricity to special contract customers pursuant to section 2(3) no. 1 of the Concession Fee Ordinance.*

https://www.destatis.de/DE/Methoden/Qualitaet/Qualitaetsberichte/Energie/einfuehrung.html[II 6] *Link to the quality reports including questionnaire of the Federal Statistical Office*

REGULAR COMPARISON OF THE ENERGY BALANCES

Comparison of the final 2023 Energy Balance with the final 2022 Energy Balance *(after update)*

The AGEB normally publishes the final Energy Balances in February of the next calendar year but one. In order to be able to provide data at an earlier stage, EEFA and ZSW will make an early estimate in February. In each May, an initial provision energy balance including the satellite balance for renewable energy is made. In September, the Federal Statistical Office then provides early estimates for the energy balance. Soon after that, in September, the evaluation tables, which map the time series of individual energy sources in the energy balance, are produced.

In these comparisons, both absolute and relative discrepancies are calculated to make it possible to identify any significant discrepancies between Energy Balances. Such significant discrepancies have to be individually explained. Positions with discrepancies are analysed by Energy Balance lines and Energy Balance columns in light of a combination of the criteria "discrepancies in TJ" and "discrepancies in %". Discrepancies of 10,000 TJ and 20% are used as thresholds.

With these criteria, the comparison of the final 2023 Energy Balance with the final 2022 Energy Balance (after update) yields 26 positions. These are shown in the overview below and explained in the following section. The differences shown here correspond to the statistical changes with respect to the previous year. The general reasons for such differences include economic trends, structural changes, changes in prices, weather-related effects and special developments such as the decision to discontinue use of nuclear power. Such general trends in energy consumption and its determining factors in 2023, in comparison to the corresponding aspects in 2022, are discussed in the annual reports of the Working Group on Energy Balances.[117]

The comparison of the Energy Balances serves the primary purpose of checking and documenting the plausibility of noticeable changes. In some balance positions, changes determined using the aforementioned criteria are not unusual, however. For example, this applies to changes in stocks, which by nature differ significantly from year to year.

[117] AG Energiebilanzen (Working Group on Energy Balances): Energy consumption in Germany drops to lowest level since 1990. March 2023. www.ag-energiebilanzen.de.

Overview: Noticeable differences when comparing the final energy balance for 2023 with the final energy balance for 2022

EM column	*EB line*	*TJ*	*%*	*Explanatory remarks:*
Hard coal	*2*	*-318 735.3*	*-27.6*	*Data according to statistics*
Hard coal	*7*	*-20 227.5*	*-59.4*	*Data according to statistics*
Hard coal	*11*	*-195 856.0*	*-38.8*	*Data according to statistics*
Hard coal	*12*	*-10 543.4*	*-44.0*	*Data according to statistics*
Hard coal	*15*	*-14 367.0*	*-22.5*	*Data according to statistics*
Crude lignite	*1*	*-276 709.8*	*-23.2*	*Data according to statistics*
Crude lignite	*11*	*-246 423.7*	*-24.2*	*Data according to statistics*
Crude oil	*3*	*17 847.7*	*100.0*	*Data according to statistics*
Crude oil	*41*	*-10 048.7*	*-63.8*	*Data according to statistics*
Gasoline	*2*	*70 520.3*	*88.3*	*Data according to statistics*
Gasoline	*3*	*18 599.2*	*100.0*	*Data according to statistics*
Naphtha	*2*	*- 108 480.9*	*-33.9*	*Data according to statistics*
Naphtha	*43*	*- 78 667.2*	*-28.1*	*Data according to statistics*
Diesel fuels	*3*	*18 872.0*	*1646.2*	*Data according to statistics*
Fuel oil, heavy	*43*	*- 12 522.2*	*-26.7*	*Data according to statistics*
Blast furnace gas and basic oxygen furnace gas	*54*	*13 146.3*	*21.2*	*Data according to statistics*
Natural gas, petroleum gas	*2*	*-1 523 746.3*	*-32.2*	*Data according to statistics*

Natural gas, petroleum gas	*5*	*-1 127 188.0*	*-61.3*	*Data according to statistics*
Natural gas, petroleum gas	*7*	*- 314 032.9*	*-94.8*	*Data according to statistics*
Electricity	*2*	*71 911.8*	*40.5*	*Data according to statistics*
Electricity	*5*	*- 59 411.9*	*-21.5*	*Data according to statistics*
Electricity	*23*	*- 198 940.7*	*-22.5*	*Data according to statistics*
Electricity	*25*	*- 98 977.1*	*-79.2*	*Nuclear power phase-out of the Federal Government*
Electricity	*55*	*- 12 222.3*	*-21.6*	*Data according to statistics*
Nuclear power	*2*	*- 299 930.5*	*-79.2*	*Nuclear power phase-out of the Federal Government*
Nuclear power	*13*	*- 299 930.5*	*-79.2*	*Nuclear power phase-out of the Federal Government*

Comparison of the final 2023 Energy Balance (as of January 2025) with the 2023 estimated Energy Balance (as of September 2024 - "early estimates")

In these comparisons, both absolute and relative discrepancies are calculated to make it possible to identify any significant discrepancies between Energy Balances. Such significant discrepancies have to be individually explained. Positions with discrepancies are analysed, by Energy Balance lines and Energy Balance columns, in light of a combination of the criteria "discrepancies in TJ" and "discrepancies in %". Discrepancies of 10,000 TJ and 20% are used as thresholds.

No position results from these criteria when comparing the early estimates energy balance for 2023 (as of September 2024) with the final energy balance for 2023 (as of January 2025).

The differences between the 2023 estimated Energy Balance and the 2023 final Energy Balance correspond to the differences arising at the time of the compilation of the balance compared with the estimate made four months earlier. The general reasons for such differences include economic trends, structural changes, changes in prices, weather-related effects and special developments such as the decision to discontinue the use of nuclear power.

In addition, it must be noted that data discrepancies can occur in that other data sources have to be used to prepare the estimated Energy Balances, in some cases, than are used to prepare the final Energy Balances. Furthermore, differences can occur as a result of changes in methods.

The comparison of the Energy Balances serves the primary purpose of checking and documenting the plausibility of noticeable changes. In some balance positions, changes determined using the aforementioned criteria are not unusual, however. For example, this applies to changes in stocks, which by nature differ significantly from year to year.

Overview: Noticeable differences in the comparison of the 2023 estimated balance with the 2023 Energy Balance

EM column	*EB line*	*TJ*	*%*	*Explanatory remarks:*

Annex 6.5 Energy Data Action Plan for inventory improvement

Since 2012, the German Environment Agency, working in cooperation with the Federal Ministry for Economic Affairs and Energy (BMWE), the Working Group on Energy Balances (AGEB) and the Federal Statistical Office, has been developing an action plan for improving the energy data inventory, which sets out how the objections raised during the inventory review are to be addressed. This fulfils the action plan requirement set forth in Paragraph 39 of the 2011 review report (FCCC/ARR/2011/DEU). Items that were concluded or marked as completed in the previous report are not listed again here.

Table 488: Energy Data Action Plan for inventory improvement

No.	Subject	Competence	Responsibility for execution	Reference (para)	Quotation from 2011 review report (FCCC/ARR/2011/DEU)	Instrument for implementation /publication	Activity for improvement	Result planned/achieved	Time perspective	Note
1	Energy Data Action Plan for inventory improvement	BMWK/UBA/AGEB/StBA	UBA	39	address review relevant issues in an action plan in the 2011 submission. […] The ERT reiterates the recommendation of the previous review report that Germany prepare a plan for the remaining abovementioned issues, and to report on it and on any progress achieved in its next annual submission	Action plan; NIR	The action plan is prepared for the first time for the 2013 inventory report	A coordinated Energy Data Action Plan for inventory improvement is available for the 2012 inventory review process and will be updated annually	Ongoing	
3.1	Discrepancies between provisional and final EB	BMWK/AGEB/StBA/StaLas	AGEB; UBA	39	Significant differences between the preliminary and final NEB	QC report; NIR	Energy data consistency analysis (EDKA)	Identification and clarification of discrepancies, along with differentiation and addressing of a) Informational deficits b) Documentation requirements c) Data problems d) Methodological changes	Ongoing	
3.2	Discrepancies between provisional and final EB	AGEB	AGEB	39	Significant differences between the preliminary and final NEB	QC	The AGEB is working to reduce estimation errors. Since the mandate to prepare Energy Balances for the years 2018 to 2020, it has been stipulated that the existing estimation methods and reconciliation models must be continuously optimised and documented in writing.	AGEB reports on plausibility checks The AGEB reviews new procedures and methods for preparing the estimated Energy Balance. Specific proposals in this regard have been made (cf. the report of the EEFA research institute regarding approaches in estimation and modelling for the preparation of provisional Energy Balances.	Ongoing	
3.3	Discrepancies between provisional and final EB	AGEB, UBA	UBA	39	Significant differences between the preliminary and final NEB	Inventory description	In the framework of work on the inventory and the 2015 National Inventory Report (NIR), discrepancies are described and the results	The status of this work is documented in the 2015 inventory description: documentation, revision of data for earlier years, reduction of estimation errors	Ongoing since 2012	

No.	Subject	Competence	Responsibility for execution	Reference (para)	Quotation from 2011 review report (FCCC/ARR/2011/DEU)	Instrument for implementation /publication	Activity for improvement	Result planned/achieved	Time perspective	Note
							presented in a discussion about differences.			
4	Complex National System	BMWK/UBA/AGEB	UBA	39	The previous review report noted several issues related to Germany's NEB (such as [...] the complexity of the NEB compiling process that may contribute to the problems with regard to timeliness and quality.	NaSE	Exchange on the results of the inventory review and derivation of the need for action	Annual energy data workshops held since 2010	Ongoing since 2010	
5	Quality assurance	EEFA/DIW/StBA/AGEB/UBA	AGEB/UBA	39	Lack of QA/QC procedures in place for some data sources used to compile the NEB	NIR	Joint AGEB quality report in the new Annex 2 of the NIR 2012 and in subsequent inventory reports	The NEB is subject to QA/QC procedures in accordance with the national system	Ongoing since 2012	
6.1	Discrepancies between EB and IEA data	BMWK, AGEB, persons responsible for questionnaires	BMWK	39	Low comparability with the IEA data		To be jointly defined in the framework of the action plan	Introduction of a transition procedure for assuring compatibility between the Energy Balance and surveys in the areas of electricity and heat (cf. in this regard the report of the EEFA research institute to the AGEB and the Federal Ministry for Economic Affairs and Climate Action (BMWK). The transition has been successfully carried out as part of comprehensive revision of the questionnaires. Efforts to minimise discrepancies are being continued in other areas of the surveys and the Energy Balance. AGEB reports on plausibility checks Revision of the questionnaire for 2003-2011. Revision of the NEB 2023 undertaken	Completed or ongoing	

No.	Subject	Competence	Responsibility for execution	Reference (para)	Quotation from 2011 review report (FCCC/ARR/2011/DEU)	Instrument for implementation /publication	Activity for improvement	Result planned/achieved	Time perspective	Note
6.2	Discrepancies between EB and IEA data	BMWK, AGEB, persons responsible for questionnaires	BMWK	45	The ERT also noted differences between the inventory data and the corresponding IEA data (e.g. for solid fuels exports, the data show differences of over 60 per cent in some recent years […] Germany has provided some explanations for the divergences and informed the ERT that it is continuing to investigate these differences. The ERT considers that the differences cause no underestimation of emissions, but reiterates the recommendation of the previous review report that Germany explain the reasons for these differences between its inventory data and the corresponding IEA data in its next annual submission.		To be jointly defined in the framework of the action plan	See 6.1	Ongoing	

Annex 6.6 CO_2 emission factors

The CO_2 emission factors were completely revised for the 2015 report. For the first time, it was possible to draw extensively on data from emissions trading. Emissions trading data were available on relevant calorific values, emission factors, fuel quantities and data quality. The data were subjected to thorough quality control. For example, only factors on level 3 (measurement) entered into the calculations. In addition, emission factors were replaced if it was clear that they had been taken from lists. In emissions trading, some substance flows are not unambiguously named, and this can lead to erroneous material allocations in solid fuels categories. With regard to coal, it was possible to identify these misallocations using the calorific values, and then carry out the necessary resorting. Lignite and hard coal can be clearly differentiated using calorific values. Annually weighted average values were calculated from the quality-checked data. To make it possible to determine whether the resulting factors are representative, the underlying fuel quantities were compared with the corresponding quantities in the Energy Balance. In addition, every effort was made to achieve the greatest possible consistency between calorific values and emission factors.

In addition to the data from emissions trading, other data sources were evaluated, archive data were reviewed and measurements of our own were carried out. The recalculations up to 1990 were carried out with widely differing procedures, chosen in each case in accordance with the specific subject area. This was done with a view to assuring time series consistency and obtaining the most realistic solutions possible. Finding well-documented archive data for the year 1990 presented a special challenge, since the documents from that period are available only in paper form and are kept at various different institutions. What is more, data are seldom kept for a period of longer than 20 years.

Since no reliable and representative data are available on the carbon content remaining in ash, an oxidation factor of 1 was assumed. That figure is also the default value in the 2006 IPCC Guidelines (IPCC, 2006a).

A more detailed is provided in the following report: CO_2-Emissionsfaktoren für fossile Brennstoffe (CO2 emission factors for fossil fuels) - 2022 update (Juhrich, 2022).

Annex 6.6.1 Hard coal

For hard coal, an cross-sectoral emission factor is calculated, which in this case ensures that the total emissions are determined as accurately as possible. One exception is coking coal for the iron and steel industry, which differs considerably from steam coal. Another exception is anthracite coal used in the residential sector and in other small combustion plants; this coal has considerably higher calorific values and carbon-content levels.

For the other types of hard coal, emissions trading data from the years 2005-2014 were evaluated. There are substance flows that can be correlated with specific areas of origin. This makes it possible to determine origin-specific CO_2 emission factors and calorific values. Apart from the coal for which origin-specific data are available, there are quantities of mixed coal and coal of uncertain origin to consider. CO_2 emission factors and calorific values were determined for all individual coal fractions (Germany, South Africa, Australia, Indonesia, Colombia, Norway, Poland, Czech Republic, Russia, the U.S. and Venezuela). In addition, weighted averages were calculated for the other hard coal types for which specific values cannot be obtained. Two different methods for recalculating the emission factors for hard coal were reviewed. On the one hand, a weighted average for each year was calculated using the data on the various individual

areas of origin and the import flow figures from hard coal statistics. On the other, a weighted average was formed from all of the emission factors reported and checked in the emissions trading framework. The following figure shows the results of this comparison:

Table 489: Comparison of CO_2 emission factors for hard coal

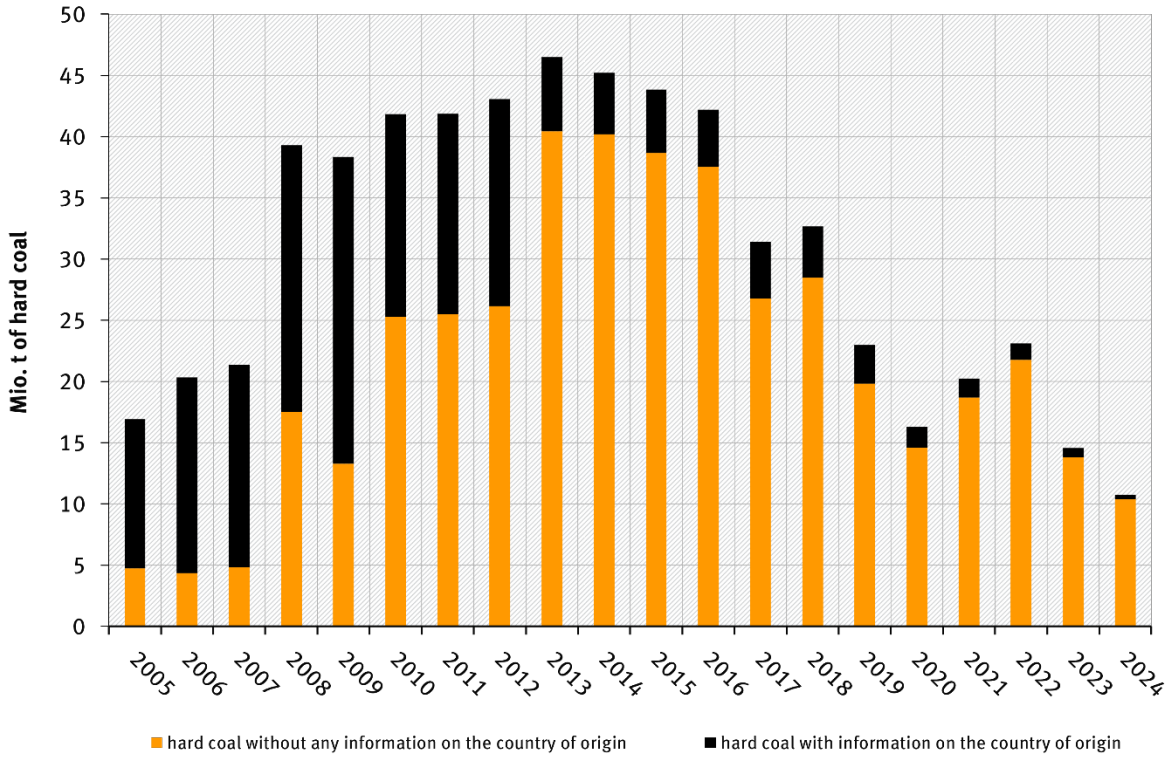
[t CO_2/TJ]	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Calculation via imports	93.874	93.976	93.865	93.924	93.993	94.003	94.181	93.652	93.276	93.888
Weighted EF from all ETS data	93.606	93.940	93.792	94.317	94.121	94.032	94.228	93.675	93.363	93.560
Difference	0.29%	0.04%	0.08%	-0.42%	-0.14%	-0.03%	-0.05%	-0.02%	-0.09%	0.35%

Since the differences are very small in most years, as of the year 2006 the weighted emission factors for all hard coal reported in the emissions trading framework (apart from that in the iron and steel sector) can be used – regardless of the area of origin involved. For the recalculation back to 1990, the origin-specific emission factors calculated from emissions trading data are combined with the relevant import flows. This produces a consistent time series.

Between 2014 and 2021, the CO_2 emission factors for hard coal were always below 94 t CO_2/TJ. In 2022, the value, at 94.3 t CO_2/TJ, was higher. This occurred because the structure of coal imports changed considerably in that year as a result of a prohibition on imports of Russian hard coal. Within an extremely short time, Russian hard coal, which until then had accounted for an important share of hard coal use, had to be replaced with hard coal from other areas of origin. In 2023, the emission factor was again above the level of 2014-2021, at 94.1 t CO2/TJ.

The following figure shows the quantities of hard coal that can be evaluated for the emission factors and calorific values measured in emissions trading.

Figure 134: Hard coal quantities for which emission factors and calorific values measured in the emissions trading framework are available

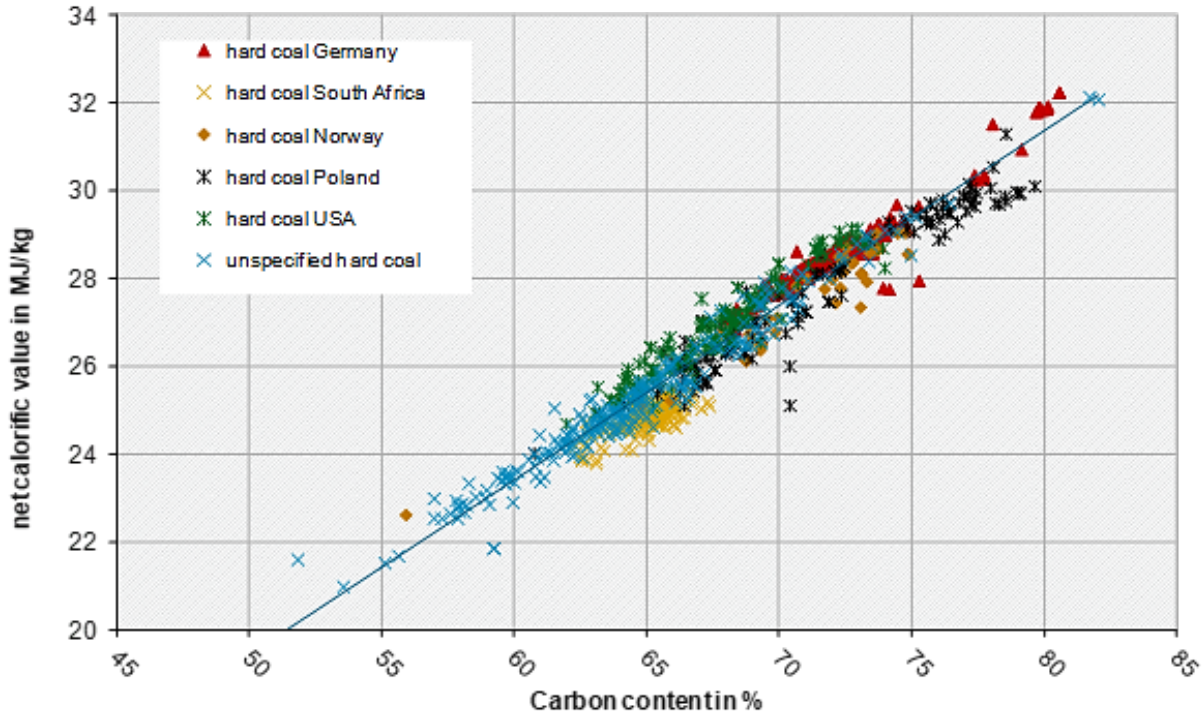


Source: own illustration, German Environment Agency

It emerges that the quality of the values increases – particularly as of the year 2008 – due to changes in regulations. Furthermore, the quantity of hard coal that can be clearly allocated to a specific mining area decreases significantly. For this reason, the most sensible approach from a technical standpoint is to form a weighted average for all hard coal, regardless of area of origin. This is the only way to ensure that the emission factors are representative.

All in all, very thorough quality checks were conducted, and numerous evaluations were carried out. As the following figure illustrates, it is possible to develop fairly clear origin profiles, and there is a clear relationship between carbon content and calorific value.

Figure 135: Relationship between carbon content and calorific values for various qualities of hard coal



Source: own illustration, German Environment Agency

Most types of hard coal have a carbon content (with respect to the original substance) of between 60 and 75%. The average, depending on the year concerned, lies between 65 and 66%. The hard coal in the lower range, with a carbon content as low as 56% and a calorific value of no more than 22 MJ/kg, can be referred to as “high-ballast coal”. The hard coal in the upper range, as of a calorific value of about 30 MJ/kg, is of coking coal quality. The highest carbon-content levels are found in anthracite.

The figure does not include values for the coking coal used in Germany. Coking coal was evaluated separately due to its special characteristics. Furthermore, no evaluable calorific values are reported for the iron and steel industry with regard to coal in emissions trading, meaning that only weight-based emission factors have been determined for this sector. Consequently, the coal quantities in that area have also been recorded in tonnes. Since the available statistics give virtually no calorific value figures, it seems useful to calculate with natural units. After intensive discussions with the responsible experts of the German Emissions Trading Authority (DEHSt), it proved possible to determine representative emission factors for the hard coal used in the iron and steel industry. From the same data set, it was possible to generate emission factors for hard coal coke, hard coal tar and benzene.

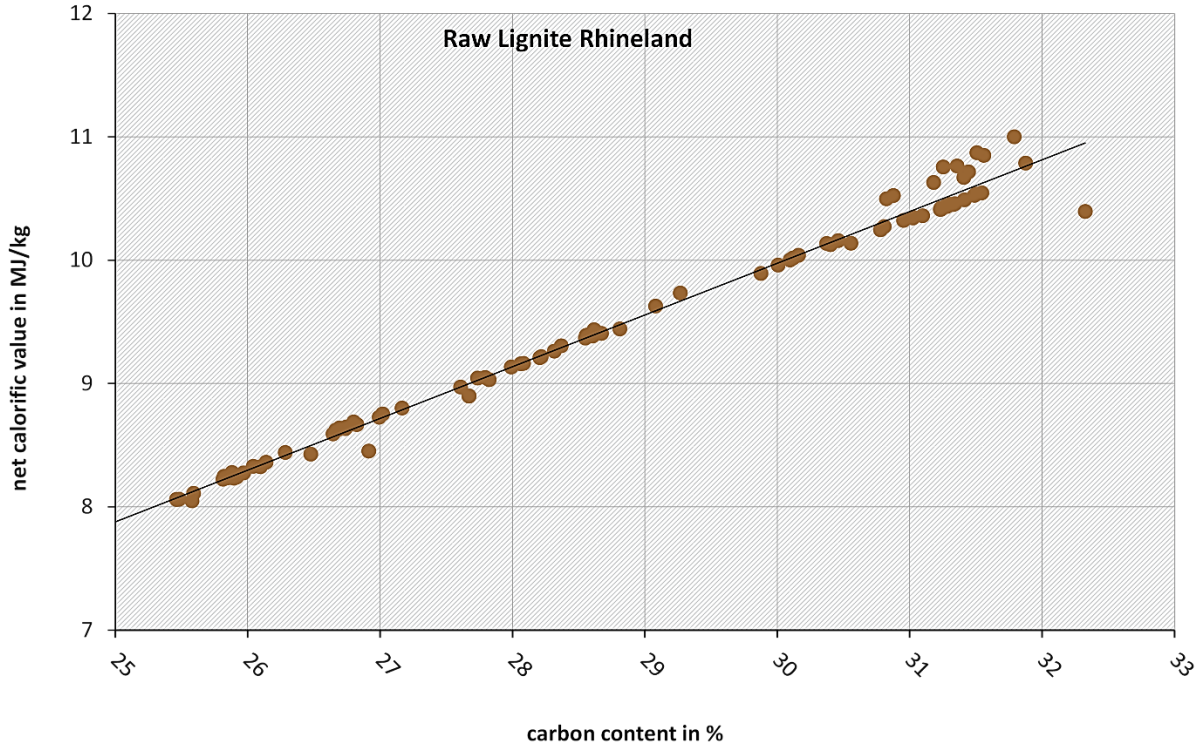
With regard to hard coal coke, an average, energy-based emission factor was calculated for all other industrial sectors from the emissions trading data for the years 2005-2013. The emission factors for the subsequent years differ only slightly, and thus calculations can continue to use the average value.

Since emissions trading statistics do not cover the hard coal briquettes used in small combustion plants, we carried out our own analyses for that area in a project. The resulting values have been entered back to the year 1990, since no representative values are available for the base year.

Annex 6.6.2 Lignite

The raw lignite used for electricity generation for the public grid can be allocated to specific mining districts using lignite statistics. For the period as of the year 2005, the emission factors are determined from emissions trading data. The carbon content figures (with respect to the original substance) are also available for specific mining districts. The following figure provides an example:

Figure 136: Relationship between carbon content and calorific values using the example of hard coal quality



Source: own illustration, German Environment Agency

The variances in sulphur content are larger in lignite than they are in hard coal. Since sulphur content has a noticeable effect on calorific value and thus on the relationship between carbon content and calorific value, lignite has to be evaluated specific to the mining district. As Figure 136 shows, there is a clear correlation between calorific value and carbon content. Consequently, for each relevant year the carbon content and the energy-related CO_2 emission factor can be calculated using the respective formula from the calorific value known for that year. This makes it possible to recalculate the figures back to 1990 – and thus to form a consistent time series. There are certainly some uncertainties, as smaller mines with different sulphur contents were probably still in operation in 1990. But this can no longer be determined retroactively. Hardly any carbon analyses were carried out in 1990 because carbon content was not an issue at that time. Only a few individual analyses were carried out, and their results are not necessarily representative. For example, only calorific value data are available for lignite from the Land of Hesse (Hessische Braunkohle), which was mined until 2003. For recalculation purposes, a mid-level sulphur content was assumed, a level between those found in the Mitteldeutsch ("central German") and Rhenish mining districts. This coal is of little relevance in terms of quantity, however. Between 1991 and 1992, the applicable emission factor changed

sharply because two power stations in that mining district went offline during that period, and they had been fired for some time with low-quality coal.

For raw lignite inputs in district heating stations, a weighted emission factor is calculated from lignite inputs for the public electricity supply. For industry and the residential, institutional and commercial (small consumers) sectors, a weighted emission factor was calculated, from sales statistics of the DEBRIV Federal German association of lignite-producing companies and their affiliated organisations that reflects the distribution of the relevant mining districts.

The emission factors for lignite briquettes were determined on the basis of emissions trading data for the period as of 2005. From those data, mining district-specific averages for each specific year were formed. A weighted average was then calculated using DEBRIV sales statistics. The emissions trading data cannot be used directly, since they do not completely reflect and cover the areas being reported on. The residential, institutional and commercial sectors do not take part in emissions trading. To ensure that the fuel-quality figures are the same, the ETS-based data evaluations were compared with our own analyses for briquettes in the residential sector. The two data sets show good agreement. While lignite briquettes are a standardised product for which certain quality requirements apply, mining district-specific differences still occur in the form of carbon content and sulphur content variances in the raw lignite used. The recalculation back to 1990 proved to be considerably more complicated than the calculation for raw lignite. From the ETS data for the period 2005 – 2013, it was possible to calculate an average CO_2 emission factor only for Rhenish lignite briquettes. That factor can also be used for the years 1990 – 2004. In the new German federal states, a great many briquette factories were closed in the early 1990s. This considerably changed fuel quality levels in that region. No briquettes are now produced from central German (Mitteldeutsch) lignite. Consequently, no current relevant measurements are available. For this reason, we had to rely on archive data in this area. Data from analyses carried out by Mohry in 1986, and data from the 1986 "Jahresbericht der Kohleindustrie der DDR" ("annual report on the coal industry of the GDR") were available. It emerged that the carbon content previously assumed for central German (Mitteldeutsch) briquettes was much too high. When calculating the average values, it was ensured that the emission factors corresponded to the calorific values published by DEBRIV. As a result, it was possible to calculate an annual CO_2 emission factor for each mining district. From those factors, it was then possible using DEBRIV sales statistics to calculate weighted annual emission factors.

Data on lignite dust and fluidised bed coal are easier to obtain, since emissions trading data are available from all relevant mining districts. For the recalculations back to 1990, average values from the years 2005 and 2008-2013 were used depending on data quality. In an approach similar to the one used for raw lignite and briquettes, a weighted emission factor was calculated for lignite dust and fluidised bed coal using DEBRIV sales statistics. As of the year 2005, the emission factors from emissions trading are entered directly into the calculation. Weighted factors are then calculated using mining district-specific sales statistics.

Lignite coke is currently being produced in only one mining district. In general, hearth furnace coke is used primarily for its properties as a material. Since fuel quality in this category fluctuates very little, an average was formed from the ETS data for the period 2008-2013 and then used for recalculations back to 1990. For the new German federal states, only one data source was available. These are analyses carried out by the Ingenieurschule für Bergbau und Energetik "Ernst Thälmann" (the "Ernst Thälmann" school of engineering, specialising in mining and energy technology) in Senftenberg. It seems plausible, however, that the coke studied in those analyses, in comparison to Rhenish coke, had a considerably lower carbon content and

much higher ash and sulphur content. Consequently, the emission factor calculated for the new German federal states is lower.

The emission factor determined for 2014, from emissions trading data, at 109,317 t CO_2/TJ, is very close to the average value calculated for 2005-2013, 109.578 t CO_2/TJ.

The data set from the Ingenieurschule für Bergbau und Energetik "Ernst Thälmann" in Senftenberg also included analyses for air-dried peat. The calorific value is consistent with the corresponding value used in the Energy Balance. The values for the lignite tar oil used in refineries in the new German federal states come from the same data source.

No data were available for the lignite tar used in the new German federal states. As an alternative, analysis data from the research report Vertrag Nr. (contract no.) 7220-EB/106 (DEBRIV 1980) were used. Lignite tar has not been used since 1991.

The ETS data can be used to generate CO_2 emission factors for meta-lignite for the period as of 2008. At present, only very small quantities of meta-lignite are used in Germany. To make it possible to calculate the applicable emission factors for the period back to 1990, the carbon/calorific value ratio was determined from the available ETS data. It was then possible using the calorific values known from the DEBRIV lignite statistics to produce a consistent time series.

Annex 6.6.3 Petroleum

Crude oil and naphtha are not used in combustion systems in Germany. For this reason, the emissions trading data do not include any carbon-content figures for these raw materials. In addition, no analysis values are available from other sources. For this reason, the default values from the 2006 Guidelines are used. The relevant factors are used only for the Reference Approach and for the transformation balance for refineries. Default values are also used for aviation gasoline and lubricants.

For the calculation of the CO_2 emission factors for gasoline, research report 502-1 of the German Society for Petroleum and Coal Science and Technology (DGMK), "Zusammensetzung von Ottokraftstoffen aus deutschen Raffinerien" ("Composition of gasoline fuels produced by German refineries")(Schmiedel, 2003) was comprehensively evaluated. The study looked at the components of the fuels involved in great detail. As a result, data are available on the average concentrations of 113 individual substances and 16 substance groups in the categories regular gasoline, super (premium) and super plus (premium plus) for all German refineries. The carbon content of the specified substances and the corresponding concentration were used to calculate a weighted carbon content for each of the three fuel grades, from which a weight-based emission factor was derived.

The factors were reviewed and updated in 2020 by PetroLab as part of a project "Analyse von Ottokraftstoffen und Flugbenzin zur Validierung der Faktoren" ("Analysis of gasoline fuels and aviation gasoline for validation of factors"). The results, which only relate to the fossil fuel fractions, are similar to those obtained in the DGMK study. The following table shows the mean values of the factors as obtained in projects to date:

Table 490: Comparison of CO_2 emission factors for the fossil fraction of motor fuel

	Units	Regular	Super (premium)	Super leaded	Super plus (premium plus)
Petrolab 2022	t CO_2/t	-	3.171	-	3.137
DGMK 2002	t CO_2/t	3.183	3.185	-	3.141

	Units	Regular	Super (premium)	Super leaded	Super plus (premium plus)
DGMK 1994	t CO_2/t	3.179	3.188	3.193	3.156
Max. difference	%	0.129	-0.551		-0.618

The level of the emission factor depends mainly on the fractions of aromatic compounds, kerosenes, ethers and other oxygen compounds involved, which differ in terms of their carbon content.

At the time the DGMK study was being carried out, gasoline did not yet contain any biogenic fractions. For this reason, it was not necessary to differentiate between the various fuel fractions involved. In the 2022 PetroLab study, on the other hand, differentiation between biogenic and fossil fuel fractions was required, since the fractions now have to be reported separately.

The energy-related emission factor used in the inventories is derived on the basis of the calorific values annually published by the Working Group on Energy Balances (AGEB, 2025d).

It was not possible to determine based on the various projects' analysis data a calorific value related solely to the fossil fuel fraction. As a result, for the time being the calculations are being carried out with the weight-specific emission factors given in Table 490. For conversion into energy units, the lower net calorific value used by the working group, 43,543 kJ/kg, is used. Pursuant to this approach, the derived energy-related emission factor is 72,787 kg CO_2/TJ (for 2022) – which lies within the range given by the IPCC Guidelines.

For the period as of 2005, the factors determined in the PetroLab study are used, since in 2005 a reduction of the aromatic content from 42 to 35% was required as a result of the amendment of the Fuel Quality Directive. It can be assumed that implementation did not take place on a year-by-year basis but rather on a rolling basis. For this reason, the figures between the years 2002 and 2005 were obtained by interpolation.

The basis for calculation of the emission factor for diesel fuel is research report (Forschungsbericht) 583 of the German Society for Petroleum and Coal Science and Technology (DGMK): "Zusammensetzung von Dieselkraftstoffen aus Deutschen Raffinerien 1999-2002" ("Composition of diesel fuels from German refineries, 1999-2002"). Winter and summer samples from 13 refineries were analysed for this study. From the analysis results, average values for the fuel quality in summer and in winter were calculated. In Germany, the availability of "winter diesel" is regulated by law. The law requires filling stations to offer winter diesel from 15 November to 28 February. In addition, a transition phase has to be taken into account, and thus a usage period of about 4 months can be expected for winter diesel. Consequently, diesel-powered vehicles operate with summer diesel for 8 months. A weighted emission factor was calculated from the analysis results for summer and winter diesel based on this distribution.

The CO_2 emission factors for light fuel oil, petroleum coke, heavy fuel oil and other petroleum products were calculated from emissions trading data. The relevant average values for the years 2005-2013 were applied to the years back to 1990. As of 2005 (or 2008, as relevant), year-specific, weighted average values from emissions trading will be used for petroleum coke, heating oil (heavy) and other petroleum products. It is difficult to draw an exact line between heavy fuel oil and other petroleum products. In accordance with the Mineral Oil Statistics (Mineralölstatistik), "other petroleum products" were defined as residual substances from refineries and the emission factor was calculated accordingly.

For refinery gas, a weight-based CO_2 emission factor was calculated from the ETS data. Since the annual fluctuations for such gas are small, the same factor formed from the average values for the years 2005-2013 was used for all years. While the lower calorific values specified in the

context of emissions trading show only slight annual fluctuations, the calorific values used in the Energy Balance vary significantly in some cases and are inconsistent with the ETS data. The refinery gas quantities reported in the Energy Balance come from the Mineral Oil Statistics. These values are consistent with the ETS data. In the interest of consistency, the lower calorific values used in the Energy Balance were chosen for inventory preparation. The emission factor will then be adjusted accordingly.

For determination of the emission factors for LP gas, first the applicable carbon content levels for butane and propane were calculated using molar masses. The respective fractions for the two components are published in the annual report of the German Liquid Petroleum Gas Association (Deutscher Verband Flüssiggas e.V.). The data up to 1990 were also provided by the association. A weighted emission factor is calculated for all of them based on the respective fraction of the two components, which is divided by the lower heating value used in the Energy Balance. The LP gas emission factors published in the NID apply only to energy-related consumption. The data for material-related use differ, since the relevant mixtures contain more butane than propane on average. Gas for energy-related use tends to contain more propane than butane. Unfortunately, the ratios between the two fuels are no longer available as of the report year 2017. For this reason, the existing butane-to-propane ratio will be carried forward in future. This is not expected to have a major impact. The fractions for the two fuels varied only insignificantly over the years.

Annex 6.6.4 Gases

According to the IPCC definition of fuels, some gaseous fuels are classified as solid fuels, as these are produced or manufactured from solid fuels according to the logic of the guidelines. This applies to coke oven gas, town gas, blast furnace gas and basic oxygen furnace gas. The other relevant produced gases are allocated to the liquid fuels category, since those gases are produced primarily by the chemical industry in non-energy-related consumption of naphtha and other petroleum products. These allocations are necessary to enable the Reference Approach to produce useful results.

For determination of emission factors for coke oven gas, blast furnace gas, basic oxygen furnace gas and petroleum gas, emissions trading data are used. For the recalculations back to 1990, average values were calculated from the ETS data for the period 2005-2013 and then used for the years 1990-2004. In energy statistics, blast furnace gas and basic oxygen furnace gas are reported only as a gas mixture. For this reason, a weighted emission factor for these mixtures was calculated from the individually determined emission factors for the two gases and produced quantities of blast furnace gas and basic oxygen furnace gas. There are certainly differences in the mixing ratio for the individual areas of application. Emissions trading data only partially cover combustion of blast furnace gas and basic oxygen furnace gas, but the calculation method used here ensures that the total emissions of such gases are still calculated correctly.

Until 1996, town gas was still used in Germany. In in the Energy Balance, it is combined with coke oven gas. The applicable fractions of coke oven gas and town gas cannot be determined on the usage side (the situation is similar to that for combustion of blast furnace gas and basic oxygen furnace gas). For this reason, here as a well a weighted emission factor is calculated – in this case from the produced quantities of coke oven gas and town gas. The values for town gas have been obtained from the firms of GASAG and DBI Gas- und Umwelttechnik GmbH Leipzig. Detailed analyses are available for the years 1989-1991. The different gases were mixed to yield mixtures with fairly constant town gas quality. DBI Gas- und Umwelttechnik GmbH Leipzig

provided information on the mixing ratios in which the gas fractions are combined to produce summer and winter-quality grades. The emission factors were weighted accordingly. The figures for fuel gas, which is used only in the new German federal states, were obtained from a data set provided by the Ingenieurschule für Bergbau und Energetik "Ernst Thälmann" (the "Ernst Thälmann" school of engineering, specialising in mining and energy technology) in Senftenberg. The term "fuel gas" is not clearly defined. Since this gas has been used primarily in mine power stations, it can be assumed to be lignite-based. These gases can vary widely in composition, however. Consequently, the applicable emission factors can also vary widely. They lie within the range 118.6 – 131 t CO_2/TJ. Taking a conservative approach so as not to overestimate base year emissions, the lowest emission factor is used for the inventory. The 1989 annual report for the energy sector (Energiewirtschaftlicher Jahresbericht 1989) gives a calorific value of 5.3 MJ/Nm^3 for "other gas", a figure that indicates a higher emission factor. Since coke oven gas, town gas and fuel gas are reported in combined form in the Energy Balance, the calorific values for these individual gases can no longer be determined.

Other produced gases are used primarily in the chemical industry. The category to which that term refers includes gases with high calorific values and large hydrogen fractions as well as flare gases with low calorific values and large nitrogen fractions. The emission factor is calculated from emissions trading data for the chemical industry. In the process, the total consisting of the emissions from use of other gases in the EU Emissions Trading System (ETS) is obtained. Fuel input quantities cannot be determined from emissions trading data, since some operators provide fuel inputs in tonnes, while others specify them in m^3. Only in individual cases are calorific values specified. The energy statistics provide relatively low fuel input figures, and the figures' annual changes do not always seem plausible. For this reason, the fuel quantities given in reporting for large combustion plants are used. This procedure ensures consistency with the air pollutant emission inventory. Finally, the CO_2 quantity determined from the ETS – the quantity resulting from combustion of other gases – is divided by the fuel input figure from reporting for large combustion plants to obtain a CO_2 emission factor. These CO_2 factors are roughly similar to those for refinery gas. This seems plausible, because the other gases produced by the chemical industry are similar to refinery gas. For this reason, many operators list these gases as refinery gas in energy statistics.

For mine gas, a methane content figure was calculated using the methane use data provided by the Gesamtverband Steinkohle (GVSt) hard coal mining association and the total methane quantities listed (in cubic metres) in the Energy Balance. A CO_2 emission factor was then calculated using the corresponding gas composition. Statistical differences result in some years, and thus calculations are carried out with the lowest methane content figure for the purposes of a conservative approach.

Since the natural gas quantities recorded in the emissions trading context are not representative, and since default emission factors are often used in this category, the company DBI Gas- und Umwelttechnik GmbH Leipzig carried out its own analyses as part of the project "Messungen der Erdgasqualität an verschiedenen Stellen im Netz zur Ableitung bzw. Verifizierung von durchschnittlichen Emissionsfaktoren und Heizwerte von Erdgas" (2014; measurements of natural gas quality at various locations within the network for the purposes of derivation and verification of average emission factors and calorific values for natural gas). Measurements were carried out at 32 locations throughout Germany for the project. The measurement points were selected to ensure that all important imported gases and the country's own domestic production were taken into account. In addition, a mixture distributed in Germany was analysed. In cases where measurement at a border crossing point was not possible, alternative measuring points were found. Within the relevant gas quality ranges, the

emission factors fluctuate only very slightly. And the values fluctuate very little overall. In an approach similar to that used for other fuels, no sector-specific emission factors were determined for natural gas. In this case, this is not possible due to the available data. It thus seems more realistic to determine weighted emission factors at the national level. They were calculated on the basis of the measurements carried out, import flows and the country's own production. Since 2015, it has no longer been possible to use this calculation method, since large quantities of imports are subject to confidentiality. As a result, for the period as of 2015, the weighted average values calculated from emissions trading data have been used, even though these average values are not fully representative of the actual situation. In previous years, the different factors were very similar.

In 2022, the emission factor for natural gas changed noticeably, rising above 56 t CO_2/TJ for the first time since the beginning of the time series in 1990. This resulted from a considerable reduction in gas deliveries from Russia that had to be replaced by gas with other quality grades. The new emission factor 56.2 t CO_2/TJ is closer to the emission factor for Norwegian natural gas, which was imported in large quantities to offset the shortfall in Russian gas. This trend continued in 2023.

Annex 6.6.5 Waste and special fuels

For waste, a carbon content pursuant to VDI 3460 is assumed. Energy statistics serve as the data source for the calorific values. The data for special fuels were obtained from the project "Inputs of secondary fuels" (Einsatz von Sekundärbrennstoffen) Lechtenböhmer, Nanning, et al. (2006b), FKZ 204 42 203/02). These data still need to be reviewed using emissions trading data and corrected as necessary. In general, it is difficult to compare data on fuels with relevant biomass fractions with ETS data, since the emission factors for fuels do not always take account of the biomass fractions. What is more, the terms used in the ETS are not always unambiguous. And since the calorific values of special fuels vary considerably more than those of conventional fuels, calorific values cannot be used for unambiguous identification of special fuels. All of these factors considerably complicate such comparisons. While cross-sector emission factors are largely determined for conventional fuels, sector-specific calculations must be made for special fuels.

For a few special fuels, emissions trading data were already evaluated. This applies to waste oil and waste plastics. These values are used in the carbon balance for the iron and steel industry. The emission factor for waste tyres was calculated from ETS data from the year 2010.

Annex 6.6.6 Biomass fuels

The emission factors for the biomass fuels that are used as substitute fuels in industry have also been obtained as part of the project "Inputs of secondary fuels" (Einsatz von Sekundärbrennstoffen) Lechtenböhmer, Nanning, et al. (2006b), FKZ 204 42 203/02). The CO_2 emission factors for wood have been obtained from the research report "Effiziente Bereitstellung aktueller Emissionsdaten für die Luftreinhaltung" ("Efficient provision of current emissions data for purposes of air quality control"; (Struschka et al., 2008)).

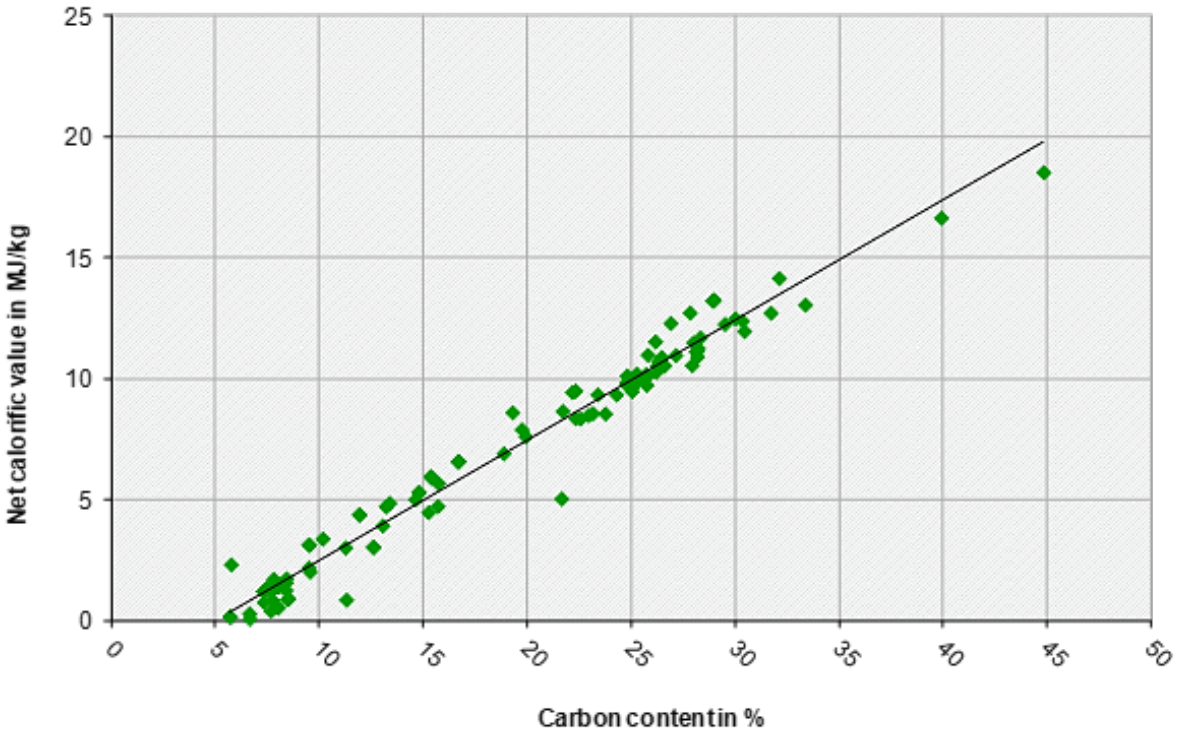
Emissions factors for sulphate and sulphite liquor were calculated for the liquor from pulp production based on information provided by the operator regarding the material composition. A weighted mean is formed annually by applying those two values to the produced quantities of sulphite and sulphate wood pulp.

The process for calculation of the CO_2 emission factors for biogas, landfill gas and sewage gas began with evaluation of relevant calorific values from energy statistics. Averages of those calorific values were then calculated for each category from the values for the years 2009-2011. Corresponding methane quantities were then determined from each such average calorific value. Since, in addition to methane, these gases consist mainly of carbon dioxide and a small nitrogen fraction, the calorific value is determined using the methane content. Biogases also contain other hydrocarbons, which account for approximately 1% of their composition. A CO_2 emission factor was then calculated using this gas composition.

The emission factor for bioethanol was calculated on the basis of the number of carbon atoms and the molar mass of ethanol. The relevant calorific value is published by the Bundesverband der Deutschen Bioethanolwirtschaft German bioethanol industry association. For biodiesel, we did not carry out any analyses of our own. For this reason, the default emission factor given in the 2006 IPCC Guidelines (IPCC, 2006a) used.

For determination of the CO_2 emission factors for sewage sludge, waste wood and animal meal, data from emissions trading were evaluated. For animal meal and waste wood, a median was formed from data on carbon content and calorific value available for the period 2005 to 2014. For sewage sludge, data from municipal waste management companies were also included in the evaluation. Since sewage sludges are used both in their original state and in a dry state, the spectrum of calorific values ranges from < 1 MJ/kg to 18 MJ/kg. Consequently, the standard deviation for the emission factors is so high that it would not be useful to form an average or median. Since the carbon content correlates very well with the calorific value, a suitable formula can be derived from the graphic (cf. the following figure).

Figure 137: Relationship between carbon content and calorific values for various sewage sludges



Source: own illustration, German Environment Agency

As a result, the carbon content and emission factors can be calculated using the calorific values, as given in energy statistics, for co-incineration and mono-incineration.

Annex 6.6.7 List of carbon dioxide emission factors derived for energy & industrial processes

The following tables provide an overview of the carbon dioxide emission factors used in the inventory.

Table 491: CO_2 emission factors derived for emissions reporting for the period as of 1990; energy

Fuel-based emission factors	Units	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024
Coals												
Hard coal												
Raw hard coal (power stations, industry)	t CO2/TJ	93.1	93.1	93.5	93.9	94.0	93.5	93.6	93.9	94.3	94.1	94.4
Hard coal briquettes	t CO2/TJ	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9
Hard coal coke (without iron & steel industry)	t CO2/TJ	108.1	108.1	108.1	108.1	108.1	108.1	108.3	107.8	108.6	108.6	109.6
Hard coal coke for the iron & steel industry	t CO2/t	3.29	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
Anthracite (heat market for households, commerce, trade, services)	t CO2/TJ	97.6	97.6	97.6	97.6	97.6	97.6	97.6	97.6	97.6	97.6	97.6
Ballast hard coal, *old German federal states*	t CO2/TJ	95.2										
Coking coal, *Germany*	t CO2/t	2.96	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.8	2.8	2.8
Hard coal for the iron & steel industry	t CO2/t	2.92	2.9	2.9	3.0	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Other hard coal products	t CO2/t	3.30	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Hard coal tar	t CO2/t	3.27	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Benzene	t CO2/t	3.38	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.3	3.4
Lignite												
Raw lignite												
Public district heating stations, *Germany*	t CO2/TJ		111.7	110.8	111.1	110.7	111.0	110.6	110.8	110.8	109.4	109.4
Old German federal states	t CO2/TJ	113.8										
New German federal states	t CO2/TJ	110.0										
Industry, commercial and institutional and residential (“small consumers”), *Germany*	t CO2/TJ		106.0	109.8	108.2	106.3	104.0	105.9	105.8	105.4	104.4	103.6
Old German federal states	t CO2/TJ	114.7										
New German federal states	t CO2/TJ	107.7										
Public power stations; mining district:												
Rhineland	t CO2/TJ	114.8	113.9	113.1	113.2	113.3	113.1	113.3	113.1	113.1	113.9	113.8
Helmstedt	t CO2/TJ	98.7	98.7	98.7	98.7	96.7	99.5	NO	NO	NO	NO	NO
Hesse	t CO2/TJ	112.2	103.2	103.5	NO	NO	NO	NO	NO	NO	NO	NO
Lausitz	t CO2/TJ	111.2	111.3	111.5	111.2	110.6	110.9	110.2	111.0	111.1	107.5	107.4
Central Germany	t CO2/TJ	105.7	103.9	102.9	104.0	103.4	102.9	103.6	103.2	103.2	101.7	101.6
Lignite briquettes, *Germany*	t CO2/TJ		98.3	99.0	99.3	99.0	99.4	99.2	99.2	98.1	99.4	101.0
Old German federal states	t CO2/TJ	99.5										
New German federal states	t CO2/TJ	96.6										
Lignite tar, *new German federal states*	t CO2/TJ	82.9										

Fuel-based emission factors	Units	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024
Lignite tar oil, *new German federal states*		78.6										
Pulverised lignite and fluidised bed coal *Germany*	t CO2/TJ		97.6	98.1	98.1	98.0	98.0	97.5	97.5	97.4	97.2	97.4
Old German federal states	t CO2/TJ	98.3										
New German federal states	t CO2/TJ	96.1										
Lignite coke, *Germany*	t CO2/TJ		109.6	109.6	109.6	109.6	109.6	109.6	109.6	109.6	109.6	109.6
Old German federal states	t CO2/TJ	109.6										
New German federal states	t CO2/TJ	100.2										
Peat, old federal states, *Germany*		101.8	101.8	101.8	101.8	NO	NO	NO	NO	NO	NO	NO
Meta-lignite (“hard lignite”)	t CO2/TJ	96.4	96.4	96.5	NO	94.9	94.5	94.4	93.6	94.0	93.4	93.7
Petroleum												
Crude oil [4)]	t CO2/TJ	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3
Gasoline	t CO2/TJ	73.1	73.1	73.1	72.9	72.8	72.8	72.8	72.8	72.8	72.8	72.8
Naphtha *Germany* [4)]	t CO2/TJ		73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3
Old German federal states [4)]	t CO2/TJ	73.3										
New German federal states [4)]	t CO2/TJ	73.3										
Kerosene [4)]	t CO2/TJ	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3
Aviation gasoline	t CO2/TJ	71.2	71.2	71.2	71.2	71.2	71.2	71.2	71.2	71.2	71.2	71.2
Diesel fuel, *Germany*	t CO2/TJ		74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0
Old German federal states	t CO2/TJ	74.0										
New German federal states	t CO2/TJ	74.0										
Light heating oil, *Germany*	t CO2/TJ		74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0
Old German federal states	t CO2/TJ	74.0										
New German federal states	t CO2/TJ	74.0										
Heavy fuel oil	t CO2/TJ	79.8	79.8	79.8	79.6	79.7	80.9	79.7	79.5	79.5	79.6	80.6
Petroleum	t CO2/TJ	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0
Petroleum coke (not including coke burn-off in catalyst regeneration)	t CO2/TJ	94.8	94.8	94.8	94.8	94.6	97.6	103.4	101.8	99.6	100.6	99.3
LP gas, Germany (energy-related consumption)	t CO2/TJ		65.3	64.4	65.3	65.3	66.3	66.3	66.3	66.3	66.3	66.3
Old German federal states	t CO2/TJ	65.6										
New German federal states	t CO2/TJ	65.6										
Refinery gas, *Germany*	t CO2/TJ		56.9	56.7	57.0	66.4	62.0	57.2	57.1	57.3	57.1	56.4
Old German federal states	t CO2/TJ	54.6										
New German federal states	t CO2/TJ	54.6										
Other petroleum products, *Germany*	t CO2/TJ		82.1	82.1	82.1	82.5	82.3	80.4	81.9	82.1	82.5	81.9
Old German federal states	t CO2/TJ	82.1										
New German federal states	t CO2/TJ	82.1										
Lubricants [4)]		73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3
Gases												
Coke oven gas, *Germany*	t CO2/TJ		41.0	41.0	40.7	40.3	41.3	41.0	41.5	40.9	40.5	40.8
Old German federal states	t CO2/TJ	41.0										
New German federal states	t CO2/TJ	43.6										
Coking-plant and city gas, *Germany*	t CO2/TJ		42.6									
Old German federal states	t CO2/TJ	43.2										
New German federal states	t CO2/TJ	58.3										
Blast furnace gas and basic oxygen furnace gas, *Germany*	t CO2/TJ		257.1	258.7	252.9	259.7	261.3	256.4	254.5	257.6	257.7	256.1
Old German federal states	t CO2/TJ	264.6										
New German federal states	t CO2/TJ	264.6										
Fuel gas, *New German federal states*	t CO2/TJ	118.4										
Other produced gases, *Germany*	t CO2/TJ	61.5	61.5	61.5	61.5	61.5	63.7	56.0	55.6	54.3	57.7	57.5
Natural gases												
Natural gas, *Germany*	t CO2/TJ		55.8	55.8	55.9	55.9	55.9	55.8	55.8	56.2	56.3	56.4

Fuel-based emission factors	Units	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024
Old German federal states	t CO2/TJ	55.7										
New German federal states	t CO2/TJ	55.5										
Petroleum gas	t CO2/TJ	61.9	61.9	61.9	61.9	61.4	61.6	61.0	61.1	61.1	60.8	61.0
Mine gas	t CO2/TJ	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1
Waste [2)]												
Household waste/municipal waste	t CO2/TJ	109.6	96.9	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5
Industrial waste, *Germany*	t CO2/TJ		71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1
Old German federal states	t CO2/TJ	73.9										
New German federal states	t CO2/TJ	74.9										
Special waste, Germany	t CO2/TJ		83.0	83.0	83.0	83.0	83.0	83.0	83.0	83.0	83.0	83.0
Special fuels [1)]												
Used oil	t CO2/TJ	75.7	75.7	75.7	75.7	75.9	75.3	76.9	82.4	81.3	81.9	71.9
Waste plastics	t CO2/TJ	80.9	80.9	80.9	80.9	80.9	80.9	80.9	80.9	80.9	80.9	80.9
Waste tyres	t CO2/TJ	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4
Bleaching clay	t CO2/TJ	NO	78.2	78.2	78.2	78.2	78.2	78.2	78.2	78.2	78.2	78.2
Sewage sludge (2 MJ/kg)	t CO2/TJ	NO	NO	NO	168.9	168.9	168.9	168.9	168.9	168.9	168.9	168.9
Sewage sludge (4 MJ/kg)	t CO2/TJ	NO	NO	NO	120.4	120.4	120.4	120.4	120.4	120.4	120.4	120.4
Sewage sludge (6 MJ/kg)	t CO2/TJ	NO	NO	NO	104.2	104.2	104.2	104.2	104.2	104.2	104.2	104.2
Sewage sludge (8 MJ/kg)	t CO2/TJ	NO	NO	NO	96.1	96.1	96.1	96.1	96.1	96.1	96.1	96.1
Sewage sludge (10 MJ/kg)	t CO2/TJ	NO	NO	NO	91.3	91.3	91.3	91.3	91.3	91.3	91.3	91.3
Solvents (waste)	t CO2/TJ	74.2	74.2	74.2	74.2	74.2	74.2	74.2	74.2	74.2	74.2	74.2
Biomass fuels [3)]												
Spent liquors from pulp production	t CO2/TJ	121.1	121.1	110.3	104.8	98.3	97.8	95.4	97.8	97.8	94.7	94.0
Fibre/de-inking residues	t CO2/TJ	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9
Firewood, untreated	t CO2/TJ	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1
Waste wood, wood scraps (industry)	t CO2/TJ	107.8	107.8	107.8	107.8	107.8	107.8	107.8	107.8	107.8	107.8	107.8
Waste wood, wood scraps (commercial/institutional)	t CO2/TJ	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4
Bark	t CO2/TJ	80.6	80.6	80.6	80.6	80.6	80.6	80.6	80.6	80.6	80.6	80.6
Animal meals and fats	t CO2/TJ	85.8	85.8	85.8	85.8	85.8	85.8	85.8	85.8	85.8	85.8	85.8
Biogas	t CO2/TJ	90.6	90.6	90.6	90.6	90.6	90.6	90.6	90.6	90.6	90.6	90.6
Landfill gas	t CO2/TJ	111.4	111.4	111.4	111.4	111.4	111.4	111.4	111.4	111.4	111.4	111.4
Sewage gas	t CO2/TJ	104.9	104.9	104.9	104.9	104.9	104.9	104.9	104.9	104.9	104.9	104.9
Bioethanol	t CO2/TJ	NO	NO	NO	71.6	71.6	71.6	71.6	71.6	71.6	71.6	71.6
Biodiesel [4)]	t CO2/TJ	NO	70.8	70.8	70.8	70.8	70.8	70.8	70.8	70.8	70.8	70.8
Other factors unit [kg/t]												
Flue-gas desulphurisation	kg/t	440.0	440.0	440.0	440.0	440.0	440.0	440.0	440.0	440.0	440.0	440.0

1) Fuels as defined in the inventory data may differ from the designations used in other standards and are only specified in the inventory and supported by EF.

2) The CO_2 emission factors for waste are based on the entire carbon content of the waste (both fossil and biogenic). Biomass is defined in accordance with the mass percentage.

3) Listed for selected fuels, whereby calculated CO_2 emissions are only provided for information purposes and are not included in the total quantities in the inventory; biomass fractions from special fuels (see above) are not listed separately, because their CO_2 EFs are not differentiated.

4) Default values

Note: The information and FAQs provided by the German Emissions Trading Authority (DEHSt) must be taken into account in any use of substance data from the NID in the context of the ETS.

Table 492: CO_2 emission factors derived for emissions reporting for the period as of 1990, industrial processes

[kg CO2/t (raw material or product)]	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024
2.A.1 Production of cement clinkers	530.00	530.00	530.00	530.00	530.00	530.00	530.00	530.00	530.00	530.00	530.00
2.A.2 Production of burnt lime	746.00	746.00	746.00	746.00	746.00	746.00	746.00	746.00	746.00	746.00	746.00

[kg CO2/t (raw material or product)]	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024
2.A.2 Production of dolomite lime	867.00	867.00	867.00	867.00	867.00	867.00	867.00	867.00	867.00	867.00	867.00
2.A.3 Production of container glass	193.00	193.00	193.00	193.00	193.00	193.00	193.00	193.00	193.00	193.00	193.00
2.A.3 Production of flat glass	208.00	208.00	208.00	208.00	208.00	208.00	208.00	208.00	208.00	208.00	208.00
2.A.3 Production of household and table glassware	120.00	120.00	120.00	120.00	120.00	120.00	120.00	120.00	120.00	120.00	120.00
2.A.3 Production of special glass	113.00	113.00	113.00	113.00	113.00	113.00	113.00	113.00	113.00	113.00	113.00
2.A.3 Production of glass fibres	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00
2.A.3 Production of rock wool	299.00	299.00	299.00	299.00	299.00	299.00	299.00	299.00	299.00	299.00	299.00
2.A.3 Production of glass[1)]	118.94	115.64	112.76	115.53	122.23	117.62	115.82	116.47	115.06	113.96	114.19
2.A.4.a Production of ceramic[2)]	71.79	74.93	69.47	61.55	59.24	54.77	53.26	53.61	53.34	49.55	48.69
2.A.4.b Use of soda ash	415.00	415.00	415.00	415.00	415.00	415.00	415.00	415.00	415.00	415.00	415.00
2.B.1 Production of ammonia[3)]	2227.63	2246.17	2160.68	2190.69	2171.33	1507.97	1380.36	1387.44	1428.54	1447.93	1353.99
2.B.5 Production of calcium carbide	C	C	C	C	C	C	C	C	C	C	C
2.B.7 Production of soda ash	C	C	C	C	C	C	C	C	C	C	C
2.B.8 Petrochemicals	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00
2.B.8.f Production of carbon black	1,960	1,960	1,960	1,960	1,960	1,960	1,960	1,960	1,960	1,960	1,960
2.C.1 Production of electrical steel	8.50	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40
2.C.1 Production of oxygen steel; limestone input	440.00	440.00	440.00	440.00	440.00	440.00	440.00	440.00	440.00	440.00	440.00
2.C.2 Production of ferroalloys	1500.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
2.C.3 Production of primary aluminium	1367.00	1367.00	1367.00	1367.00	1367.00	1367.00	1367.00	1367.00	1367.00	1367.00	1367.00
2.C.5 Production of refined lead (D)		371.00	220.00	220.00	220.00	220.00	220.00	220.00	220.00	220.00	220.00
2.C.5 Production of refined lead (old German federal states)	434.00										
2.C.5 Production of refined lead (new German federal states)	200.00										
2.C.6 Zinc production: primary and resmelted zinc	1720.00	1720.00	1720.00	1720.00	1720.00	1720.00	1720.00	1720.00	1720.00	1720.00	1720.00

C= Confidential data

D: Reference to Germany as a whole

1) 2.A.3 for all glass types: CO2-EF = (EM total, including inputs of used glass)/activity data

2) 2.A.4.a for all products: CO2-EF = EM total/activity data

3) 2.B.1: CO2-EF = (EM - Recovery amount)/activity data

Note: The information and FAQs provided by the German Emissions Trading Authority (DEHSt) must be taken into account in any use of substance data from the NIR in the context of the ETS.

Annex 7 Other detailed methodological descriptions for individual source or sink categories

Annex 7.1 Other detailed methodological descriptions for CRF 1 (Energy)

Annex 7.1.1 Energy industry (1.A.1)

Annex 7.1.1.1 Methodological issues of determination of emission factors (Chapter 3.2.4.2)

This section of the 2022 NIR explains the key steps in the research projects Rentz et al. (2002) and Fichtner et al. (2011) in determining emission factors, excluding CO_2 emission factors.

Annex 7.1.2 Transport (1.A.3)

Annex 7.1.2.1 Transport – Civil aviation (1.A.3.a)

Annex 7.1.2.1.1 Derivation of additional emission factors (1.A.3.a)

Kerosene

Sulphur dioxide emissions are directly dependent on the sulphur content of kerosene, which is subject to regional and temporal fluctuations. IPCC (2006a) gives an EF of 1 kg SO_2/t kerosene, which is based on a sulphur content of 0.05% by weight. According to information of the Fachausschuss für Mineralöl- und Brennstoff-Normung[118] (FAM; technical committee for petroleum and fuels standardisation), kerosene in Germany typically has a total sulphur content of about 0.01% by weight, i.e. one-fifth of the content given by the IPCC. The 2009 inventory report uses a sulphur-content figure of 0.021% by weight for kerosene on the basis of measurements from the year 1998 (Döpelheuer, 2002). Since an emission factor that decreases over time appears plausible due to improved processes and lower limit values, a linear decrease between the reference years 1990 (1.08 g SO_2/kg kerosene), 1998 (0.4 g) and 2009 (0.2 g) is assumed here. In addition, it is assumed that all of the sulphur in the fuel is converted into sulphur dioxide. - Because the emission factor depends directly and solely on the sulphur content of the kerosene, this emission factor is used for both flight phases.

NO_X and CO emissions are calculated using implied emission factors based on TREMOD-AV calculations. These results are based on aircraft-type-specific and operating condition-specific emission factors taken largely from the EMEP/EEA database. Adjusted emission factors have to be used in some cases when specific aircraft types cannot be directly allocated to the proper categories, even using data on technically similar aircraft types. These emission factors were determined using emissions functions in the context of regression calculations that calculate the emission factor for each engine type as a function of take-off weight. The emission factors of the existing types as specified in Knörr et al. (2012) serve as the basis for these functions.

In each case, the NMVOC emission factors are obtained from the difference between the emission factor for hydrocarbons and that for methane.

[118] Personal e-mail communication with Dr Feuerhelm, FAM Hamburg, 9 June 2009

Aviation gasoline

In an approach similar to that used for kerosene, the following emission factors are taken from the TREMOD AV model:

Table 493: 2024 emission factors for aviation gasoline, in [kg/TJ]

	1.A.3.a (domestic flights)		1.D.1.a (international flights)	
	L/TO	Cruise	L/TO	Cruise
CO_2	71,199			
CH_4	162	0.00	153	0.00
N_2O	2.30			
SO_2	0.46			
NO_X	98.9	148	85.5	142
NMVOC	650	590	613	585
CO	16,766	20,433	18,812	21,247

Source: TREMOD AV (Knörr, Allekotte, et al., 2025)

Table 494: Overview of the emission factors for kerosene, in [kg/TJ]

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024
CO_2	73,256										
SO_2	19.7	19.5	19.5	19.5	19.6	19.6	19.6	19.6	19.6	19.6	19.6
Kerosene, L/TO, national (1.A.3.a)											
CH_4	9.02	9.05	9.06	9.71	9.88	9.65	11.2	20.1	23.1	18.2	12.2
N_2O	2.81	2.79	2.79	2.79	2.80	2.80	2.80	2.80	2.80	2.80	2.80
NO_X	290	320	282	282	273	300	308	286	272	288	305
NMVOC	36.1	36.2	36.2	38.8	39.5	38.6	44.8	80.4	92.2	72.8	48.7
CO	227	225	273	293	305	273	280	402	442	372	369
Kerosene, cruise, national (1.A.3.a)											
CH_4	0.00										
N_2O	2.34										
NO_X	330	367	336	340	334	368	379	357	358	375	376
NMVOC	16.0	17.6	17.7	18.6	20.1	21.1	23.7	36.3	35.8	28.2	21.2
CO	150	152	177	194	205	198	217	272	310	237	305
Kerosene, L/TO, international (1.D.1.a)											
CH_4	15.4	9.37	9.13	6.76	5.92	5.49	5.33	5.17	4.77	4.72	4.46
N_2O	2.11	2.09	2.09	2.09	2.10	2.10	2.10	2.10	2.10	2.10	2.10
NO_X	296	306	287	302	323	342	352	368	367	365	365
NMVOC	61.7	37.5	36.5	27.0	23.7	21.9	21.3	20.7	19.1	18.9	17.8
CO	253	230	251	240	221	204	198	189	189	187	184
Kerosene, cruise, international (1.D.1.a)											
CH_4	0.00										

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024
N_2O	2.34										
NO_X	313	316	313	328	337	351	365	379	378	378	375
NMVOC	13.5	9.09	9.15	6.13	5.33	4.72	4.44	4.49	4.13	4.21	4.13
CO	74.4	62.1	61.0	48.5	42.6	38.1	36.5	35.1	34.8	34.6	37.4

Source: TREMOD AV (Knörr, Allekotte, et al., 2025)

[a] pursuant to IPCC (2006a): Volume 2, Chapter 3.6, Table 3.6.5: Methane emissions during cruise flight are negligibly low.

Annex 7.1.2.2 Derivation of activity data for road transport (1.A.3.b)

Annex 7.1.2.2.1 Harmonisation with the Energy Balance

The basis for CSE data collection for the road transport sector consists of energy consumption data provided by the Working Group on Energy Balances (AGEB). For each year, the sum of the activity data for the various individual structural elements must be equivalent to the Energy Balance data, in terajoules (TJ). The relevant basic Energy Balance data are shown in Table 495 below.

Table 495: Energy inputs in road transport, since 1990

Year	Gasoline	Diesel	Biofuels	CNG, LPG & LNG	Petroleum	Lubricants [a]
Energy input pursuant to Energy Balances 1990-2024 (last revision: 10/2025) in TJ						
1990	1,330,479	735,920		138		2,543
1991	1,332,285	785,174		137		1,702
1992	1,344,129	853,502		229		1,299
1993	1,350,617	907,787		184	473	872
1994	1,276,637	932,060		184	559	596
1995	1,299,982	964,013	1,504	138	610	455
1996	1,299,879	964,580	2,046	115	638	372
1997	1,297,487	979,586	3,652	106	357	266
1998	1,300,463	1,022,794	4,081	106	637	206
1999	1,300,602	1,097,036	5,370	100	637	116
2000	1,237,055	1,108,105	12,276	94.0	414	82.7
2001	1,199,318	1,097,416	16,740	98.0	471	74.5
2002	1,166,381	1,105,842	20,460	607	472	77.3
2003	1,107,428	1,069,729	29,948	3,185		72.8
2004	1,073,174	1,102,318	40,029	4,666		72.4
2005	1,002,361	1,081,211	78,865	5,496		79.3
2006	967,016	1,125,137	143,944	10,845		79.6
2007	891,408	1,065,886	155,699	14,607		79.7
2008	852,680	1,090,704	126,100	22,616		83.6
2009	827,600	1,113,086	113,751	29,078		88.7
2010	790,544	1,155,828	120,289	28,478		82.5
2011	787,483	1,182,061	115,903	28,916		80.1

Year	Gasoline	Diesel	Biofuels	CNG, LPG & LNG	Petroleum	Lubricants [a]
2012	739,581	1,211,695	120,012	26,644		75.4
2013	738,174	1,267,041	109,168	28,556		77.7
2014	741,983	1,287,335	113,191	25,920		74.2
2015	731,258	1,342,885	105,665	24,546		80.4
2016	732,014	1,380,618	106,023	23,136		82.6
2017	735,005	1,427,136	108,141	20,936		79.5
2018	713,836	1,385,288	112,512	22,034		78.5
2019	720,708	1,391,411	111,583	19,587		79.6
2020	649,012	1,244,496	134,924	14,932		82.6
2021	653,665	1,255,404	120,783	17,567		73.0
2022	674,363	1,252,038	122,597	16,912		78.1
2023	690,409	1,189,167	128,297	14,865		68.9
2024	703,886	1,175,978	117,701	10,090		68.8

Sources: Evaluation tables for Energy Balances; Official Mineral Oil Statistics (Amtliche Mineralöldaten) (BAFA, 2025b).
[a] Biodiesel, biogasoline and biomethane; [b] as a component of 1:50 two-stroke fuel mixtures

The Energy Balance is also used to model transport quantity structures in TREMOD. For example, the German Economic Institute (DIW) carries out a fuel consumption calculation in order to derive total mileage travelled Heilwig (2002). Some of the results of the calculation are incorporated into TREMOD for passenger car transport. The DIW uses a fuel consumption calculation to determine total domestic mileage; TREMOD uses some other sources and assumptions to estimate total domestic mileage – especially for goods transport (cf. the detailed description in Knörr et al. (2002)). This estimate also takes the basic figures of the Energy Balance into account.

On the other hand, due to the many dependencies and uncertainties in the model and the basic data that must be taken into account, no feasible means is available for comparing mileage and energy consumption, for each year and each vehicle layer, in such a manner that the results yield the Energy Balance sum and the mileage and mean energy consumption figures in the time series are plausible. For this reason, the TREMOD results for the energy consumption are corrected at the end of the process so that the total for each reference year corresponds to the relevant figure in the Energy Balance.

Since TREMOD calculates energy consumption in tonnes, the results first have to be converted into TJ. This is done with the calorific values provided by the Working Group on Energy Balances. While a uniform value of 43.542 MJ/kg is assumed for gasoline over all years, year-specific values are used for diesel fuels (see Table 496).

Table 496: Mean calorific values for diesel fuels and liquefied petroleum gas in road transport, in MJ/kg

Validity period	Diesel fuel	Liquefied petroleum gas
1990-1992	42.70	
from 1993 onwards	42.96	
2003	42.83	46.33

Validity period	Diesel fuel	Liquefied petroleum gas
2004	42.43	46.32
2005	42.22	46.12
2010	42.68	45.84
2015	42.57	45.12
2016	42.24	45.90
2017	42.70	44.75
2018	42.89	45.78
2019	42.69	45.53
2020	42.97	46.08
2021	42.67	46.05
2022	42.72	45.97
2023	42.76	45.96
2024	42.85	45.91

Source: Working Group on Energy Balances (AGEB)

The correction factors are derived in TREMOD separately for the various vehicle categories, as follows:

- Firstly, a correction factor for gasoline is derived from the calculated gasoline consumption for all vehicle categories and from gasoline sales pursuant to the Energy Balance.
- The correction factor for gasoline is then also used to bring fuel consumption of vehicles with diesel engines, among passenger cars and other vehicles ≤ 3.5 t (light duty vehicles (LDVs) and motor homes and motorised two-wheelers (MTWs)) into line with the Energy Balance.
- The difference between the corrected diesel fuel consumption of passenger cars and other vehicles ≤ 3.5 t and the Energy Balance is then allocated to heavy duty vehicles and buses.
- The correction factor for heavy duty vehicles and buses is calculated from their energy consumption calculated according to the domestic principle and the difference calculated for this group in relation to the Energy Balance.

The following table summarises the correction factors used.

Table 497: Correction factors for harmonisation with the Energy Balance

	Gasoline fuels [a]	Diesel fuels [a]	
	Passenger cars, light commercial vehicles, motorised two-wheelers	Passenger cars, light commercial vehicles	Heavy commercial vehicles, buses
1990	1.09	1.09	0.98
1995	1.05	1.05	0.93
2000	1.00	1.00	0.96
2005	0.95	0.95	0.78
2010	0.87	0.87	0.88
2011	0.88	0.88	0.85
2012	0.86	0.86	0.92
2013	0.88	0.88	0.93
2014	0.89	0.89	0.87
2015	0.89	0.89	0.89
2016	0.90	0.90	0.87
2017	0.90	0.90	0.89
2018	0.88	0.88	0.86
2019	0.87	0.87	0.87
2020	0.91	0.91	0.90
2021	0.91	0.91	0.85
2022	0.93	0.93	0.84
2023	0.92	0.92	0.83
2024	0.92	0.92	0.80

[a] In each case, including biogenic admixtures

Source: (Knörr, Heidt, et al., 2025)

Annex 7.1.2.2.2 Allocation of biofuels, petroleum, natural gas and LP gas to the structural elements

The Energy Balance includes data on biomass and other fuels, broken down by individual vehicle categories. Those data are allocated as follows:

- The figures for biodiesel and bioethanol are divided in accordance with the various vehicle categories' (not including ship categories) shares of consumption of the corresponding fossil fuels.
- In the Energy Balances, biomethane is not listed separately; it is included as a component of natural gas. The specific quantities involved are available in the Renewable Energy Statistics (Erneuerbare Energien-Statistik – EE-Stat), however. They are broken down in accordance with the various relevant vehicle types' shares of natural gas consumption.
- Petroleum is allocated to buses (on roads outside urban areas) in accordance with the buses shares of consumption of conventional diesel fuel.

Annex 7.1.2.2.3 Activity data for evaporation

The activity data for evaporation emissions are set as total gasoline consumption, on municipal roads (= city); the corresponding figure for mopeds is the total consumption. The corrected Energy Balance figures are used.

Annex 7.1.2.3 Derivation of emission factors

Annex 7.1.2.3.1 Emission factors from TREMOD

In the Central System of Emissions (CSE), implied emission factors, in [kg/TJ] or [kg/t], generated from more-specific TREMOD data, are given for the categories engine type and evaporation. For gasoline and diesel fuel, those values can be derived directly from TREMOD. To this end, emissions in [t] and energy consumption in [TJ] (converted from the results "energy consumption in t", using the calorific values pursuant to Table 495) are derived from the TREMOD results and allocated to the relevant structural elements. The implied emission factors (IEFs) result as the quotient of specific emissions in [t] divided by the specific energy consumption in [TJ].

Equation 105:

$$IEF\ [kg\ pro\ TJ]_{\ Inventar} = EM\ [kg]_{\ spezifisch,TREMOD} \div AR\ [TJ]_{\ spezif.Verbrauch,TREMOD}$$

A similar procedure is used for the implied emission factors for evaporation:

Equation 106:

$$IEF\ [kg\ pro\ t]_{\ Inventar} = EM\ [kg]_{\ spezifisch,TREMOD} \div AR\ [t]_{\ spezif.Verbrauch,TREMOD}$$

In general, TREMOD data that have not been corrected in accordance with the Energy Balance are used for this derivation. However, using the corrected emissions and energy consumption would, since the correction factor in the calculation of the IEF according to

Equation 107:

$$EM_{korr.} \div AR_{korr.} = EM_{TREMOD} \div AR_{TREMOD}$$

cancels out, leading to identical results.

Annex 7.1.2.3.2 Emission factors for biodiesel, bioethanol, petroleum, natural gas and LP gas

The emission factors for biodiesel and petroleum are consistently set to the same values as those for conventional diesel fuel. Those for bioethanol, on the other hand, are set to the same values as those for conventional gasoline.

Exceptions:

- The EF (CO_2) used for biodiesel, 70.8 t/TJ, is a default pursuant to IPCC (2006a): Volume 2, Chapter 2 – Stationary Combustion, p. 2.20, Tab. 2.4.
- The EF (SO_2) for petroleum is set to 24 kg/TJ for those years in which diesel fuel has a higher value. In all other years, the lower value for diesel fuel is used.

The emission factors for LP gas and natural gas, like those for diesel fuel and gasoline, are taken from the "Handbook for emission factors of road transports 4.2" ("Handbuch für Emissionsfaktoren des Straßenverkehrs 4.2"; (Keller et al., 2017).

Annex 7.1.2.3.3 International comparison of (implied) emission factors

The following tables show the implicit emission factors derived for the German emissions inventory and for the year 2024 for methane and nitrous oxide from passenger cars (1.A.3.b i), light (1.A.3.b ii) and heavy duty vehicles (1.A.3.b iii, including buses) and motorised two-wheelers (1.A.3.b iv) with the corresponding implicit emission factors of other reporting countries according to the 2023 submission. The international values were taken from the GHG Locator (UNFCCC, 2023a),

Table 498: Implied emission factors for CH_4 and N_2O from passenger cars, in kg/TJ

	Gasoline		Diesel fuel		CNG		LPG	
	CH_4	N_2O	CH_4	N_2O	CH_4	N_2O	CH_4	N_2O
Germany	4.49	0.29	3.61	3.57	16.80	0.25	1.90	0.82
Belgium	6.11	0.44	0.05	2.52	20.90	0.35	7.35	0.90
Denmark	4.04	0.63	0.06	2.77	12.90	0.37	10.30	2.66
France	11.90	0.98	0.25	3.36	30.10	0.72	11.70	0.90
Italy	9.88	0.91	0.10	2.74	20.20	0.47	8.69	0.73
Netherlands	8.93	0.73	0.35	2.21	92.00	3.00	2.33	0.84
Spain	7.73	0.81	0.19	3.31	22.10	0.55	8.13	0.64
EU-27	7.35	0.72	0.91	3.16	21.40	0.51	9.37	1.40
United Kingdom	5.68	0.60	0.08	2.99	IE	IE	IE	IE

Table 499: Implied emission factors for CH_4 and N_2O from light duty vehicles, in kg/TJ

	Gasoline		Diesel fuel		CNG	
	CH_4	N_2O	CH_4	N_2O	CH_4	N_2O
Germany	9.59	0.57	2.47	2.81	7.43	0.17
Belgium	5.02	0.75	0.05	1.78	IE	IE
Denmark	5.37	2.02	0.08	2.01	12.8	0.40
France	11.7	0.94	0.10	2.47	21.9	0.71
Italy	6.09	1.46	0.11	1.84	NO	NO
Netherlands	4.04	1.86	0.68	1.48	92.0	3.00
Spain	18.8	1.74	0.24	2.11	NO	NO
EU-27	10.6	1.64	0.46	2.29	26.0	0.89
United Kingdom	3.92	0.97	0.05	2.29	IE	IE

Table 500: Implied emission factors for CH_4 and N_2O from heavy duty vehicles, in kg/TJ

	Diesel fuel		CNG & LNG	
	CH_4	N_2O	CH_4	N_2O
Germany	0.09	4.27	34.8	NA
Belgium	0.69	4.04	50.1	NE
Denmark	0.63	4.60	26.8	3.08
France	0.58	2.38	60.3	NO
Italy	1.94	3.23	56.4	NO
Netherlands	0.43	3.99	92.0	3.00
Spain	1.59	3.46	49.6	NO
EU-27	1.18	3.47	57.8	1.24
United Kingdom	0.77	4.52	53.2	0.10

Table 501: Implied emission factors for CH_4 and N_2O from motorised two-wheelers, in kg/TJ

	Gasoline	
	CH_4	N_2O
Germany	120	1.16
Belgium	41.3	1.25
Denmark	71.5	1.22
France	24.0	1.16
Italy	61.0	1.35
Netherlands	99.3	1.10
Spain	69.0	1.43
EU-27	72.1	1.29
United Kingdom	41.5	1.21

Annex 7.1.3 CO_2 emissions from lubricant co-combustion in two-stroke gasoline engines

The German greenhouse gas inventory covers CO_2 emissions from co-combustion of lubricants for all mobile sources. In accordance with emissions reporting requirements, emissions from two-stroke gasoline engines are allocated directly to the emission sources, since in those cases lubricants are seen as part of the relevant two-stroke fuel mixtures. On the other hand, all co-combustion emissions not caused by two-stroke engines are reported under CRF 2.D.1 (product use). (see Chapter 4.5.1)

For the entire time series as of 1990, it is simplified to assume that the two-stroke fuel mixture used in Germany consists of 49 parts gasoline and one part lubricants (mixture of 1:50). Since the 1980s, this mixing ratio has been the standard for most vehicles with two-stroke engines. No reliable usage data are available on motors that use mixtures of 1:100 (newer mobile devices such as chainsaws, lawnmowers, etc.).

Mopeds and small motorcycles are now virtually the only types of vehicles with two-stroke engines that are found on German roads. Until the end of the 1990s, the passenger car and commercial vehicle fleet included a share of vehicles with two-stroke engines produced in the former GDR.

TREMOD contains separate sets of consumption data for passenger and light commercial vehicles (up to 1999) and for two-wheel vehicles.

TREMOD MM contains current figures on use of mobile devices with two-stroke engines for both the Residential (1.A.4.b ii) and Forestry (1.A.4.c ii) sectors.

The figures on gasoline consumption in road transport and by mobile sources in the Commercial and Institutional, and Residential, sectors agree with the corresponding figures in the Energy Balance.

To obtain a complete picture of the fuel consumption that must be assigned to two-stroke engines, the relevant quantities of lubricants added to fuel have been calculated in accordance with the mixing ratio of 1:50. Starting from a fraction r_V of 2% by volume, the fraction relative to the amount of energy in terajoules r_E must be determined based on the ratio of the average densities (ρ) and calorific values (H_i) of both components:

Equation 108:

$$r_{E\%} = r_{V\%} \times \frac{\rho_{Lubricant}}{\rho_{fuel}} \times \frac{\mathrm{H_i}_{\mathrm{Lubricant}}}{\mathrm{H_i}_{\mathrm{fuel}}}$$

Equation 109:

$$r_{E\%} = 2\,\% \times \frac{0{,}875\,\frac{\mathrm{kg}}{\mathrm{l}}}{0{,}750\,\frac{\mathrm{kg}}{\mathrm{l}}} \times \frac{40{,}000\,\frac{\mathrm{kJ}}{\mathrm{kg}}}{43{,}543\,\frac{\mathrm{kJ}}{\mathrm{kg}}} = 2{,}1435\,\%$$

The lubricant quantities in [TJ] that are co-combusted as part of two-stroke fuel mixtures are then calculated from the annual energy inputs in [TJ] that are assigned to two-stroke engines and the fraction r_E.

The CO_2 emissions from lubricant co-combustion in two-stroke engines in road transport can thus be listed separately (cf. Chapters 3.2.8.2 & Annex 7.1.2.2). In the CRT tables, this is done under CRF *1.A.3.b v – Other (please specify): CO_2 from lubricant co-incineration in 2-stroke road vehicles.*

In the category of mobile machines and devices, no separate lubricant quantities are calculated in terajoules; instead, the energy consumption attributable to these two-stroke engines is adjusted upwards by 2.1435% for the sake of simplicity. The CO_2 emissions from lubricant co-combustion in two-stroke engines in mobile machines and devices are thus included in the total emissions of the relevant sectors (cf. Chapter 3.2.10). Consequently, the emissions are also not listed separately within the CRT tables.

Emission factors

To make it possible to show CO_2 emissions from combusted two-stroke fuel mixtures in the inventory, weighted implied emission factors were formed for the entire time series. These consist of a 49/50ths fraction based on the year-specific EF (CO_2) for gasoline (or the Tier 1 EF for bioethanol) and a 1/50th fraction based on the default value 73,300 kg CO_2/TJ for lubricants pursuant to (IPCC, 2006a): Volume 2, Chapter 2 – Stationary Combustion, page 2.20, Table 2.4.

These IEFs, which include 2% by vol. for lubricants, are thus slightly higher than the values used for the relevant pure fuels (gasoline, bioethanol).

Table 502: Derivation of the EF (CO_2) for two-stroke fuel mixtures, in kg/TJ

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024
Gasoline	73,069	73,075	73,094	72,875	72,810	72,832	72,779	72,778	72,787	72,782	72,782
Bioethanol						71,607					
Lubricants[a]						73,300					
Two-stroke mix											
fossil	73,074	72,841	72,790	72,883	72,820	72,841	72,790	72,788	72,797	72,797	72,797
biogenic						71,607					

Source: Own calculations

[a] Default emission factor pursuant to IPCC (2006a): Volume 2, Chapter 2 – *Stationary Combustion*, page 2.20, Table 2.4

Table 503: CO_2 from lubricants co-combusted in two-stroke gasoline engines, in kilotonnes

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024
1.A.3.b	186	33.3	6.06	5.81	6.05	5.89	6.06	5.35	5.72	5.05	5.04
1.A.4.b ii	2.35	1.90	1.33	1.65	1.26	1.05	0.95	0.95	0.95	0.90	0.89
1.A.4.c ii	4.52	4.39	4.86	4.43	2.72	2.55	3.73	3.78	3.59	3.37	2.89
Total	193	39.6	12.3	11.9	10.0	9.50	10.7	10.1	10.3	9.32	8.83

Source: Own calculations based on (Heidt et al., 2025; Knörr, Heidt, et al., 2025)

Recalculations with respect to the 2025 submission

Compared with the previous reporting, a new calculation of the fuel consumption of two-stroke engines in road transport and households (1.A.4.b ii) has been undertaken for the years from 2003 onwards.

Table 504: Revised quantities of co-combusted lubricants as of 2003, in terajoules

	2003	2004	2005	2010	2015	2020	2021	2022	2023
2026 submission	158	157	163	137	130	147	138	141	128
2025 submission	158	157	161	172	157	161	154	158	144
Absolute change	-0.02	-0.01	1.40	-34.9	-27.4	-14.2	-15.7	-17.7	-16.4
Relative change	-0.01%	0.00%	0.87%	-20.3%	-17.4%	-8.79%	-10.2%	-11.2%	-11.4%

Source: Own calculations

At the same time, the carbon dioxide emission factors for the two-stroke mixture and the emission factor for fossil-based gasoline 2023 were consolidated.

Table 505: Revised emission factors, in [kg/TJ]

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
for fossil-based gasoline in four-stroke engines										
2026 submission	73,069	73,075	73,094	72,875	72,810	72,832	72,779	72,778	72,787	72,782
2025 submission	73,069	73,075	73,094	72,875	72,810	72,832	72,779	72,778	72,787	72,787
Absolute change	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-4.16
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.01%
Derived from this: for fossil-based gasoline in two-stroke engines, including 2% lubricant (EF = 73,300 kg/TJ)										
2026 submission	73,074	72,841	72,790	72,883	72,820	72,841	72,790	72,788	72,797	72,797
2025 submission	73,074	73,079	73,098	72,883	72,820	72,841	72,790	72,788	72,797	72,797
Absolute change	0.00	-238	-309	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Relative change	0.00%	-0.33%	-0.42%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Source: Own calculations

These revisions give rise to newly calculated carbon dioxide emissions.

Table 506: Revised carbon dioxide emissions, in kilotonnes

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
2026 submission	193	39.6	12.3	11.9	10.0	9.50	10.74	10.1	10.3	9.32
2025 submission	193	39.6	12.3	11.8	12.6	11.5	11.8	11.2	11.6	10.5
Absolute change	0.000	-0.007	-0.006	0.10	-2.54	-1.99	-1.03	-1.14	-1.29	-1.19
Relative change	0.00%	-0.02%	-0.05%	0.87%	-20.2%	-17.3%	-8.7%	-10.2%	-11.2%	-11.3%

Carbon dioxide from lubricant co-combustion in four-stroke gasoline engines and in other engines in vehicles and in mobile machinery and equipment, on the other hand, is reported separately under CRF 2.D.1, as emissions from product use. (see Chapter 4.5.1)

Annex 7.1.4 Fossil CO_2 from biofuels

The following section presents the procedure used for the calculation of the fossil fractions of the biofuels used, as well as of the carbon dioxide emissions resulting from their use.

Methodological issues

The basis for the calculation consists of the CO_2 emissions resulting from the use of biodiesel and biogasoline in the various source categories.

Table 507: CO_2 emissions resulting from the use of biodiesel and bioethanol, in kilotonnes

	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024
from bioethanol	NO	NO	496	2,223	2,240	2,096	2,200	2,272	2,389	2,399
from biodiesel	106	895	5,517	6,895	5,670	7,975	6,746	6,686	6,849	5,584
TOTAL	106	895	6,012	9,118	7,910	10,071	8,946	8,959	9,238	7,982

Source: Own calculations

In a next step, the fossil fractions of these emissions are calculated. To this end, several conservative assumptions are made:

- 100% of the biodiesel is produced from fatty acid methyl ester (FAME).
- 5.50% of the carbon contained in the FAME used is of fossil origin [119].
- 90% of the biogasoline is produced from bioethanol, and 10% is produced from ethyl tertiary butyl ether (ETBE).
- 66.67% of the carbon contained in the ETBE used is of fossil origin [120].

With these assumptions, the following shares of fossil carbon in the biodiesel and biogasoline used result[121]:

- 5.50% of the carbon contained in the biodiesel used in Germany is of fossil origin.
- 6.66% of the carbon contained in the biogasoline used in Germany is of fossil origin.

Based on the total emissions shown above, the quantities of fossil carbon dioxide listed in the following table are added to the total national emissions.

Table 508: CO_2 emissions from fossil fractions of biofuels used, in kilotonnes

	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024
from bioethanol	NA	NA	33.0	148	149	140	147	151	159	160
from biodiesel	5.86	49.3	303	379	312	439	371	368	377	307
TOTAL	5.86	49.3	336	527	461	578	518	519	536	467

Source: Own calculations

Uncertainties and time series consistency

The uncertainties used here correspond to the figures provided in the various source categories for the biofuels actually used. These uncertainties are used consistently throughout the entire time series.

Specific quality assurance/control and verification

General quality control and quality assurance, covering a scope wider than the biofuels actually used in the various source categories, was not carried out. This will only take place after the country-specific methodology has been successfully implemented.

Specific recalculations

Compared to the 2024 submission, recalculations are made based on corrected biofuel quantities within the individual CRF categories for all years from 2004 onwards. The main reason for this comprehensive correction lies in the revision of the national energy balances starting in 2003.

[119] WG I – Note on fossil carbon content in biofuels; Calculating the fossil fuel content of biofuels that replace fossil diesel (biodiesel)
[120] WG I – Note on fossil carbon content in biofuels; Table 1 – Carbon content and fossil fraction of carbon content of biogasoline
[121] Fossil carbon is added to biofuels in the form of either methanol or isobutylene: The methanol is needed for transesterification, i.e. the conversion of vegetable and animal oils into fatty acid methyl esters (FAME). Isobutylene, on the other hand, is used to synthesise ETBE (ethyl tert-butyl ether), which is added to bioethanol to increase its octane rating.

Table 509: Revised fossil CO_2 emissions from biofuels 2004-2023, in kilotonnes

	2004	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023
Fossil CO_2 from bioethanol												
2026 submission	5.53	33.0	148	149	150	147	151	146	140	147	151	159
2025 submission	5.53	33.0	147	149	150	147	151	146	140	147	151	159
Absolute change	0.00	0.00	0.94	-0.05	-0.04	-0.02	-0.02	-0.03	-0.01	0.00	0.00	0.01
Relative change	-0.32%	-0.20%	-0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.14%
Fossil CO_2 from biodiesel												
2026 submission	164	303	379	312	312	321	337	334	439	371	368	377
2025 submission	164	304	379	312	312	321	337	334	439	371	368	377
Absolute change	-0.53	-0.60	-0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.54
Relative change	-0.32%	-0.20%	-0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.14%
Fossil CO_2 from biofuels total												
2026 submission	169	336	527	461	462	468	488	480	578	518	519	536
2025 submission	170	337	526	461	462	468	488	480	578	518	519	536
Absolute change	-0.53	-0.59	0.90	-0.05	-0.04	-0.02	-0.03	-0.03	-0.01	0.00	0.00	-0.53
Relative change	-0.31%	-0.18%	0.17%	-0.01%	-0.01%	0.00%	-0.01%	-0.01%	0.00%	0.00%	0.00%	-0.10%

Source: Own calculations

Planned improvements

Currently, no improvements in addition to the annual revision of the underlying models are planned.

Where previous reports have listed improvements in this chapter, those improvements are presented, in overview form, in Table 468 in Chapter 10.4 Inventory Improvements. Improvements that have been completed are listed in Table 467 in the same chapter.

Annex 7.2 Other detailed methodological descriptions for CRF 2 (industrial processes)

This chapter is currently not required.

Annex 7.3 Other detailed methodological descriptions for CRF 3 (agriculture)

Annex 7.3.1 Distributions of housing, storage and application procedures and grazing data (3.B, 3.D)

Table 510 to Table 513 show the applicable distributions, aggregated at the national level (and rounded to whole-number percentages), of housing, storage and application procedures. They also include data on grazing.

The relevant emissions were calculated not with the data shown in Table 510 to Table 513, but with the data underlying those data. Those underlying data have federal state level resolution, cf. Chapter 2.5 in (Vos et al., 2026). The tables also include information about emission factors (including that for NH_3).

Table 510: Frequency distributions of animal housing procedures (in %) and relevant litter quantities and NH_3 emission factors

livestock category	housing type	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	bedding material (straw) kg place d^{-1}	NH_3-N EF for housing, kg NH_3-N per kg TAN in excreta
dairy cows	tied systems, straw based	32	15	13	11	8	5	5	4	4	3	3	3	3	3	3	5.0	0,066
	tied systems, slurry based	38	36	33	24	17	12	11	10	9	9	9	9	9	9	9		0,066
	loose housing, straw based	2	3	4	7	8	7	7	6	6	6	6	6	6	6	6	5.0	0,169
	loose housing, slurry based	29	46	50	58	65	73	74	76	77	78	78	78	78	78	78		0,169
	loose housing, deep bedding	0	0	0	0	1	3	3	4	4	4	4	4	4	4	4	8.0	0,169
	time spent on pastures (in % of year)	20	15	12	11	10	9	8	8	8	7	7	7	7	7	7		
male beef cattle	tied systems, straw based	4	2	2	5	6	4	4	3	3	3	3	3	3	3	3	2.0	0,066
	tied systems, slurry based	7	4	4	8	9	7	6	5	5	4	4	4	4	4	4		0,066
	loose housing, slurry based	83	89	87	69	53	55	56	56	57	57	57	57	57	57	57		0,169
	loose housing, sloped floor	6	4	6	17	27	21	20	19	18	17	17	17	17	17	17	2.5	0,169
	Loose housing, deep bedding, straw based	0	0	1	2	4	12	14	15	17	19	19	19	19	19	19	5.0	0,169
	time spent on pastures (in % of year)	4	4	3	3	4	8	9	9	10	11	11	11	11	11	11		
female beef cattle	tied systems, straw based	8	9	9	10	11	7	7	6	5	5	5	5	5	5	5	2.0	0,066
	tied systems, slurry based	14	18	17	14	11	9	8	8	8	8	8	8	8	8	8		0,066
	loose housing, slurry based	45	50	51	47	44	47	48	49	50	51	51	51	51	51	51		0,169
	loose housing, straw based	33	23	23	27	30	24	22	21	19	18	18	18	18	17	17	3.0	0,169
	Loose housing, deep bedding, straw based	0	0	0	2	5	13	15	16	18	19	19	19	19	19	19	6.0	0,169
	time spent on pastures (in % of year)	20	19	20	19	17	16	16	16	15	15	15	15	15	15	15		
dairy heifers	tied systems, straw based	8	8	8	9	9	7	6	5	5	4	4	4	4	4	4	2.0	0,066
	tied systems, slurry basedw	16	17	16	13	9	7	7	7	6	6	6	6	6	6	6		0,066
	loose housing, slurry based	49	49	49	46	45	48	49	50	51	51	51	51	51	52	52		0,169
	loose housing, straw based	27	26	26	30	32	25	23	22	20	19	19	19	19	19	19	3.0	0,169
	Loose housing, deep bedding, straw based	0	0	0	2	5	13	15	16	18	20	20	20	20	20	20	6.0	0,169
	time spent on pastures (in % of year)	20	20	20	20	20	18	18	18	17	17	17	17	17	17	17		
calves	tied systems, straw based	50	50	50	0	0	0	0	0	0	0	0	0	0	0	0	2.5	0,066
	loose housing, deep bedding	50	50	50	100	100	100	100	100	100	100	100	100	100	100	100	2.5	0,169

																	bedding material	NH_3-N EF for housing,
	time spent on pastures (in % of year)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
suckler cows	tied systems, straw based	9	8	8	10	12	9	8	8	7	7	7	7	7	7	7	5.0	0,066
	tied systems, slurry based	3	3	3	4	4	4	4	3	3	3	3	3	3	3	3		0,066
	loose housing, slurry based	6	6	7	11	15	15	15	15	15	15	16	16	16	16	16		0,169
	Loose housing, straw based	0	0	5	29	48	41	40	38	37	35	35	35	35	35	35	8.0	0,169
	loose housing, deep bedding	82	83	79	45	22	32	34	36	37	39	39	39	39	39	39	8.0	0,169
	time spent on pastures (in % of year)	43	43	45	46	49	53	54	55	56	56	56	56	56	56	56		
mature males > 2 years	tied systems, straw based	14	15	15	14	12	9	8	7	7	6	6	6	6	6	6	5.0	0,066
	tied systems, slurry based	7	8	9	8	7	5	5	4	4	4	4	4	4	4	4		0,066
	loose housing, slurry based	32	35	35	32	30	30	30	30	30	30	30	30	30	30	30		0,169
	loose housing, straw based	47	42	39	38	36	31	29	29	28	27	27	27	27	27	27	5.0	0,169
	Loose housing, deep bedding, straw based	0	0	1	7	15	25	27	29	31	33	33	33	33	33	33	8.0	0,169
	time spent on pastures (in % of year)	35	33	32	33	35	41	42	43	44	46	45	45	45	45	45		
fattening pigs	fully slatted floor, slurry	47	57	63	68	73	78	79	80	81	82	81	82	82	82	82		0.29
	partly slatted floor, slurry	41	34	31	26	22	18	17	16	15	15	15	15	15	15	15		0.29
	plane floor with bedding	8	6	5	4	4	3	3	2	2	2	2	2	2	2	2	0.3	0.40
	deep bedding, straw based	3	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1.0	0.40
	free ventilated, kennel house, slurry based	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0.20
	free ventilated, kennel house, straw based	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0.20
	free ventilated, deep bedding, straw based	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1.0	0.35
	free ventilated kennel house, slurry based, with yard	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0.29
	Free ventilated, plane floor, straw based with yard	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0.29
	time spent on pastures (in % of year)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
weaners	fully slatted floor, slurry	52	57	63	67	72	77	78	79	80	81	81	81	81	81	81		0.29
	partly slatted floor, slurry	36	33	29	26	22	18	18	17	16	15	15	15	15	15	15		0.29
	plane floor with bedding	9	7	5	5	5	3	3	3	2	2	2	2	2	2	2	0.15	0.40
	deep bedding, straw based	3	3	3	2	2	1	1	1	1	1	1	1	1	1	1	0.20	0.40

																	bedding material	NH_3-N EF for housing,
	free ventilated, kennel house, slurry based	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0.20
	free ventilated, kennel house, straw based	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.15	0.20
	free ventilated, deep bedding, straw based	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0.20	0.35
	free ventilated kennel house, slurry based, with yard	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0.29
	Free ventilated, plane floor, straw based with yard	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0.29
	time spent on pastures (in % of year)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
sows	straw based	43	26	24	19	13	10	9	9	8	7	7	7	7	7	7	0.5	0.34
	slurry based	57	74	76	81	87	90	91	91	92	93	93	93	93	93	93		0.34
	time spent on pastures (in % of year)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
boars	straw based	36	23	22	18	16	11	10	10	9	9	9	9	9	9	7	0.5	0.34
	slurry based	64	77	78	82	84	89	90	90	91	91	91	91	91	91	93		0.34
	time spent on pastures (in % of year)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
laying hens	cages; ≥2010: small group housing systems	94	94	87	74	20	10	9	9	8	7	5	5	5	4	4		*)
	floor management, aviary	5	4	7	14	61	63	62	64	61	61	62	62	60	60	59	0.5/0.2 (from 2010) kg per place a^{-1}	*)
	free range, organic farming	1	2	6	12	20	28	29	27	31	32	33	33	35	36	37	0.5/0.3 (from 2010) kg per place a^{-1}	*)
	time spent on pastures (in % of year)	0	0	1	1	2	2	2	2	3	3	3	3	3	3	3		
broilers	floor management	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	1.0/0.48 (from 2010) kg per place a^{-1}	0.09 kg per kg of total N excreted
pullets	floor management	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.20 kg per place a^{-1}	0.09 kg per kg of total N excreted
ducks	floor management	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	22 kg per place a^{-1}	0.16 kg per kg of total N excreted
geese	floor management	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	9.0 kg per place a^{-1}	0.57
turkeys, female	floor management	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	12 kg per place a^{-1}	0.222 kg per kg of total N excreted
turkeys, male	floor management	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	18 kg per place a^{-1}	0.222 kg per kg of total N excreted
horses	straw based system	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	8.0/5.0	0.22
	time spent on pastures (in % of year)	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21		

																	bedding material	NH_3-N EF for housing,
sheep without lambs	straw based system	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.40	0.22
	time spent on pastures (in % of year)	55	55	55	55	55	55	55	55	56	55	55	56	56	56	55		
lambs	straw based system	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.16	0.22
	time spent on pastures (in % of year)	57	57	57	57	55	55	55	55	56	55	55	56	56	56	55		
goats	straw based system	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.40	0.22
	time spent on pastures (in % of year)	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34		
deer	time spent on pastures (in % of year)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100		
rabbits	straw based system	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.01	0.22
	time spent on pastures (in % of year)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
ostriches	straw based system	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.40	0.57
	time spent on pastures (in % of year)	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80		
Fur animals	straw based system	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.00	0.27
	time spent on pastures (in % of year)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		

*) cf. Table 513: Laying hens, housing-specific partial NH_3 emission factors

Table 511: Frequency distributions of storage systems (in %), quantities of digested energy crops and corresponding emission factors

livestock category	storage type	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	NH_3-N EF for storage kg NH_3-N per kg TAN in storage system	NH_3-N EF for storage kg NH_3-N per kg TAN in storage system (leachate/urine)	N_2O EF for storage kg N2O-N per kg N in storage system	N_2O EF for storage kg N_2O-N per kg N in storage system	CH_4 MCF for storage % von Bo < 10 °C	maximum CH_4 producing capacity (Bo) m^3 CH_4 per kg VS
cattle, untreated slurry	open tank (% of total untreated slurry)	1	1	1	5	8	10	10	11	11	12	12	12	12	12	12	0,150		0,000		17.0	0.23
	solid cover (% of total untreated slurry)	22	21	21	23	23	20	19	19	18	18	18	18	18	18	18	0,015		0,005		17.0	0.23
	natural crust (% of total untreated slurry)	42	44	43	39	37	37	38	38	38	38	38	38	38	38	38	0,045		0,005		10.0	0.23
	plastic film (% of total untreated slurry)	0	1	1	2	3	4	4	5	5	5	5	5	5	5	5	0,023		0,005		17.0	0.23
	artificial crust (chaff) (% of total untreated slurry)	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0,030		0,005		17.0	0.23
	storage below animal confinements > 1 month (% of total untreated slurry)	36	34	33	31	30	28	27	27	26	26	26	26	26	26	26	0,045		0,002		17.0	0.23
cattle, digestion of slurry	Gg N	0.03,	0.34,	2.99,	19	80	122	121	122	119	115	117	123	118	107	107						
cattle, digestion of solid manure	Gg N	0.00,	0.03,	0.23,	2	6	10	10	10	9	9	9	10	11	9	9						
cattle, storage of digestates	gas tight storage (% of slurry)	0	5	9	15	41	61	63	64	65	69	73	76	77	80	80	0,000		0,000		2,683	0.23
cattle, storage of digestates	open tank (% of slurry)	100	95	91	85	59	39	37	36	35	31	27	24	23	20	20	0,045		0,005		3,090	0.23

livestock category	storage type	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	NH_3-N EF for storage kg NH_3-N per kg TAN in storage system	NH_3-N EF for storage kg NH_3-N per kg TAN in storage system (leachate/urine)	N_2O EF for storage kg N2O-N per kg N in storage system	N_2O EF for storage kg N_2O-N per kg N in storage system	CH_4 MCF for storage % von Bo < 10 °C	maximum CH_4 producing capacity (Bo) m^3 CH_4 per kg VS
cattle, storage of digestates	gas tight storage (% of solid manure)	0	5	9	15	41	61	63	64	65	69	73	76	77	80	80	0,000		0,000		1,198	0.23
cattle, storage of digestates	open tank (% of solid manure)	100	95	91	85	59	39	37	36	35	31	27	24	23	20	20	0,045		0,005		1,611	0.23
dairy cows, solid manure	heap (% of total solid manure)	100	99	99	99	97	82	79	75	71	67	67	67	67	67	67	0,600	0,013	0,010	0,005	2.0	0.23
	Deep bedding (% of total solid manure)	0	1	1	1	3	18	21	25	29	33	33	33	33	33	33	0,000		0,010		17.0	0.23
male beef cattle, solid manure	heap (% of total solid manure)	98	95	94	93	88	68	63	59	55	51	51	51	51	51	51	0,600	0,013	0,010	0,005	2.0	0.23
	Deep bedding (% of total solid manure)	2	5	6	7	12	32	37	41	45	49	49	49	49	49	49	0,000		0,010		17.0	0.23
female beef cattle, solid manure	heap (% of total solid manure)	100	100	99	96	89	71	67	63	58	54	54	54	54	54	54	0,600	0,013	0,010	0,005	2.0	0.23
	Deep bedding (% of total solid manure)	0	0	1	4	11	29	33	37	42	46	46	46	46	46	46	0,000		0,010		17.0	0.23
dairy heifers, solid manure	heap (% of total solid manure)	100	100	99	95	89	71	67	63	58	54	54	54	54	54	54	0,600	0,013	0,010	0,005	2.0	0.23
	Deep bedding (% of total solid manure)	0	0	1	5	11	29	33	37	42	46	46	46	46	46	46	0,000		0,010		17.0	0.23
calves, solid manure	heap (% of total solid manure)	50	50	50	0	0	0	0	0	0	0	0	0	0	0	0	0,600	0,013	0,010	0,005	2.0	0.23
	deep bedding (% of total solid manure)	50	50	50	100	100	100	100	100	100	100	100	100	100	100	100	0,000		0,010		17.0	0.23
suckler cows, solid manure	heap (% of total solid manure)	10	9	14	47	73	61	59	56	54	51	51	51	51	51	51	0,600	0,013	0,010	0,005	2.0	0.23

livestock category	storage type	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	NH_3-N EF for storage kg NH_3-N per kg TAN in storage system	NH_3-N EF for storage kg NH_3-N per kg TAN in storage system (leachate/urine)	N_2O EF for storage kg N2O-N per kg N in storage system	N_2O EF for storage kg N_2O-N per kg N in storage system	CH_4 MCF for storage % von Bo < 10 °C	maximum CH_4 producing capacity (Bo) m^3 CH_4 per kg VS
	deep bedding (% of total solid manure)	90	91	86	53	27	39	41	44	46	49	49	49	49	49	49	0,000		0,010		17.0	0.23
mature males, solid	heap (% of total solid manure)	100	100	98	88	76	61	58	55	52	50	50	50	50	50	50	0,600	0,013	0,010	0,005	2.0	0.23
	Deep bedding (% of total solid manure)	0	0	2	12	24	39	42	45	48	50	50	50	50	50	50	0,000		0,010		17.0	0.23
pigs, untreated slurry	open tank (% of total untreated slurry)	47	27	25	16	9	10	10	11	11	11	11	11	11	11	11	0,150		0,000		25.0	0.30
	solid cover (% of total untreated slurry)	18	22	22	20	18	17	17	17	17	16	16	16	16	16	16	0,015		0,005		25.0	0.30
	natural crust (% of total untreated slurry)	3	13	15	22	28	23	22	21	20	20	20	19	20	19	19	0,105		0,005		15.0	0.30
	plastic film (% of total untreated slurry)	0	6	6	6	7	9	10	10	11	11	11	11	11	11	11	0,023		0,005		25.0	0.30
	artificial crust (chaff) (% of total untreated slurry)	0	1	1	3	4	4	4	4	4	4	4	4	4	4	4	0,030		0,005		25.0	0.30
	storage below animal confinements > 1 month (% of total untreated slurry)	32	32	32	33	34	37	37	37	38	38	38	38	38	38	38	0,105		0,002		25.0	0.30
pigs, digested slurry	Gg N	0.01,	0.13,	1.11,	8	32	53	52	53	51	49	49	47	49	42	42.39						
pigs, storage of digestates	gas tight storage (% of digestates)	0	5	9	15	41	61	63	64	65	69	73	76	77	80	80	0,000		0,000		3,475	0.30
pigs, storage of digestates	open tank (% of digestates)	100	95	91	85	59	39	37	36	35	31	27	24	23	20	20	0,045		0,005		3,879	0.30

livestock category	storage type	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	NH_3-N EF for storage kg NH_3-N per kg TAN in storage system	NH_3-N EF for storage kg NH_3-N per kg TAN in storage system (leachate/urine)	N_2O EF for storage kg N2O-N per kg N in storage system	N_2O EF for storage kg N_2O-N per kg N in storage system	CH_4 MCF for storage % von Bo < 10 °C	maximum CH_4 producing capacity (Bo) m^3 CH_4 per kg VS
fattening pigs/weaners, solid manure	heap (% of total solid manure)	74	70	69	72	73	67	65	64	62	60	60	60	60	59	55	0,600	0,030	0,010	0,005	3.0	0.30
	deep bedding (% of total solid manure)	26	30	31	28	27	33	35	36	38	40	40	40	40	41	45	0,000		0,010		25.0	0.30
sows/boars, solid manure	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0,600	0,030	0,010	0,005	3.0	0.30
laying hens	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0,140		0,001		1.5	0.39
broilers	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0,170		0,001		1.5	0.36
pullets	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0,170		0,001		1.5	0.39
ducks	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0,240		0,001		1.5	0.36
geese	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0,160		0,001		1.5	0.36
turkeys, female	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0,240		0,001		1.5	0.36
turkeys, male	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0,240		0,001		1.5	0.36
poultry, digested solid manure	Gg N	0.00,	0.05,	0.41,	3	11	24	24	24	23	23	24	23	26	25	24.69						
poultry, storage of digestates	gas tight storage (% of digestates)	0	5	9	15	41	61	63	64	65	69	73	76	77	80	80	0,000		0,000		1,149	0.36/0.39 (see animal-specific values above)
poultry, storage of digestates	open tank (% of digestates)	100	95	91	85	59	39	37	36	35	31	27	24	23	20	20	0,045		0,005		1,562	0.36/0.39 (see animal-specific

livestock category	storage type	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	NH_3-N EF for storage kg NH_3-N per kg TAN in storage system	NH_3-N EF for storage kg NH_3-N per kg TAN in storage system (leachate/urine)	N_2O EF for storage kg N2O-N per kg N in storage system	N_2O EF for storage kg N_2O-N per kg N in storage system	CH_4 MCF for storage % von Bo < 10 °C	maximum CH_4 producing capacity (Bo) m^3 CH_4 per kg VS
																						values above)
horses	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0,350		0,010		2.0	0.30
sheep	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0,320		0,010		2.0	0.19
goats	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0,280		0,010		2.0	0.18
deer	heap (% of total solid manure)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO		NO		NO	0.18
rabbits	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.09		0,010		2.0	0.32
ostriches	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.16		0,001		1.5	0.25
Fur animals	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0,350		0,010		2.0	0.25
digestion of energy crops	amount of energy crops digested (kt dry matter)	3	42	366	3089	11164	20118	20011	19683	19397	19400	19815	19440	20881	20223	20223						
	gas tight storage (% of digestates)	0	5	9	16	42	65	67	69	71	75	79	83	82	86	86	0,000		0,000		1.0	0.38
	open tank (% of digestates)	100	95	91	84	58	35	33	31	29	25	21	17	18	14	14	0,045		0,005		1,414	0.38

*) digestion of slurry, solid manure, poultry manure and energy crops: MCFs are overall values for the system “re-storage (if existent) + digester + storage of digestates”

Table 512: Frequency distributions of application procedures (in %) and corresponding emission factors

livestock category	application type	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	NH3-N EF for application, kg NH3-N per kg TAN applied
cattle, untreated slurry	broadcast, without incorporation	10	2	2	1	0	0	0	0	0	0	0	0	0	0	0	0.50
	broadcast, incorporation < 1 h	4	4	4	5	5	11	10	10	10	9	9	9	9	9	9	0.10
	broadcast, incorporation < 4h	0	2	2	7	11	7	6	5	4	3	3	3	3	3	3	0.26
	broadcast, incorporation < 6h	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.35
	broadcast, incorporation < 8h	0	0	1	3	5	0	0	0	0	0	0	0	0	0	0	0.40
	broadcast, incorporation < 12h	0	21	20	9	1	0	0	0	0	0	0	0	0	0	0	0.43
	broadcast, incorporation < 24h	33	9	8	4	0	0	0	0	0	0	0	0	0	0	0	0.46
	broadcast, incorporation < 48h	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.50
	broadcast, vegetation	0	0	2	10	16	14	12	10	8	6	0	0	0	0	0	0.50
	broadcast, grassland	44	43	41	42	43	44	42	40	38	36	36	36	36	37	37	0.60
	trailing hose, without incorporation	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0.46
	trailing hose, incorporation < 1 h	0	2	2	1	1	3	3	3	3	3	3	3	3	3	3	0.04
	trailing hose, incorporation < 4h	0	2	2	2	2	1	1	1	1	1	1	1	1	1	1	0.15
	trailing hose, incorporation < 6h	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.20
	trailing hose, incorporation < 8h	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0.24
	trailing hose, incorporation < 12h	0	9	8	4	0	0	0	0	0	0	0	0	0	0	0	0.30
	trailing hose, incorporation < 24h	1	2	2	1	0	0	0	0	0	0	0	0	0	0	0	0.39
	trailing hose, incorporation < 48h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.46
	trailing hose, vegetation	0	0	0	3	4	4	4	5	5	5	11	11	11	11	11	0.35
	trailing hose, short vegetation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.46
	trailing hose, grassland	0	0	0	2	3	3	4	4	4	4	4	4	4	4	4	0.54
	Trailing shoe, without incorporation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.46
	trailing shoe, incorporation < 1 h	0	0	0	0	0	1	2	3	4	4	4	4	4	4	4	0.04
	trailing shoe, incorporation < 4 h	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0.15

																	NH3-N EF for application,
cattle, solid manure	trailing shoe, incorporation < 8 h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.24
	trailing shoe, incorporation < 12 h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.30
	trailing shoe, vegetation	0	0	0	0	0	2	3	4	6	7	7	7	7	7	7	0.36
	trailing shoe, grassland	0	1	1	1	1	4	5	7	9	11	11	11	11	11	11	0.36
	injection (open slot), bare soil	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0.24
	injection (open slot), vegetation	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0.24
	injection (open slot), grassland	0	2	2	1	1	1	1	1	2	2	2	2	2	2	2	0.24
	grubber and injection, bare soil	0	1	1	2	3	3	4	4	4	4	4	4	4	4	4	0.04
	grubber and injection, vegetation	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0.24
	grubber and injection, grassland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.24
	broadcast, without incorporation	11	2	3	3	3	3	3	3	3	3	3	3	3	3	3	0.90
	broadcast, incorporation < 1 h	6	11	11	12	13	14	15	15	15	15	15	15	15	15	15	0.09
	broadcast, incorporation < 4h	0	8	9	15	21	28	30	32	33	35	35	35	35	35	35	0.45
	broadcast, incorporation < 12h	9	30	32	32	30	26	23	21	18	15	15	15	15	15	15	0.81
	broadcast, incorporation < 24h	49	24	22	13	6	0	0	0	0	0	0	0	0	0	0	0.90
	broadcast, incorporation < 48h	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.90
	broadcast, arable land, vegetation	0	0	1	3	6	9	10	10	10	11	11	11	11	11	11	0.90
	broadcast, grassland	19	25	23	22	20	19	20	20	20	21	21	21	21	21	21	0.90
pigs, untreated slurry	broadcast, without incorporation	7	4	4	2	0	0	0	0	0	0	0	0	0	0	0	0.25
	broadcast, incorporation < 1 h	4	8	8	7	6	8	7	6	5	4	4	4	4	4	4	0.04
	broadcast, incorporation < 4h	0	1	2	6	9	5	4	3	2	1	1	1	1	1	1	0.09
	broadcast, incorporation < 6h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.11
	broadcast, incorporation < 8h	0	0	0	3	5	0	0	0	0	0	0	0	0	0	0	0.13
	broadcast, incorporation < 12h	0	28	25	12	1	0	0	0	0	0	0	0	0	0	0	0.16
	broadcast, incorporation < 24h	48	4	3	2	0	0	0	0	0	0	0	0	0	0	0	0.21
	broadcast, incorporation < 48h	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25
	broadcast, vegetation	31	23	24	23	22	19	15	11	8	4	0	0	0	0	0	0.25
	broadcast, grassland	0	0	0	2	3	2	2	2	2	2	2	2	2	2	2	0.30

																	NH3-N EF for application,
	trailing hose, without incorporation	1	2	2	1	0	0	0	0	0	0	0	0	0	0	0	0.18
	trailing hose, incorporation < 1 h	0	5	5	4	4	9	9	9	9	9	9	9	9	9	9	0.02
	trailing hose, incorporation < 4h	0	1	2	4	6	4	4	4	3	3	3	3	3	3	3	0.06
	trailing hose, incorporation < 6h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.08
	trailing hose, incorporation < 8h	0	0	0	2	3	0	0	0	0	0	0	0	0	0	0	0.0925
	trailing hose, incorporation < 12h	0	10	9	4	1	0	0	0	0	0	0	0	0	0	0	0.11
	trailing hose, incorporation < 24h	4	2	2	1	0	0	0	0	0	0	0	0	0	0	0	0.14
	trailing hose, incorporation < 48h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.17
	trailing hose, vegetation	0	0	3	18	31	35	35	37	37	38	42	42	43	42	42	0,125
	trailing hose, short vegetation	2	8	8	3	0	0	0	0	0	0	0	0	0	0	0	0,175
	trailing hose, grassland	0	0	0	1	2	2	2	2	2	2	2	2	2	2	2	0.21
	trailing shoe, without incorporation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,175
	trailing shoe, incorporation < 1 h	0	0	0	0	0	1	2	3	4	5	5	5	5	5	5	0.02
	trailing shoe, incorporation < 4 h	0	0	0	0	0	1	1	1	2	2	2	2	2	2	2	0.06
	trailing shoe, incorporation < 8 h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0925
	trailing shoe, incorporation < 12 h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.11
	trailing shoe, vegetation	0	0	0	1	1	4	8	11	14	18	17	18	17	18	17	0.12
	trailing shoe, grassland	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0.12
	injection (open slot), bare soil	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0.06
	injection (open slot), vegetation	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2	0.06
	injection (open slot), grassland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.06
	grubber and injection, bare soil	0	3	3	4	4	6	6	7	7	7	7	7	7	7	7	0.02
	grubber and injection, vegetation	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0.06
	grubber and injection, grassland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.06
	broadcast, without incorporation	38	30	30	18	9	2	3	3	4	5	5	5	5	5	5	0.90
pigs, solid manure	broadcast, incorporation < 1 h	4	16	16	16	16	17	17	17	18	18	18	18	18	18	18	0.09
	broadcast, incorporation < 4h	0	2	4	14	24	35	36	36	37	37	37	37	37	37	37	0.45

																	NH3-N EF for application,
cattle and pigs, leachate	broadcast, incorporation < 12h	0	18	20	23	24	23	19	16	12	9	9	9	9	9	9	0.81
	broadcast, incorporation < 24h	50	34	30	20	9	0	0	0	0	0	0	0	0	0	0	0.90
	broadcast, incorporation < 48h	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.90
	broadcast, arable land, vegetation	0	0	2	9	15	22	23	24	25	27	27	27	27	27	27	0.90
	broadcast, grassland	0	0	0	1	1	2	2	3	3	4	4	4	4	4	4	0.90
	broadcast, without incorporation	50	50	45	20	0	0	0	0	0	0	0	0	0	0	0	0.20
	broadcast, incorporation < 1 h	0	0	0	2	3	5	5	5	5	5	5	5	5	5	5	0.02
	broadcast, incorporation < 4h	0	0	1	5	8	10	8	7	5	4	4	4	4	4	4	0.07
	broadcast, incorporation < 8h	0	0	1	4	7	0	0	0	0	0	0	0	0	0	0	0,116
	broadcast, incorporation < 12h	0	0	0	2	3	0	0	0	0	0	0	0	0	0	0	0,144
	broadcast, vegetation	0	0	2	9	15	13	11	10	8	7	0	0	0	0	0	0.20
	broadcast, grassland	50	50	50	49	47	48	47	46	45	44	44	44	44	44	44	0.20
	trailing hose, without incorporation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.18
	trailing hose, incorporation < 1 h	0	0	0	0	1	2	3	3	4	4	4	4	4	4	4	0.01
	trailing hose, incorporation < 4h	0	0	0	1	2	2	2	2	2	2	2	2	2	2	2	0.05
	trailing hose, incorporation < 8h	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0.09
	trailing hose, incorporation < 12h	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0.12
	trailing hose, vegetation	0	0	0	2	4	9	10	11	12	12	19	19	19	19	19	0.10
	trailing hose, grassland	0	0	0	2	3	4	4	5	6	7	7	7	7	7	7	0.14
	Trailing shoe, without incorporation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.18
	trailing shoe, incorporation < 1 h	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0.01
	trailing shoe, incorporation < 4 h	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0.05
	trailing shoe, incorporation < 8 h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.09
	trailing shoe, incorporation < 12 h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.12
	trailing shoe, vegetation	0	0	0	0	0	1	2	3	4	5	5	5	5	5	5	0.08
	trailing shoe, grassland	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2	0.08
	injection (open slot), bare soil	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04

																	NH3-N EF for application,
	injection (open slot), vegetation	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0.04
	injection (open slot), grassland	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0.04
	grubber and injection, bare soil	0	0	0	2	3	2	2	3	3	4	4	4	4	4	4	0.01
	grubber and injection, vegetation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04
	grubber and injection, grassland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04
	broadcast, without incorporation	9	7	7	5	3	1	1	2	2	2	2	2	2	2	2	0.90
	broadcast, incorporation < 1 h	0	0	1	9	16	23	24	25	27	28	28	28	27	28	28	0.00
	broadcast, incorporation < 4h	0	0	3	17	32	46	44	42	39	37	37	37	37	37	37	0.18
poultry, solid manure	broadcast, incorporation < 12h	0	20	18	17	14	10	9	7	6	4	4	4	4	4	4	0.40
	broadcast, incorporation < 24h	91	73	69	45	22	0	0	0	0	0	0	0	0	0	0	0.45
	broadcast, arable land, vegetation	0	0	1	6	12	17	18	20	22	23	23	23	23	23	23	0.90
	broadcast, grassland	0	0	0	1	2	3	3	4	5	6	6	6	6	6	6	0.90
	broadcast, without incorporation	100	100	94	64	33	3	3	3	3	3	3	3	3	3	3	0.90
	broadcast, incorporation < 1 h	0	0	1	4	7	11	11	12	13	13	13	13	13	13	13	0.09
	broadcast, incorporation < 4h	0	0	2	10	19	27	28	29	30	31	31	31	31	31	31	0.45
other animals, solid manure	broadcast, incorporation < 12h	0	0	2	9	17	25	23	20	18	15	15	15	15	15	15	0.81
	broadcast, incorporation < 24h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.90
	broadcast, arable land, vegetation	0	0	1	4	7	10	11	11	12	13	13	13	13	13	13	0.90
	broadcast, grassland	0	0	1	9	16	23	24	24	24	25	25	25	25	25	25	0.90
	broadcast, without incorporation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.50
	broadcast, incorporation < 1 h	5	5	5	6	5	7	7	6	5	5	5	5	5	5	5	0.10
	broadcast, incorporation < 4h	8	9	8	9	9	5	4	3	2	2	2	2	2	2	2	0.26
	broadcast, incorporation < 8h	6	6	6	6	6	0	0	0	0	0	0	0	0	0	0	0.40
Digested manure and digested energy crops	broadcast, incorporation < 12h	1	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0.43
	broadcast, vegetation	13	14	13	14	14	10	8	6	4	3	0	0	0	0	0	0.50
	broadcast, grassland	12	13	12	13	13	8	8	8	7	6	6	6	6	6	6	0.60
	trailing hose, without incorporation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.46

																NH3-N EF for application,
	trailing hose, incorporation < 1 h	3	3	3	3	3	9	9	9	9	8	8	8	8	8	8	0.04
	trailing hose, incorporation < 4h	6	7	7	8	7	5	5	4	4	3	3	3	3	3	3	0.15
	trailing hose, incorporation < 8h	5	5	5	5	5	0	0	0	0	0	0	0	0	0	0	0.24
	trailing hose, incorporation < 12h	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0.30
	trailing hose, vegetation	17	17	17	18	17	18	18	17	17	17	19	19	19	19	19	0.35
	trailing hose, grassland	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	0.54
	trailing shoe, without incorporation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.46
	trailing shoe, incorporation < 1 h	0	0	0	0	0	2	3	4	5	6	6	6	6	6	6	0.04
	trailing shoe, incorporation < 4 h	0	0	0	0	0	1	1	2	2	2	2	2	2	2	2	0.15
	trailing shoe, incorporation < 8 h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.24
	trailing shoe, incorporation < 12 h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.30
	trailing shoe, vegetation	1	1	1	1	1	5	7	9	11	12	13	12	13	13	13	0.36
	trailing shoe, grassland	1	1	1	1	1	3	4	5	6	7	7	7	7	7	7	0.36
	injection (open slot), bare soil	1	1	1	0	1	2	2	2	2	2	2	1	1	1	1	0.24
	injection (open slot), vegetation	1	1	1	1	1	2	2	2	3	3	3	3	3	2	2	0.24
	injection (open slot), grassland	1	1	1	1	1	2	2	2	2	3	2	2	2	2	2	0.24
	grubber and injection, bare soil	12	10	11	7	9	14	14	15	16	16	16	16	15	16	16	0.04
	grubber and injection, vegetation	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	0.24
	grubber and injection, grassland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.24

Table 513: Laying hens, housing-specific partial NH_3 emission factors

[in kg NH 3- N per excreted kg N]	≤ 2000	2001 - 2009	≥2010	2011 - 2019	≥2020
cage housing; as of 2010: small-group housing	0,164	0,164	0,066	0,066	0,066
floor management, aviary	0,351	linear interpolation	0,090	linear interpolation	0,071
intensive outdoor management, free-range management, organic production	0,351	linear interpolation	0,090	linear interpolation	0,071

Annex 7.4 Other detailed methodological descriptions for CRF 4 (LULUCF)

This chapter is currently not required.

Annex 7.5 Other detailed methodological descriptions for CRF 5 (Waste and wastewater)

This chapter is currently not required.

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