CLIMATE CHANGE
08/2026

Interim report

The EU Taxonomy in modeling

Quantifying the effect of the EU Taxonomy by modelling and an evaluation of scenarios for their EU Taxonomy alignment

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Öko-Institut, Berlin

publisher:
German Environment Agency

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KLIFOPLAN of the Federal Ministry for the Environment, Climate Action, Nature Conservation and Nuclear Safety

Project No. (FKZ) 3721 41 502 0

FB001964/ENG

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On behalf of the German Environment Agency

Imprint

Publisher
Umweltbundesamt
Wörlitzer Platz 1
06844 Dessau-Roßlau
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Internet: www.umweltbundesamt.de

Report performed by:
Fraunhofer Institute for Systems and Innovation Research ISI
Breslauer Str. 48
76139 Karlsruhe
Germany

Report completed in:
October 2025

Edited by:
Section V 1.2 Climate and Energy Strategies and Scenarios
René Lanz

DOI:
https://doi.org/10.60810/openumwelt-8191

ISSN 1862-4359

Dessau-Roßlau, January 2026

Abstract: The EU Taxonomy in modeling

The EU Taxonomy establishes a reporting obligation for large and capital-market oriented companies on the sustainability of their economic activities. How effective this regulation is in reorienting capital flows and changing financing conditions for such activities is an open question. This report proposes ways to model the effectiveness of the EU Taxonomy in this regard and discusses these options by drawing on the models applied in the Pathways project. With considerable model developments depending on the sector, a "Cost of capital" approach could yield results. In a second analysis, the report discusses the alignment of the three scenarios developed in the Pathways project ("Pathways to an EU in 2050 with net-zero GHG emissions") with the EU Taxonomy. We show that the more ambitious scenarios are aligned better and earlier with the EU Taxonomy. However, due to the mismatch between models and their variables and the technical screening criteria of the EU Taxonomy, this analysis comes with considerable uncertainty

Kurzbeschreibung: Die EU-Taxonomie in der Modellierung

Die EU-Taxonomie verpflichtet große und kapitalmarktorientierte Unternehmen zur Berichterstattung über die Nachhaltigkeit ihrer wirtschaftlichen Tätigkeiten. Wie wirksam diese Regelung bei der Umlenkung von Kapitalströmen und der Veränderung der Finanzierungsbedingungen für solche Tätigkeiten ist, bleibt offen. Der vorliegende Bericht schlägt Möglichkeiten vor, die Wirksamkeit der EU-Taxonomie in dieser Hinsicht zu modellieren, und diskutiert diese Optionen anhand der im Pathways-Projekt angewandten Modelle. Je nach Sektor ist eine unterschiedlich starke Modellentwicklung notwendig und es könnte ein „Cost of Capital"-Ansatz Anwendung finden. In einer zweiten Analyse diskutiert der Bericht die Übereinstimmung der drei im Pathways-Projekt („Pathways to an EU in 2050 with net-zero GHG emissions") entwickelten Szenarien mit der EU-Taxonomie. Wir zeigen, dass die ambitionierteren Szenarien besser und früher mit der EU-Taxonomie übereinstimmen. Aufgrund der grundsätzlichen Unterschiede zwischen den Modellen und ihren Variablen einerseits und den technischen Screening-Kriterien der EU-Taxonomie andererseits ist diese Analyse jedoch mit erheblichen Unsicherheiten behaftet.

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List of abbreviations

Abbreviation	Explanation
BEV	Battery electric vehicles
CHP	Combined heat and power
CoC	"Cost of capital" approach to modeling the EU Taxonomy
CSRD	Corporate social responsibilty directive
DNSH	Do no significant harm, referring to the criteria of the EU Taxonomy
ESG	Environmental, Social, Governance
EU ETS	EU Emissions Trading System
EUBase	Abbreviation for the reference scenario of the Pathway project
EUTarget	Abbreviation for the target scenario reaching climate neutrality with a focus on technical measures in the Pathways project
EUSupreme	Abbreviation for the target scenario reaching climate neutrality with a focus on sufficiency measures in the Pathways project
FCEV	Fuel cell electric vehicles
GHG	Green house gas
GVA	Gross value added
ICEV	Internal combustion engine vehicles
NZEB	Near zero emission buildings
PHEV	Plug-in hybrids
WACC	Weighted average cost of capital
Pathways project	The project "Pathways to an EU in 2050 with net-zero GHG emissions" (Duscha et al. 2025, forthcoming)

Summary

The **EU Taxonomy regulation establishes a reporting obligation** for large and capital market-oriented companies on the share of economic activities which are deemed sustainable (European Commission 2020b). The share of economic activity is defined as the share in investment or turnover, depending on the type of company. To do so, a **catalogue of activities and technical screening criteria** has been defined in subsequent delegated acts. Each activity must provide a significant contribution to one of six environmental objectives while not harming any of the other five (climate change mitigation, climate change adaptation, water resources, circular economy, pollution prevention and biodiversity).

The **effect of the EU Taxonomy will only be indirect**, following the use of the information the companies make available by complying with the reporting obligation established by the EU Taxonomy. As proposed by Höck et al. (2020), the risk premium of sustainable companies and projects should be lower, leading to better financing conditions. This is the measurable effect the EU Taxonomy could have on project finance. In this regard, disclosure of the taxonomy compliance of activities could steer financial flows (Lütkehermöller et al. (2020); Kölbel et al. (2020)). Lütkehermöller et al. (2020) describe three ways in which the financial sector can work toward GHG reductions (divestment, i.e., withdrawing investments that are not in line with the climate strategy; direct impact investments (so-called positive impact investment); building corporate commitments (so-called corporate engagement)). However, these are only affective if a majority of investors follows them.

The **objective of this report** is twofold: In the first analysis, we investigate **how the effect of the taxonomy could be modelled**. In a second step, we assess whether the results of the scenarios developed in the **Pathways project** ("Pathways to an EU in 2050 with net-zero GHG-emissions" (Duscha et al. (2025, forthcoming)) **are aligned with the EU Taxonomy** and more specifically the technical screening criteria it sets out.

Modeling the EU Taxonomy

Following the review of the sectoral models applied in the Pathways project, **the "Cost of capital" approach of modelling the EU Taxonomy can be seen as a realistic alternative** to modelling the effects of the EU Taxonomy as it is close enough to current modelling frameworks. In this approach, economic decisions calculated by a model are influenced by changes in the WACC (weighted average cost of capital), which is in turn determined by a scenario of the effectiveness of the EU Taxonomy. This path to modelling the taxonomy **still comes with a high burden of model development**, even if models are partly already based on economic decision making. Only few models applied in the Pathways project are partly apt for this approach,

In addition, **scenarios of the effectiveness of the EU Taxonomy** would need to be developed if the EU Taxonomy is modelled directly. These scenarios would at least add an additional variable to the policy mix currently defining the scenarios of climate change mitigation. The **link between cost of capital and effectiveness of the EU Taxonomy lacks empirical data**, which increases the overall uncertainty of such an approach. Nevertheless, by investigating sensitivities of the cost of capital, the potential boundaries of the effectiveness of the EU Taxonomy could be evaluated.

Evaluating the Pathway scenarios for taxonomy alignment

The second objective of this report is to evaluate the alignment of the scenarios developed in the Pathways project with the EU Taxonomy. Due to the data availability and model variables of the different sectoral models, such an analysis comes with **major uncertainties** and quantitative results can only be generated in limited cases. The overall qualitative assessment, however,

gives an indication of the compliance of the three Pathway scenarios with the indicators. The two **target scenarios EUTarget and EUSupreme reach taxonomy alignment earlier** and to a higher degree compared to EUBase. Between the two target scenarios, EUSupreme reaches an equal or higher EU Taxonomy alignment compared to EUTarget. This can be explained by a limited number of activities, particularly in the agricultural sector and an earlier transformation of primary steel making. There are limited or no differences in the transformation, transport and buildings sectors.

The analysis comes with considerable **uncertainties which are** linked to the **mismatch between the criteria covered by the EU Taxonomy and the modelling approach.** This is mirrored in the results the models provide and variables they work with to simulate the transformation related to climate change mitigation.

Despite its limitations, the results of this analysis provide a good impression of the compatibility of the different scenarios with the technical screening criteria of the EU Taxonomy. Even if **EU Taxonomy alignment cannot be fully assessed due to the technical limitations**, the results present a **valuable summary overview** of the assumptions and model results provided by the Pathways project **showing how the target of climate neutrality can be reached**.

Zusammenfassung

Die **EU-Taxonomieverordnung** verpflichtet große und kapitalmarktorientierte Unternehmen zur **Berichterstattung** über den Anteil ihrer wirtschaftlichen Tätigkeiten, die als nachhaltig gelten (European Commission 2020b). Der Anteil der wirtschaftlichen Tätigkeit wird je nach Art des Unternehmens als Anteil an den Investitionen oder am Umsatz definiert. Zu diesem Zweck wurde in delegierten Rechtsakten, die der EU-Taxonomie nachfolgten, ein **Katalog von wirtschaftlichen Aktivitäten und technischen Prüfkriterien** festgelegt. Jede dort definierte Tätigkeit muss einen wesentlichen Beitrag zu einem der sechs Umweltziele leisten, ohne die anderen fünf zu beeinträchtigen um als nachhaltig zu gelten (die sechs Umweltziele sind dabei Klimaschutz, Anpassung an den Klimawandel, Schutz der Wasserressourcen, Kreislaufwirtschaft, Vermeidung von Umweltverschmutzung und Biodiversität).

Die **Auswirkungen der EU-Taxonomie sind nur indirekt**, nachdem die Unternehmen die Informationen gemäß der EU-Taxonomie zur Verfügung gestellt haben und so ihrer Berichtspflicht nachkommen. Wie von Höck et al. (2020) vorgeschlagen, sollte die Risikoprämie für nachhaltige Unternehmen und Projekte niedriger sein, was zu besseren Finanzierungsbedingungen führt. Dies ist der messbare Effekt, den die EU-Taxonomie auf Projektfinanzierung haben könnte. Die Offenlegung der Taxonomiekonformität von Aktivitäten könnte so insgesamt Finanzströme lenken und die Finanzierungsbedingungen für nachhaltige Aktivitäten verbessern (Lütkehermöller et al. (2020); Kölbel et al. (2020)). Lütkehermöller et al. (2020) beschreiben drei Möglichkeiten, wie der Finanzsektor auf eine Reduzierung der Treibhausgasemissionen hinarbeiten kann (Divestment, d. h. Rückzug von Investitionen, die nicht im Einklang mit der Klimastrategie des Investors stehen; Investitionen mit positiver Wirkung (sogenannte Positive Impact Investments); positives Engagement von Unternehmen (sogenanntes Corporate Engagement)). Diese sind jedoch nur dann wirksam, wenn eine Mehrheit der Investoren ihnen folgt.

Dieser Bericht verfolgt zwei Ziele: In der ersten Analyse wird untersucht, **wie die Auswirkungen der Taxonomie modelliert werden könnten.** In einem zweiten Schritt wird bewertet, ob die Ergebnisse der im **Pathways-Projekt** ("Pathways to an EU in 2050 with net-zero GHG-emissions" (Duscha et al. (2025, forthcoming)) entwickelten **Klimaschutz-Szenarien mit der EU-Taxonomie in Einklang stehen**, insbesondere mit den darin festgelegten technischen Screening-Kriterien.

Modellierung der EU-Taxonomie

Nach der Analyse der im Pathways-Projekt angewendeten sektoralen Modelle **stellt sich der „Cost-of-capital"-Ansatz zur Modellierung der EU-Taxonomie als mögliche Alternative** zur Modellierung der Auswirkungen der EU-Taxonomie dar, da er den aktuellen Modellierungsansätzen ausreichend nahekommt. Bei diesem Ansatz werden die von einem Modell berechneten wirtschaftlichen Entscheidungen durch Änderungen des WACC (gewichtete durchschnittliche Kapitalkosten) beeinflusst, die wiederum durch ein Szenario zur Wirksamkeit der EU-Taxonomie bestimmt werden könnten. Dieser Weg zur Modellierung der Taxonomie **ist nach wie vor mit einem hohen Aufwand für die Modellentwicklung verbunden,** auch wenn die Modelle teilweise bereits auf einer wirtschaftlichen Entscheidungslogik basieren. Nur wenige der im Pathways-Projekt angewandten Modelle sind für diesen Ansatz und dann nur teilweise direkt schon geeignet.

Darüber hinaus müssten **Szenarien zur Wirksamkeit der EU-Taxonomie** entwickelt werden, wenn die EU-Taxonomie direkt modelliert wird. Dies wäre eine zusätzliche Variable im Policy-Mix, der die Klimaschutz-Szenarien definiert. Für **den Zusammenhang zwischen**

Kapitalkosten und Wirksamkeit der EU-Taxonomie fehlen empirische Daten, was die allgemeine Unsicherheit eines solchen Ansatzes erhöht. Dennoch könnten durch eine Sensitivitätsanalyse der Kapitalkosten die potenziellen Grenzen der Wirksamkeit der EU-Taxonomie bewertet werden.

Bewertung der Pathway-Szenarien über die Konformität mit der Taxonomie

Das zweite Ziel dieses Berichts ist die Bewertung der Konformität der im Pathways-Projekt entwickelten Szenarien mit der EU-Taxonomie. Aufgrund der Datenverfügbarkeit und der Modellvariablen der verschiedenen sektoralen Modelle ist eine solche Analyse mit **großen Unsicherheiten** behaftet und quantitative Ergebnisse können nur in begrenztem Umfang erzielt werden. Die qualitative Gesamtbewertung liefert jedoch einen Hinweis auf die Übereinstimmung der drei Pathways-Szenarien mit den Kriterien der Taxonomie. Die beiden **Zielszenarien „EUTarget“ und „EUSupreme “ erreichen die Übereinstimmung mit der EU-Taxonomie früher** und in höherem Maße als „EUBase“. Zwischen den beiden Zielszenarien erreicht EUSupreme eine gleiche oder höhere EU-Taxonomie-Konformität als EUTarget. Dies lässt sich auf eine begrenzte Anzahl von Aktivitäten, insbesondere im Agrarsektor, zurückführen und durch eine frühere Umstellung der Primärstahlherstellung erklären. In den Sektoren Umwandlung, Verkehr und Gebäude gibt es nur begrenzte oder keine Unterschiede.

Die Analyse ist mit erheblichen **Unsicherheiten** verbunden**,** die auf die **Diskrepanz zwischen den Kriterien der EU-Taxonomie und dem Modellierungsansatz** zurückzuführen sind**.** Der Modellierungsansatz definiert die Ergebnisse der Modelle und die Variablen, mit denen die Modelle die Transformation simulieren und somit die Daten, die zur Untersuchung der Konformität bereitstehen.

Trotz ihrer Einschränkungen vermitteln die Ergebnisse dieser Analyse einen guten Eindruck von der Vereinbarkeit der verschiedenen Szenarien mit den technischen Prüfkriterien der EU-Taxonomie. Auch wenn **die Übereinstimmung mit der EU-Taxonomie aufgrund der technischen Einschränkungen nicht vollständig bewertet werden kann**, bieten die Ergebnisse **einen wertvollen Überblick** über die Annahmen und Modellergebnisse des Pathways-Projekts, die **zeigen, wie das Ziel der Klimaneutralität erreicht werden kann**.

1 Introduction

The project "Pathways to an EU in 2050 with net-zero GHG-emissions" (Duscha et al. (2025, forthcoming), referred to as Pathways project in the following) aims at illustrating different possible pathways for a transformation of the EU and its Member States to a climate-neutral continent. For that, a reference scenario (EUBase) and two target scenarios (EUTarget, and EUSupreme) were developed and modelled. This complementary report discusses aspects of modelling the EU Taxonomy within the framework of this project.

The EU Taxonomy regulation establishes criteria under which an economic activity is regarded as environmentally sustainable and sets out reporting obligations for large companies. The information provided in this way can then be used to channel investments into sustainable activities, improving their financing conditions.

This report explores the possibilities to model the effects of the EU Taxonomy. The effectiveness of the EU Taxonomy is discussed and two conceptual modelling approaches derived, which are then contrasted with the models used in the Pathways project. In a second part, the report explores whether the three scenarios of the Pathways project can be considered in line with the EU Taxonomy requirements for sustainable activities and explores ways in which this can be assessed.

The report first gives an overview of the EU Taxonomy in Section 2, by providing an overview of the EU Taxonomy and discussing the actors regulated, the activities covered and the screening criteria applied by the EU Taxonomy. Section 3 discusses possibilities to simulate the effects of the EU Taxonomy, proposing two approaches. Section 4 then provides a qualitative evaluation of the EU Taxonomy alignment of the three scenarios of the Pathways project. This is complemented by Annex A, which gives details for each sector on the contents of Sections 3 and 4.

2 The EU Taxonomy: Overview and potential effects

2.1 Background and overview of the EU Taxonomy

The EU Taxonomy regulation entered into force in 2020 and establishes criteria under which an economic activity is regarded as environmentally sustainable (European Commission 2020b). As context, it is part of the EU Green Deal to reach the 2030 climate targets (European Commission 2019) and the action plan on financing sustainable growth (European Commission 2018b). The impact assessment of the sustainable investment framework (European Commission 2018c, 2018a) originally performed and supporting the implementation of the EU Taxonomy outlined three general objectives to be achieved by the EU Taxonomy:

1. Mainstreaming financial risks stemming from sustainability issues
2. Fostering transparency in financial and economic activity on sustainability
3. Reorienting capital flows towards sustainable investments.

In order to achieve these objectives, the following steps were set out to be required:

1. Ensure clarity and a coherent approach across sectors and Member States as regards the integration of ESG (environmental, social, governance) factors by relevant entities in their investment/advisory process
2. Increase transparency towards end-investors by improving ESG-related disclosure requirements
3. Provide clarity at EU level on what are sustainable economic activities

It was proposed to achieve these objectives by what is now known as the EU Taxonomy. The EU Taxonomy sets out reporting obligations for certain economic players and a catalogue of activities and criteria which an activity needs to comply with in order to be recognized as taxonomy conformed.

The reporting obligations cover large and capital market-oriented companies. The scope of companies has been expanded under the CSRD (Corporate Social Responsibility Directive, European Commission (2022)) and now covers large companies (defined by meeting at least two of the three following requirements: total assets greater EUR 25 million, sales greater EUR 50 million, over 250 employees) independent of their capital market orientation as well as capital market-oriented small and medium-sized companies and non-European companies meeting certain size criteria. For these companies, the EU Taxonomy creates a reporting obligation as follows: For financial players, on the shares of their portfolio that is taxonomy-compliant and for all others on the share of sales, CAPEX and OPEX that is taxonomy-compliant. These shares need to be made public, and this information can then be used by investors and other actors to support the overarching targets of the EU Taxonomy. The 2025 omnibus package (European Commission 2025) proposes changes to the scope of companies required to report under the EU Taxonomy, increasing the size thresholds to limit the number of companies required to report.

In order for an economic activity to comply with the EU Taxonomy, it needs to adhere to certain criteria summarized below, i.e. significant contribution, do no significant harm and minimum safeguards. These criteria are laid out in delegated acts following the publication of the EU Taxonomy regulation (see European Commission (2021) for the criteria on climate change mitigation and climate change adaptation). A useful overview of the catalogue is provided in the online EU Taxonomy compass.[1] The EU Taxonomy regulation foresees a review of the criteria every three years. These criteria are set out for 101 economic activities grouped into nine sectors. For agricultural activities, the screening criteria have not been published, we therefore refer to the draft delegated act (European Commission 2020a) in this study to cover this sector.

- **Significant contribution**: The activity needs to contribute to one of six environmental objectives (climate change mitigation, climate change adaptation, sustainable use and protection of water and marine resources, transition to a circular economy, pollution prevention and control, protection and restoration of biodiversity and ecosystems). Not all activities have a significant contribution criterion for each environmental objective.
- **Do no significant harm (DNSH)**: At the same time, each criterion may not harm any of the other five environmental objectives. This is set out in the so-called DNSH criteria defined for each activity.
- **Minimum safeguards**: It is carried out in compliance with the minimum safeguards set out in the EU Taxonomy regulation. These refer to the minimum social standards a company needs to meet.

2.2 Effects of the EU Taxonomy

The EU Taxonomy as such is a reporting obligation which creates data and information. The aim of the EU Taxonomy is that this information is then used to channel investments into sustainable activities (as defined by the EU Taxonomy) and improve the financial liability of such activities. So it is the way the information, which the EU Taxonomy generates, is used that determines what the effect of the EU Taxonomy will be. The effect will therefore always be indirect, which makes the assessment of the effectiveness of the EU Taxonomy challenging.

The Commission itself has published a short report in 2024 (European Commission 2024), which discusses the effect of the EU Taxonomy, and which compares stock market data of standard indices with that of companies reporting significant shares of taxonomy aligned activities. It shows that based on the analysis of this high-level indicator, the compliant companies outperformed the standard indices, underlining their attractiveness for investors. A similar result is provided by Bassen et al. (2025), who find evidence of a taxonomy regulation alignment premium of stock returns (evidence of stock price premium paid for green assets). Despite the information provided by this first empirical data, stock returns are a high-level indicator and do not show how a company would benefit from taxonomy compliance. There is also no proof of causality in such data alone, as companies performing better may also be the same companies as those reporting under the EU Taxonomy. Bassen et al. (2025) also point out that their analysis does not show that companies are making investment choices in order to be aligned with the requirements of the EU Taxonomy.

As proposed by Höck et al. (2020), the risk premium of sustainable companies and projects should be lower, leading to better financing conditions. This is the measurable effect the EU Taxonomy could have on project finance. In this regard, disclosure of the taxonomy compliance of activities could steer financial flows (Lütkehermöller et al. (2020); Kölbel et al. (2020)). Lütkehermöller et al. (2020) describe three ways in which the financial sector can work towards GHG reductions:

- divestment, i.e., withdrawing investments that are not in line with the climate strategy

[1] See here: https://ec.europa.eu/sustainable-finance-taxonomy/taxonomy-compass

- direct impact investments (so-called positive impact investment)
- building corporate commitments (so-called corporate engagement)

A strategy that to defer financing from unsustainable activities should not build on divestment alone. This can be effective if large amounts of funding are withdrawn from related financing streams. However, and very likely, other financiers are found, who in turn profit from the possibly increased risk premiums, provided that the divestment has triggered them. Divestment therefore does not cut unsustainable projects completely, despite its connotation.

Positive impact investment does the opposite and provides funds for climate-friendly investments. A potential investor following this strategy may choose to see projects viable even if financial returns are lower. In addition to achieving financial goals, environmental and social goals also determine how the investor acts and play a role in the concept of positive impact investment. In order to have an impact as an impact investor, the financing conditions must firstly be better than those provided by a neutral investor and secondly, sufficient funds must be made available by the investor to have a major impact.

Lütkehermöller et al. (2020) attribute the greatest influence to the third levy, corporate engagement. This levy requires interaction of the investor with those invested in and uses pressure by the financial institutions to invest in more sustainable assets, to enforce a governance reform or of divestment. Corporate engagement enables direct influence on over-the-counter equity and loans and on public equity when several institutions join forces. Furthermore, corporate engagement also includes softer measures such as interaction with the workforce or customers, which increases the likelihood that it will have the desired effect. However, it also requires the strongest interaction and therefore the strongest engagement of the investor.

As explained, the EU Taxonomy regulation imposes reporting requirements on financial institutions and companies, which can be seen as a precondition and thus first step towards corporate engagement but also applies to positive impact investment. In the following analyses, we adopt this understanding and see the effect of the EU Taxonomy as a combination of corporate engagement and positive impact investment. In general, however, it is important to keep in mind that the effect of the EU Taxonomy is indirect: It will only lead to investments into sustainable activities if these are valued by the investor, i.e. if sustainability is valued by society. As long as investors exist that are willing to invest independently of sustainability criteria – and this will likely always be the case in the near future – the indirect effects of those valuing sustainability will be compensated by others who do not.

3 Modeling the EU Taxonomy

As explained in the previous section, the effect of the EU on financing conditions is indirect. It sets out no thresholds for financing conditions or obligation other than reporting that could be implemented in a model directly, such as is the case in a different context with renewable energy targets. Since its effect is indirect, it would be difficult to set up a scenario where the effect of the EU Taxonomy is modelled directly. This section discusses these difficulties in detail and explains how different sectoral models would need to be extended in order to model directly the effects of the EU Taxonomy.

The technical screening criteria of the EU Taxonomy are to some degree reflected in the different models, such as the GHG emission thresholds for industrial applications or tail pipe emissions defined for different transport applications. If this is the case for a certain model, these criteria can be used to evaluate whether the results or assumptions of a scenario complies with the EU Taxonomy. This analysis is discussed and carried out in Section 4.

3.1 Conceptual discussion: Modeling the EU Taxonomy directly

Building on the discussion of the effects of the EU Taxonomy on financial market participants in Section 2, we discuss two ways in which a model can in principle be used to simulate the effects of the policy instrument:

1. A model could be used which represents financial flows and investing actors directly. This overarching model would then make a specific amount of money available to certain activities or projects which are then modelled. This option is further explored below under the heading of "**Financial flow modelling**".
2. Alternatively, the cost of capital as principal variable affecting project finance could be parameterized as a function of taxonomy effects and then be used in different models. This approach is discussed below under the heading "**Cost of capital approach**".

In both cases, the effects of the EU Taxonomy would need to be parameterized: The effect of the taxonomy is indirect, as the EU Taxonomy only defines a reporting obligation. The reporting obligation creates data and potentially knowledge in society on the sustainability of economic activities of different actors. How society turns this knowledge into action is a question of scenarios. For example, and as discussed above, knowing that activities of certain actors are not sustainable can be ignored or can lead to the exclusion of this company from access to capital by way of divestment or explicit exclusion policies. For reason of this diversity, there is no single effect of the taxonomy (as e.g. in a benchmarking threshold, a renewable energy or energy efficiency target), but the effect can only be quantified by way of scenarios or narratives that describe how it will take effect.

Equally in both cases, the models need to be based on a logic of economics. This speaks for agent-based models, but at least, economic decision making needs to be part of the model logic. The following section briefly discusses the different models used in the Pathways project and assesses in how far they would need to be expanded or altered to reflect such an approach.

Even if either of the above mentioned two approaches were implemented, it would be necessary to reflect the fact that not all economic actors are covered by the EU Taxonomy, as it limits the reporting obligation to large companies only. Some assumption would therefore be needed on the size distribution of projects to accurately reflect the taxonomy reporting obligations and related effects. Alternatively, it could be part of the scenario definition to submit more or fewer of the actors to the effects of the taxonomy. Both is possible but increases the complexity of any approach implementing the EU Taxonomy.

3.1.1 Financial flow modeling

As discussed above, there are multiple effects the taxonomy could have on the access of capital for projects, including exclusion policies that lead to divestment (where policies can also be policies of private investors or companies). To model these effects directly, a model of financial flows would need to be established. The total capital available for investment would need to be counted and pooled to be distributed among the different economic activities. In an approach with high granularity, this would lead to an agent-based model in which the agents are not only industrial companies, car fleet owners or waste water management facilities acting on the basis of economic decisions (i.e. the actors covered by reporting obligations of the EU Taxonomy), but also the investors actually making funding available, either at all or to certain conditions. The behavior of the financial investors would be defined to maximise not only profit but also adhere to their investment preferences. In a model world guided by the EU Taxonomy, this would lead to a change in the economic activities that are realized.

This modelling approach comes with several difficulties:

- **Limited data availability**: In order not only to remain a conceptual representation but retain a link to the real world, such an approach would need to be implemented based on real world data. However, data on financial actors with their investment portfolio is not available. Setting up such a database would be an enormous task with uncertain outcome.
- **Limited model interaction**: As will be discussed in the following section, the sectoral models do not all model the transition based on economic decision making, let alone are agent based. Linking these to the financial actors would therefore not be possible. Instead, new models would need to be established, which would then need to be linked to one another and the financial actor modelling. This model development needs years of model development and validation for each sectoral model.
- **Other policies need to be reflected**: The taxonomy is not the only policy influencing the decision-making process of actors and this would naturally need to be reflected in the modelling approach proposed here. This would add additional complexity, while the importance of the taxonomy would likely be limited, except for extreme cases of exclusion and divestment in large scale. This questions the effort that would need to go into establishing such a modelling approach.

3.1.2 Cost of capital approach

For the reasons of complexity and the enormous development task underlying the proposed “Financial flow modelling” approach, a more pragmatic approach could also be followed. One key element in the “Financial flow modelling” approach is the cost of capital made available to projects. In the case of any economic decision making in a model, the cost of capital is a common and key variable of the cost calculation on the basis of which decisions are taken. It is this variable that is changed by the effects of the EU Taxonomy through levers such as positive impact investment or corporate engagement discussed above. Even the more direct strategies underlying divestment or exclusion can be described by changing the cost of capital.

The cost of capital is commonly described as a composite variable, the weighted average cost of capital (WACC), which is split into different elements. While some would remain unchanged, one could establish a link between the effects of the taxonomy and parts of WACC, e.g. cost of debt. If made available to models that build on economic decision making, the improved WACC of taxonomy conform activities would in turn improve the financing conditions of such projects.

Nevertheless, this modelling approach also comes with certain difficulties and aspects to consider:

- **Parameterizing the effect of the EU Taxonomy on WACC**: There is no established link and limited literature on how strong the effect of the EU Taxonomy is for investment decisions and WACC. Limited empirical data is available to establish such a link, with Bassen et al. (2025) providing first insights. Similar to the “Financial flow modelling” approach, the effect of the taxonomy could only be investigated by way of scenarios, altering the cost of capital within certain limits defined by the scenarios. As for the financial flow modelling, assumptions on the size distribution of actors would need to be considered in the parameterization.
- **Models need to be based on economic decision making:** As discussed in the following paragraphs, this is not the case for common and established sectoral models. Even if economic decision making is part of a model, the dependency of WACC on the type of investment (taxonomy conform or not) would need to be implemented. This would at least require some form of lookup-table in the model logic. Either way, the effort to establish these models would translate to likely years of development work.

3.2 Discussion of models applied in the Pathways project

In the following, we briefly discuss changes that would be required to the sectoral models applied in the Pathways project to model the effects of the taxonomy directly. Building on the discussions in the preceding paragraphs, we consider the “Cost of capital approach” (CoC approach) more feasible and investigate what model extensions would be required to implement such an approach. In some cases, such a change would mean rebuilding the model completely. In discussing these changes, this report does not provide a full overview of alternative models which may take a different approach and therefore be closer to the technical possibility of simulating the taxonomy. Details of the modelling approach underlying each model are presented as part of Annex A.

In considering these changes, one should consider that economic decision making is not per se required to deliver reasonable and meaningful modeling results. On the contrary, economic decision making in a model often needs to be parameterized to such a degree that the effects one wants to achieve are better implemented directly. This corresponds to the empirical insight that decisions are not always taken on the basis of economic analysis alone.

- **Industry**: The FORECAST Industry model applied in the Pathways project uses a combination of approaches to simulate the transition of the industrial sector. For industrial furnaces as well as hot water and steam generation, the transition is based on a least-cost approach of lifecycle costs under perfect foresight. By model developments as described above, WACC altered by assumptions about the EU Taxonomy, as in the CoC approach, would influence the transformation. However, for energy intensive processes, the transformation is not only based on technological maturity and associated costs but also on exogenous scenario definitions. Implementing a fully cost based approach considering different WACCs would therefore need an extensive model development.
- **Transport**: The ALADIN model is structured differently for the different transport modes. For trucks, assuming one can measure the effect of the taxonomy on cost of capital, the implementation of the CoC approach would be straight forward. Cost of capital is part of the

cost function which determines the agent-based decision making in the model. Sustainable vehicles could receive a cheaper cost of capital. For cars, a better cost of capital for electric vehicles could be interpreted as monetary incentive for EVs and hence influence the logistic curve that determines the uptake of EVs. For cars and the other transport modes, a CoC approach would translate to rebuilding the model. In particular for rail, aviation and navigation, no actors are currently considered in the model.

- **Buildings**: Currently, the simulation is performed by the Low-Carbon Europe (LCBE) model on an area basis using a stock exchange approach with no economic actors considered. Economic decision making is not part of the model, which means the CoC approach cannot be applied. To make use of this in the model, one would need to shift to a more detailed representation of categories, e.g. different age classes or building types per country or country cluster, consider costs of renovation including labour costs, costs of technologies, and then base the model logic on economic decision making.
- **Energy supply**: The energy supply is calculated using Enertile, an energy system optimization model. In principle, a CoC approach could be implemented. The principal parameters such as investment, operation and maintenance (O&M), and efficiency are included in the model already, as are all activities of the taxonomy. Sensitivity analyses could provide insights into how variations in assumptions related to these activities impact the overall model outcomes. Despite the technical capabilities of the model, such an approach would still require certain model developments. To enhance the analysis of taxonomy alignment, separate modules could be developed to externally analyse the effects of taxonomy on techno-economic parameters.
- **Agriculture**: LiSE is a bottom-up analytical deterministic model consisting of natural science sub-modules (animal, plant, energy). It is not coupled to an economic model. In principle, a large proportion of agricultural emissions are caused by livestock. In order to improve the analysis of the taxonomy adjustment, higher financing costs should have an impact in this sector. Although many of the originally planned activities are included as emission reductions, their costs and financing are not part of the model. The LiSE model for Europe used in the Pathways project does not cover economic relations (e.g. abatement costs, costs for investment or operation resources). A new or different model would be required to model the EU Taxonomy directly.
- **Forestry and land use**: The Forest and Agriculture Biomass – Land use (FABio-Land) model is a simulation tool based on information on area shares of different land use categories and emission factors for activities and processes on these areas. The modelling approach of FABio-Land is therefore not suited for an explicit modelling of the EU Taxonomy. Similar developments such as for LiSE would be required to implement a CoC approach for the forestry sector. Modeling the EU Taxonomy seems particularly challenging for the forestry sector since the technical screening criteria are mostly about administrative background documents such as climate benefit analyses to be carried out or audits which are required. These aspects will likely not be part of any system analysis model.
- **Waste**: The EU Taxonomy criteria for the waste sector are mostly implicitly included in the measures implemented in the model applied in the Pathways project. The model implementation focuses on the development of emissions from treatment of waste and wastewater derived from changes in per-capita values for different activity rates[2] and

[2] Examples for activity rates would be per-capita waste generation or per-capita food waste.

emission factors. While it is possible to implicitly assess whether EU Taxonomy criteria are met (see Section 4), a different type of model would be required for an in-depth assessment of actor behavior and resulting impacts on taxonomy criteria. The same is true for a lighter implementation such as in the CoC approach.

3.3 Conclusions on modelling the EU Taxonomy

As discussed, modelling the EU Taxonomy directly as in the "Financial flow modelling" comes with likely disproportionate difficulties. However, following the review of the sectoral models applied in the Pathways project, the "Cost of capital" approach is close enough to current modelling frameworks to be seen as a realistic option to modelling at least indirectly the effects of the EU Taxonomy. Despite these existing sectoral models applied in the Pathways project, this way of modelling the EU Taxonomy still comes with a high burden of model development: During the economic decision process which needs to be implemented in the model, compliance with the screening criteria needs to be established, which speaks for significant model developments even where models are already based on economic decision making.

In addition, scenarios of the effectiveness of the EU Taxonomy still need to be developed. These EU Taxonomy scenarios at least add an additional variable to the policy mix currently defining transformation scenarios such as in the Pathways project. Also, the link between cost of capital and effectiveness of the EU Taxonomy lacks empirical data, which increases the overall uncertainty of such an approach. Nevertheless, by investigating scenarios (or sensitivity analyses) of the link between EU Taxonomy and cost of capital, the potential boundaries of the effectiveness of the EU Taxonomy could be evaluated.

For a start, this could be implemented with a model which is already based on economic decision making. Of the models used in the Pathways project, the freight transportation model of ALADIN or parts of the FORECAST modelling framework are suitable for a start. The implementation in Enertile would likely be more time consuming. As stated, however, implementing such an approach would still require certain model developments, which link activities to the EU Taxonomy screening criteria and the effect on cost of capital defined by the scenario narrative. At least, this requires a lookup-table of the EU Taxonomy screening criteria and differing costs of capital depending on the activity.

4 Evaluating the Pathway project scenarios for EU Taxonomy alignment

In this section, we discuss the approach and the results of the qualitative EU Taxonomy alignment analysis. The first section discusses the approach; results are discussed in the second section. This analysis builds on and evaluates the scenarios developed in the report "Pathways to an EU with net-zero emissions". Details on the scenarios as well as in-depth discussion of the results are provided in the corresponding publication. The EU Taxonomy alignment is done for the years 2030, 2040 and 2050 based on the current technical screening criteria of the EU Taxonomy, future changes are not anticipated.

A brief overview of the scenarios is given in the following, citing the corresponding publication:

- **EUBase**: This scenario, serving as the reference scenario for the project, analyses the ambition of existing and negotiated policy packages on the EU and Member State level with regards to the 2030 and 2050 climate targets. Reaching the EU emission reduction targets for 2030 and 2050 is not preconditioned.
- **EUTarget**: This target scenario illustrates a pathway to GHG-neutrality by putting a strong focus on technical solutions and differentiation of national strategies. It builds on EUBase but makes assumptions on additional measures to reach the EU emission reduction targets for 2030 and 2050. These assumptions reflect expert knowledge on possible technological pathways and policy developments.
- **EUSupreme**: This second target scenario is based on the common application of strong sustainability criteria in the context of mitigation technologies and a strong focus on non-technical and behavioral mitigation options. As the EUTarget scenario, the scenario builds on EUBase, but makes stronger sustainability, circularity and sufficiency assumptions illustrating a highly sustainable pathway to reach GHG-neutrality in the EU.

This section is a summary of the detailed sectoral assessment provided in Annex A of this report. In the annex, the results of each sectoral assessment are described step by step, following a standardized approach. The technical details of each model (modelling approach, relevant variables and actors in the model) are discussed with a focus of those elements that are linked to the EU Taxonomy. In each section of the annex, this is followed by an assessment of all the activities covered by the EU Taxonomy. For those activities which are reflected in the model at all, an evaluation approach is developed. By following the evaluation approach, the alignment of the model results with the criteria set out in the EU Taxonomy is evaluated. Detailed results are then shown for each activity.

4.1 Approach to the evaluation

The following paragraphs summarize the evaluation approach, which is discussed and documented in detail in Annex A. As the evaluation differs from one sectoral model to another, the reader is kindly requested to refer to the material provided in Annex Afor details. Some overarching principles and a summary of the approach is provided below. Limitations to the analysis are also discussed, which subsequently influence the value of the assessment results discussed in the following section.

Some overarching principles and limitations underly the EU Taxonomy alignment analysis:

- **Only some of the sectors** covered by the EU Taxonomy are modelled in the Pathways project.
  Only the following sectors covered by the EU Taxonomy are covered by the models and scenarios underlying this analysis: Forestry, Manufacturing, Energy supply, sewerage, waste management (remediation not covered), Transport, Construction (real estate activities only included indirectly). The EU Taxonomy covers additional economic activities, which have not been analysed (Environmental protection and restoration activities, Water supply, Information and communication, and Professional, scientific and technical activities).

- Only **one environmental objective** is covered: **climate change mitigation.**
  As the main area of analysis of the underlying models are the effects of policies in the area of climate change mitigation, the analysis in this assessment is limited to this single environmental objective covered by the EU Taxonomy. The other five environmental objectives are not covered by the underlying models, and no data is therefore available to analyse the taxonomy alignment in this regard.

- **Only substantial contribution** is analysed, DNSH compliance is not analysed.
  To be taxonomy conform, an activity needs to comply with the substantial contribution criterion of one environmental objective – in this analysis, we limit to climate change mitigation – and do no significant harm (DNSH) to any of the other environmental objectives. For this, a different and less strict set of criteria is defined in the EU Taxonomy for each activity. However, we cannot use the models and the scenario results to address these DNSH criteria (other than for climate change mitigation, which does not apply as we are assessing the stricter substantial contribution for this environmental objective). When speaking of the requirements of the EU Taxonomy in the following, this text refers to the requirements set out as substantial contribution criterion only.

- Only **parts of each substantial contribution criterion** are assessed.
  For most activities, the substantial contribution criteria are comprised of several requirements each. This depends on the sector and activity under question. E.g., to be eligible for taxonomy alignment under the activity “Electricity generation from wind power”, the substantial contribution criterion to climate change mitigation sets out no additional requirements but the electricity generation. On the other extreme, the activity “Afforestation” sets out a long list of detailed requirements which need to be met, among which details for an afforestation plan, a climate benefit analysis, guarantees of permanence and audits. In those cases where several requirements need to be met, the details given for each activity analysed are given in Annex A.

- **Actor size distribution remains unconsidered.**
  The EU Taxonomy sets out reporting obligation for large companies only. This analysis is done on the basis of model results describing the EU as a whole or in some cases Member State specific results. When the assessment finds compliance with the EU Taxonomy, this means that the results comply with the technical screening criteria of the substantial contribution definitions are met and does not consider information on underlying actors.

With these overarching limitations, the following overview briefly discusses the evaluation approach for each of the sectoral models. The reader is referred to the material provided in the annex for further details.

The alignment of the scenario results with each of the substantial contribution has been ranked on the same scale, applying the scores *no compliance – limited compliance - medium compliance - good compliance – full compliance.* In the presentation of results in the following sections, these scores are translated into numbers from 1 (no compliance) to 5 (full compliance). The assignment of evaluation results to these categories is part of the expert judgment underlying the whole analysis. The complete analysis is therefore a qualitative assessment, even if percentage values of compliance with certain criteria can be calculated to underpin the assessment.

- **Industry**: The EU Taxonomy sets out requirements on the level of products (referring to EU ETS product benchmarks for the screening criteria for the different products). However, the results of the FORECAST model only provide GHG emissions on the sectoral level. This is the reason why an analysis is possible only for steel making, where product and sector match to a degree that makes the analysis possible.[3] For this sector, the share of production capacity complying with the EU Taxonomy threshold is calculated (using Member State level results and the EU Taxonomy threshold to determine whether the volume of a Member State is compliant or not).
- **Transport**: The EU Taxonomy sets out tailpipe CO_2 emission thresholds as screening criteria. For the analysis of the compliance, the share of vehicles complying with the standards are calculated. This is possible for road transport only, for which vehicle stocks are modelled in the ALADIN model. Non-road transport subsectors are modelled using a top-down approach. Aircraft, vessel, or train stocks required for this evaluation are not included in the subsector models for aviation, navigation, and railway and an evaluation of EU Taxonomy alignment is therefore not possible.
- **Buildings**: None of the data required for a detailed assessment are readily available, let alone are they implemented in the model. The results shown below are therefore estimates based on our expertise in the field. They are nonetheless a good indicator of how well the individual scenarios align with the EU Taxonomy.
- **Energy supply**: The EU Taxonomy considers an activity aligned if certain energy supply technologies are used in an activity. For an analysis of the energy system compliance carried out here, we consider the share of each technology in 2050 in each scenario fully compliant with the EU Taxonomy since each scenario reaches full decarbonization of energy supply. In all other years, the share of a certain technology relative to the 2050 share determines EU Taxonomy compliance. Therefore, 2050 values are always compliant while the results of the other years show the path towards this final value. For example, the electricity generation share from renewable sources could be 70% in one scenario in 2050.Then an exemplar value of 35% RES-E share in 2040 receives 50%, rated as medium, EU Taxonomy compliance Some technologies are therefore also analysed in combination, e.g. all technologies for renewable electricity supply are combined.
- **Agriculture**: The technical screening criteria of those activities reflected in the model can be used to evaluate EU Taxonomy alignment directly, as these criteria also define some of the model variables. However, these EU Taxonomy criteria are in many cases not output variables, , but rather input variables to the model. For example, the share of anaerobic digestion, which can be an EU Taxonomy criteria, is not calculated as a model output, but is instead specified as an input variable. Consequently, the model estimates the amount of animal manure treated through anaerobic digestion based on assumed shares, combines with data on livestock numbers and manure quantities. Most often, the percentage of

[3] Cement and lime are two categories in the EU Taxonomy and grouped under non-metallic minerals in FORECAST results in the Pathways project, so no assessment is possible for these activities.

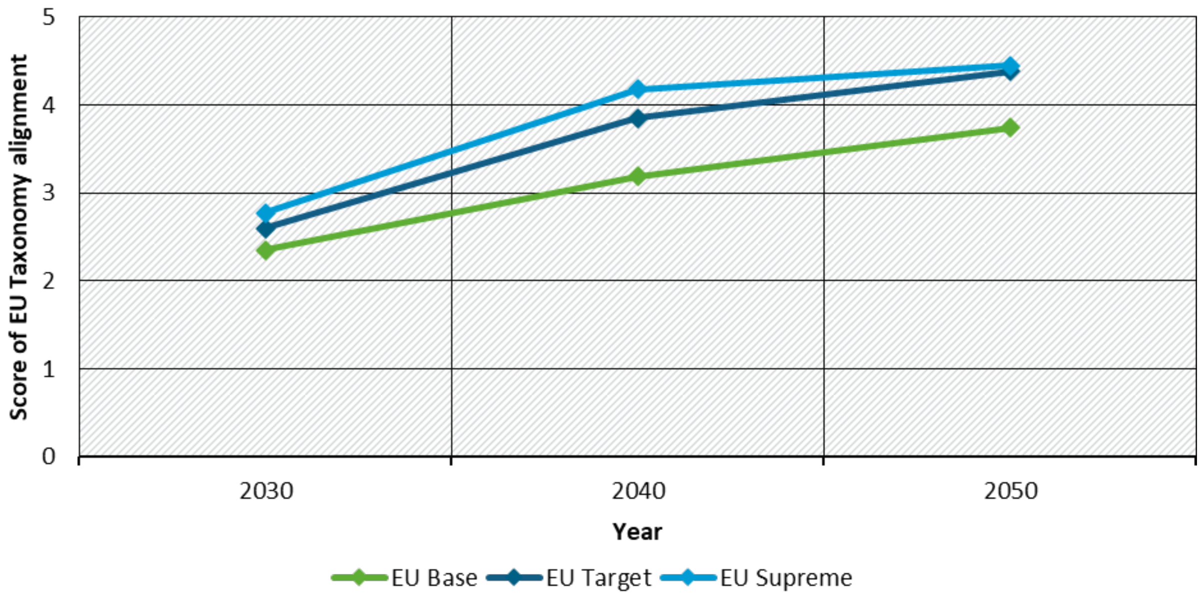
animals or the share of area to which a certain criterion applies is evaluated and used for the ranking.

- **Forestry and land use**: No evaluation is carried out. The screening criteria are too detailed and cover administrative procedures as well as background documentation. An evaluation is therefore not possible. For some criteria, it can be assumed that all of an area where any measure is carried out potentially complies with a certain sub-criterion, for others, there is no data for such an assumption. Therefore, also experts' estimates based on expertise in the field of forestry and land use cannot be applied reasonably.
- **Waste**: The possibilities to evaluate taxonomy alignment are very limited for this sector. The technical screening criteria comprise different aspects for each activity, only some of which are represented in the model. The assessment is therefore based on expert judgement, comparing the different scenarios. For this reason, ranking is noted in brackets.

4.2 Results of the evaluation

The following figures give the results of taxonomy alignment assessment for the 29 activities. These were assessed for the years 2030, 2040 and 2050 of the three scenarios EUBase, EUTarget and EUSupreme of the underlying modelling data from the report "Pathways to an EU with net-zero emissions". The approach to this analysis is described above. The numbers on the scale of 1 to 5 can be read as a a scale ranging across *no compliance – limited compliance - medium compliance - good compliance – full compliance*, correspondingly. This scale is applied for each criterion assessed for the different activities. Where a criterion cannot be assessed in a certain year or scenario, the scale is set to 0 correspondingly.

Figure 1: Aggregate score of EU Taxonomy alignment determined from the average of sectoral averages in each scenario and year



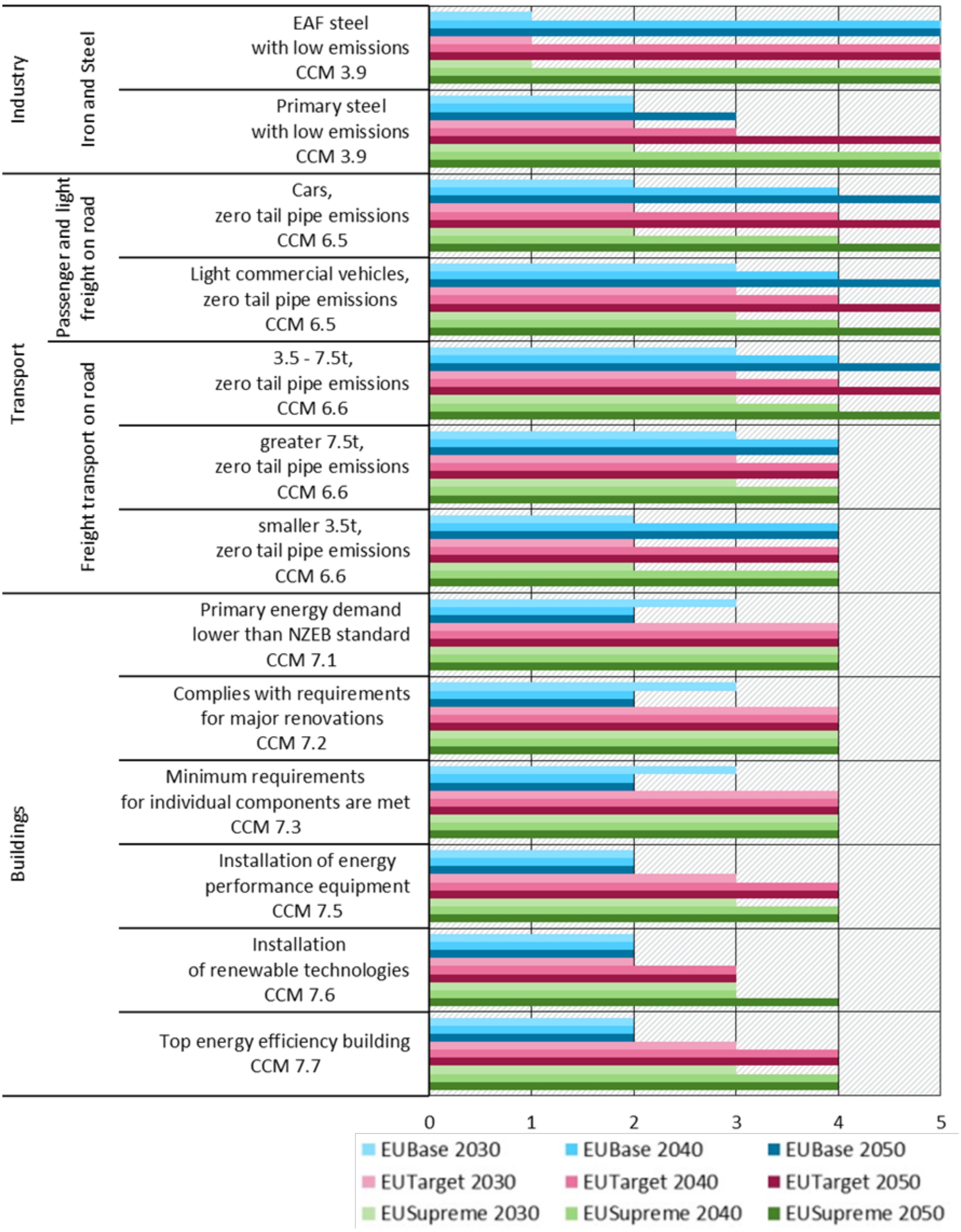
Source: Own elaboration by Fraunhofer ISI

The average of all sectoral averages[4] as an aggregate is shown in Figure 1. This aggregate figure shows that across all activities evaluated, EUTarget and EUSupreme reach the same value of

[4] This composite of averages is preferrable over the average of all indicators to compensate for the fact that ta different number of activities have been evaluated per sector.

alignment in 2050, while EUSupreme reaches higher values of compliance in 2030 and 2040. However, all assessments based on this number need to consider the uncertainties of the underlying analysis.

Figure 2: Results of the EU Taxonomy alignment analysis for energy demand sectors

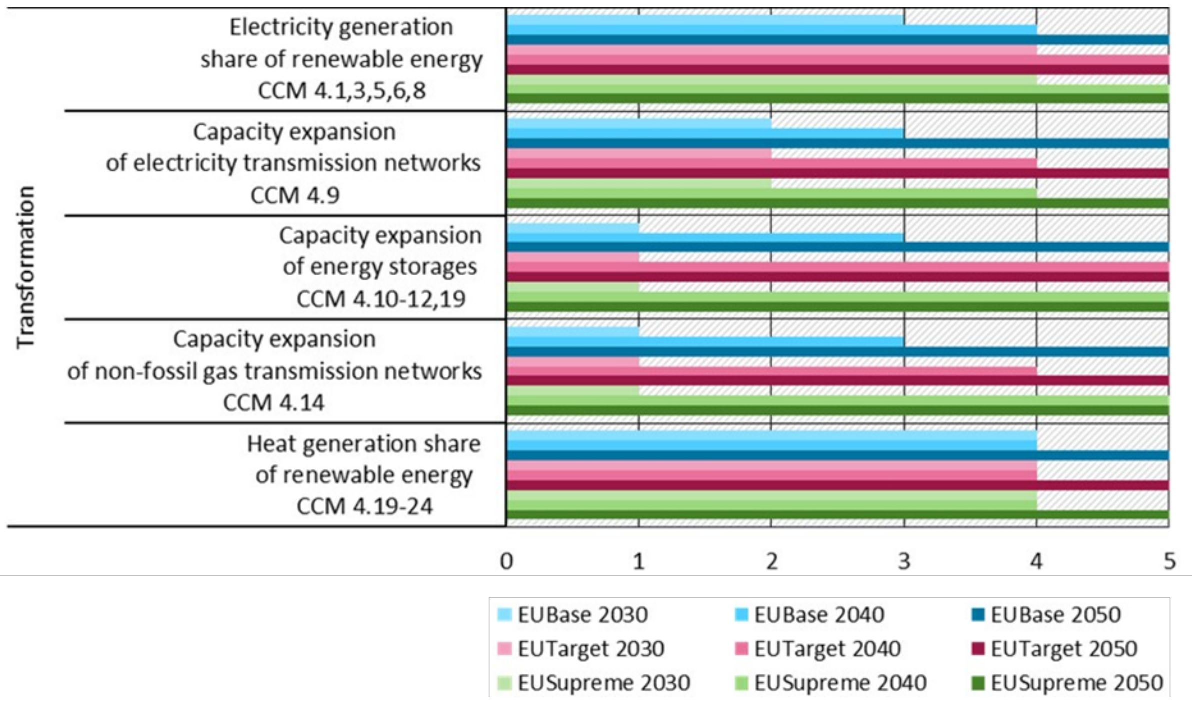


Source: Own elaboration by Fraunhofer ISI

Figure 2 to Figure 4 give a graphical representation of the results of the EU Taxonomy alignment analysis for the different sectors. Details of the sectoral results are discussed for each sector in the annex. We give a summary in the following:

- **Industry** (Figure 2): The compliance trend for the EAF is consistent across all scenarios. However, it is not expected to meet the required emissions thresholds by 2030, due to the carbon intensity of the grid but is projected to achieve full compliance from 2040 onwards. For primary steel, there are more differences among scenarios. The results of EUBase show limited compliance by 2030, with improvement towards 2050, but without reaching full compliance. By contrast, the EUTarget and EUSupreme scenarios achieve full compliance by 2050.
- **Transport** (Figure 2): The EU Taxonomy alignment analysis of EUBase, EUTarget, and EUSupreme shows that the three scenarios are fundamentally similar, reaching full compliance with the EU Taxonomy's sustainability criteria for cars and LCVs and a near-full compliance across medium-duty and heavy-duty vehicles in 2050. In 2030 and 2040, the scenarios differ slightly, particularly in heavy-duty vehicles. However, not to such a degree that this shows in the qualitative assessment on the defined scale.
- **Buildings** (Figure 2): For the activity „Construction of new buildings", we can assume that in both EUTarget and EUSupreme most new buildings are EU Taxonomy-aligned. But it all depends on how nearly zero-energy buildings (NZEBs) are defined in the different Member States and also over time. For „Renovation of existing buildings", the renovation standard is kept constant over time EUBase, whereas in EUTarget and EUSupreme the renovation standard increases in ambition starting already in the 2020s. This leads to higher EU Taxonomy alignment in both target scenarios.

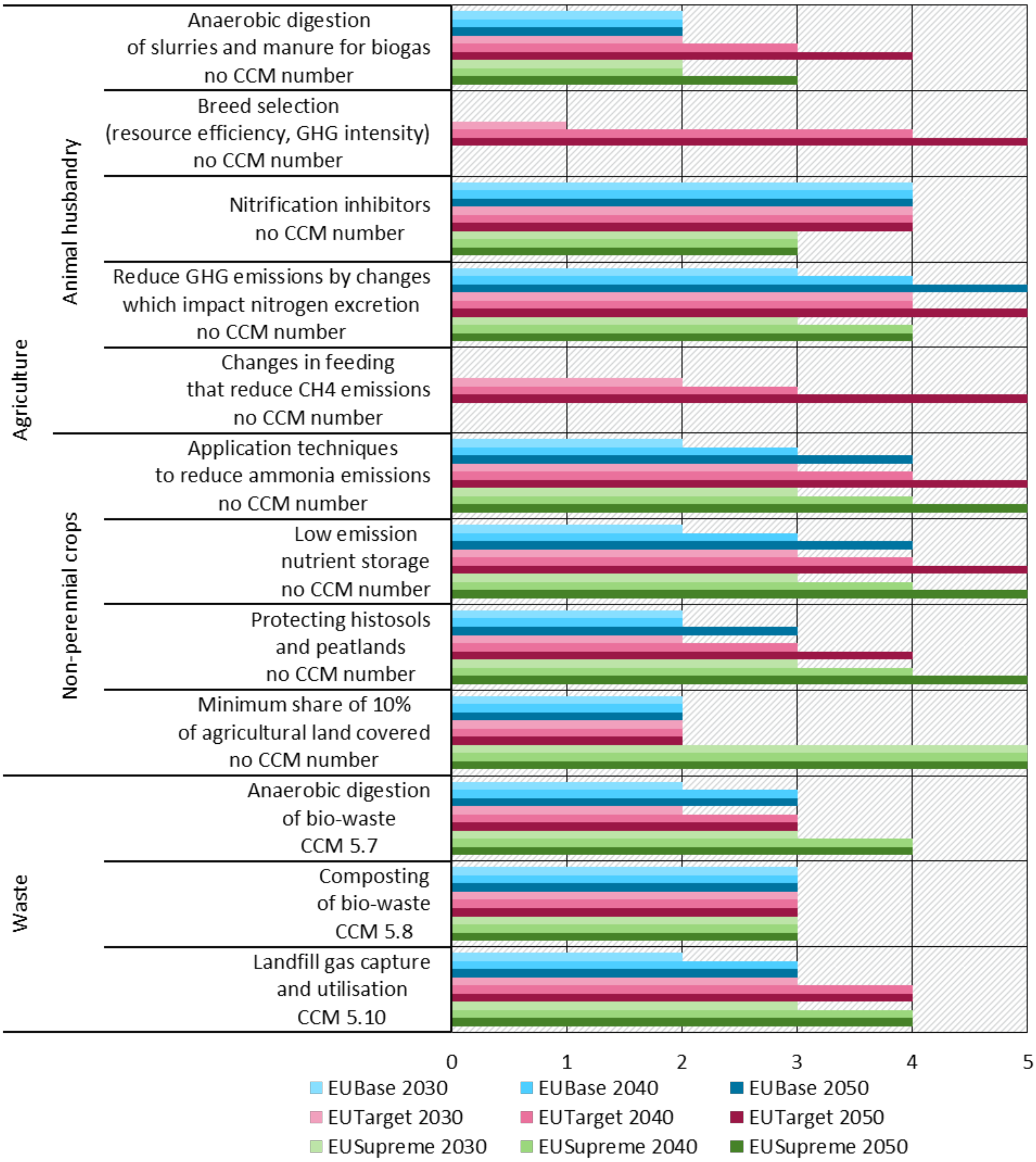
Figure 3: Results of the taxonomy alignment analysis for the transformation sector



Source: Own elaboration by Fraunhofer ISI

- **Energy supply** (Figure 3): The assessment of the three scenarios—EUBase, EUTarget, and EUSupreme—show similar but different paths to complete compliance with taxonomy criteria until 2050. EUSupreme demonstrates the strongest performance across criteria, particularly in infrastructure and energy storage. EUTarget shows proactive energy storage but fluctuates in nuclear reliance, as additional nuclear power plants are needed in 2050, which will only be realized in the last decade. EUBase exhibits the slowest progress, indicating a need for accelerated investments to meet compliance targets.

Figure 4: Results of the taxonomy alignment analysis for non-energy sectors



Source: Own elaboration by Fraunhofer ISI

- **Agriculture** (Figure 4): In the EUBase scenario, both the proportion of land for peatland rewetting and agroforestry systems is low, as are the penetration rates for technical measures. Some technical measures, such as the addition of additives, are not taken into account at all in the EUBase scenario. The EUTarget scenario shows the highest penetration rates for technical mitigation measures (e.g. 70% digestion of animal manure). In addition, the reduction effects of additives are only taken into account in this scenario. Due to uncertainties regarding impacts on other environmental media and long-term mitigation effects, these are not considered in the EUSupreme scenario. In the EUSupreme scenario, the penetration rates for technical mitigation measures are lower in general (e.g. manure fermentation), mainly because the lower livestock density and smaller-scale structures make manure fermentation rather uneconomical. On the other hand, the share of rewetted areas and the areas for biodiversity and agroforestry systems continue to increase. The evaluation in the table is only based on the expert judgement of the authors and in some cases difficult to classify.

- **Waste** (Figure 4): For activities concerning anaerobic digestion and composting of bio-waste, the overall amount of bio-waste collected separately is increasing over time, indicating efforts in waste collection in all three scenarios. While in the EUBase scenario, the share of composted bio-waste is higher than the amount of bio-waste undergoing anaerobic digestion, this changes for the EUTarget scenario and is even more pronounced in the EUSupreme scenario. A similar development can be observed for landfill gas capture and utilization. Generally, it can be observed that in the scenarios EUTarget and EUSupreme, where a higher level of ambition in terms of emission reductions is implemented, the criteria set out in the taxonomy are met at a higher rate. Close alignment with taxonomy criteria thus supports a climate-friendly development of the waste sector.

4.3 Discussion and conclusions on EU Taxonomy alignment

In summarizing, the two target scenarios reach EU Taxonomy alignment earlier and to a higher degree compared to EUBase. This is the case across most of the sectors where differences appear between the scenarios. As discussed above, there are a few sectors or criteria for which no difference in EU Taxonomy alignment was found.

Between the two target scenarios, EUSupreme reaches an equal or higher EU Taxonomy alignment compared to EUTarget. By design, EUTarget relies more heavily on technical solutions than EUSupreme. In the results of EU Taxonomy alignment this reliance on technical solutions only shows for the two activities of the agricultural sector, which are exclusively considered in this scenario (nitrification inhibitors and changes in feeding to manage methane emissions). This performance also shows in the last row of the evaluation table, which gives the average value of sectoral averages. The better performance of EUSupreme can be traced back to a few single activities in the agricultural sector[5], faster transformation of primary steel making and improved waste treatment[6] while there are only limited differences in transformation[7] and none in transportation and buildings.

The analysis comes with considerable uncertainties, which are linked to the approach. This is again linked to the mismatch between the criteria covered by the EU Taxonomy and the modelling approach, which has already been discussed above in Section 3. Because these reasons are inherent in the models, they cannot be overcome without changes to the models[8].

[5] More agricultural land covered by high diversity landscape features, improved protection of histosols and peatlands; however less changes in feeding and breed selection to reduce nitrogen excretion nd GHG emissions and less anaerobic digestion

[6] Better performance in biowaste treatment

[7] Faster uptake of nuclear energy in EUTarget, faster capacity expansion of green gas grid in EUSupreme

[8] Potentially with the exception of industry by running the model again with higher data granularity, which requires more resources.

The research question underlying the analysis is nevertheless of value. By simply reading the technical screening criteria, it becomes apparent that not all of them are currently formulated in a way that by complying with them, the overarching target of climate neutrality is reached. This points to the often-raised concern that the criteria are not fit to define climate neutral activities. In the industry sector, surely an installation complying with the benchmark will not suffice to comply with the target – while standards in transport and other sectors are much stricter. However, it is interesting to better understand under which circumstances actors comply with the EU Taxonomy, where circumstances will be reflected in the scenario definitions such as those underlying the three scenarios of the Pathways project. Whenever actors comply with the EU Taxonomy, this should lead to EU Taxonomy alignment in certain sectors, which in turn should show in the model results. However, this EU Taxonomy alignment is likely not achieved by the policy instrument which the EU Taxonomy is today but is rather the result of the other policy instrument, as is the case in the Pathways project. The indirect effects which the EU Taxonomy is expected to unfold are discussed in Section 2: While the taxonomy is expected to influence the access to finance for climate friendly economic activities, it does not ban other kinds of activities or limit their access to project finance. Other policy instruments therefore currently dominate in terms of effectiveness as long as the information provided by the EU Taxonomy is not picked up by a majority of financial players to channel investments into sustainable activities.

For some sectors, such as industry, energy supply and transport, the key indicators discussed by Duscha et al. (2025, forthcoming) may present a less direct but more complete measure of EU Taxonomy alignment (GHG emissions, renewable energy share or energy carrier). However, the analysis performed in this section gives an evaluation of some criteria otherwise not discussed in overview sections by Duscha et al. (2025, forthcoming), as is the case for the sectors agriculture and buildings. Together with the overview of the indicators given in Table 1 for the other sectors, the results of this analysis provide a good impression of the compatibility of the different scenarios with the target of climate neutrality. Even if EU Taxonomy alignment can only be assessed in some cases due to the technical limitations discussed in detail above, the results present a valuable overview of alignment with the overarching target of climate neutrality.

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A Detailed sectoral evaluation of taxonomy alignment

Each of the following sections discusses taxonomy alignment for the seven sectors analysed in this regard, based on the modelling results of their respective models (model name given in brackets): Industry (Forecast Industry), Transport (Aladin), Buildings (LCBE), Transformation (Enertile), Agriculture (LiSE), Forestry and land use (FABio-Land) and waste (Waste_Mod).

The sections follow the same structure. First, the model is briefly classified, followed with a technical description, which focusses on those elements necessary to understand how the taxonomy is or is not reflected in the different models. This technical description discusses the modelling approach, the main driving forces of the model and relevant variables as well as the actors described by the model. This is followed by the list of activities governed by the taxonomy in each sector, which also makes transparent whether the different activities are considered in the model.

The following section then focusses on those activities which are considered in the model and discusses how the taxonomy alignment has been evaluated. This is the methodological description underlying the taxonomy alignment analysis. Note that only the significant contribution criteria to climate change mitigation have been evaluated. Even by limiting the analysis to these aspects, not all elements of significant contribution could be evaluated. This is also made transparent in the sectoral methodological sections. The last section of each sectoral analysis then shows the results of this alignment analysis structured by activity. A brief discussion of the results precedes the tabular results.

Note that, where possible, the text has been structured in tabular form to render the analysis and the results more accessible. The definition of activities and criteria has been adopted from the EU Taxonomy regulating documents (European Commission 2020b, 2021).

A.1 Industry – Model FORECAST Industry

A.1.1 Classification of the model

FORECAST Industry model is a hybrid simulation model that combines a bottom-up simulation approach with top-down methods.

A.1.2 Short technical description

FORECAST utilises highly detailed technological data on industrial processes, and the integration of site-specific information, to calculate energy demand and associated greenhouse gas (GHG) emissions. Additionally, FORECAST incorporates a top-down approach, aligning its detailed process-level simulations with aggregated macroeconomic energy balances to ensure consistency with Eurostat (Fleiter et al. 2018). It is designed to project energy demand and GHG emissions. FORECAST includes distinguished technology modules:

1. Energy-Intensive Processes:
    a. This module provides a detailed representation of energy-intensive subsectors at the process level, e.g., blast furnace processes in steel production.
    b. Transition to low-carbon or carbon-neutral processes is exogenously determined based on scenario definitions, technological maturity, and associated costs.

   c. Diffusion of energy-efficiency technologies is simulated based on their payback periods.

2. Industrial Furnaces (Process Heat >500°C):
   a. This module calculates high-temperature heat requirements derived from the process module.
   b. It simulates fuel-switching decisions based on parameters such as energy prices, CO_2 prices, and historical trends (Rehfeldt et al. 2018).
3. Hot Water and Steam Generation & Distribution:
   a. This cross-sectoral module focuses on steam production used extensively in chemical, paper, and food industries.
   b. Technical changes, including the choice of alternative heat-generation technologies, are simulated using discrete-choice methods. (Rehfeldt et al. 2020)
4. Space Heating Demand:
   a. Space heating is calculated using sector-specific energy demand per square meter of floor area.
   b. The module incorporates a stock-based approach, modeling capital turnover through the age distribution of buildings.
5. Electric Motor Systems and Lighting:
   a. Motor systems and lighting are modelled as cross-sectoral technologies applied in multiple industrial sectors

A.1.3 Subsectors considered in the model

FORECAST Industry model employs a hierarchical structure. It systematically disaggregates the industry into individual economic branches or subsectors based on energy balances. Each subsector encompasses specific processes characterized by distinct energy consumption patterns and activity levels. The subsector structure is aligned with energy balances and economic classifications, specifically utilizing the NACE Rev. 2 framework.

Table 1: Subsectors present in the FORECAST model

Subsector	NACE
Steel industry	24.1, 24.2, 24.3, 24.51, 24.52
Non-ferrous metal industry	24.4, 24.53, 24.54
Paper and printing industry	17, 18
Non-metallic mineral products industry	23
Chemical industry	20
Food and beverage industry	10, 11, 12
Machinery and other metalworking industries	25, 26, 27, 28, 29, 30
Other industries	Represents the remaining manufacturing activities within Section C not classified

A.1.4 Driving forces and exogeneous model variables

The input data required for modeling includes overarching activity indicators, includes the following:

1. Activity Variables (Macroeconomic):
    a. Sector-specific Economic Output (Gross Value Added (GVA)):
    Represents the economic activity level in each subsector (e.g., steel, chemicals, food industry).
    b. Physical Production Volumes:
    Activity level of industrial processes (e.g., tons of steel, cement).
2. Technological Parameters
    a. Specific Energy Consumption (SEC):
    Energy required per unit of physical production (e.g., GJ per ton of steel).
    b. Capital Costs and Investment Parameters:
    Investment costs, lifetime, and operational costs of technologies (e.g. heat pumps, boilers)
    c. Efficiency Parameters:
    Energy efficiency improvement for individual technologies (motors, boilers, lighting systems, etc.).
3. Structural Data:
    a. Energy and GHG Balances:
    Historical and current sector-level balances (Eurostat, AG-Energiebilanzen).
    b. Spatial distribution of industries:
    Regional location
    c. Technology distribution
4. Energy price:
    a. Energy Prices (€/MWh):
    Prices of fuels, electricity, natural gas, biomass, hydrogen.
5. Policy and Instrumental Variables:
    a. CO_2 Price (€/tCO_2)
    b. Subsidies and Incentives:
    Economic incentives promoting adoption of efficient or low-carbon technologies.
    c. Standards and Regulation:
    Minimum efficiency levels or emissions standards that influence technological choice

A.1.5 Relevant variables of the model for the EU Taxonomy alignment analysis

Internal variables and results variables that could be used in the analysis of the taxonomy:

1. GHG Emission (Mt CO_2eq.):
    a. Direct and indirect emissions by subsector/process
2. Energy Demand Variables

   a. Energy Demand by energy carrier at subsector/process level
3. Technological Diffusion and Stock Variables
   a. Technology Shares (%):
      Share of technologies adopted within each industrial subsector or specific processes.
   b. Installed Capacities:
      Installed capacities of technologies (e.g., electric boilers, heat pumps)
4. Marginal Abatement Costs (€/tCO_2):
   a. Marginal Abatement Costs (€/tCO_2):
5. Investment Expenditures (€):
   a. Capital expenditures for technology adoption and retrofittin g.

A.1.6 Representation of actors in the model

Table 2: Actors considered in the model in the industry sector

Description of actor	Consideration in the model
Industrial companies/subsectors	Companies/subsectors, as according to the classification discussed above, are the primary decision-making entity in the model. For fuel switch processes, they are implicitly modelled as technologies are selected based on abatement costs calculated from detailed techno-economic parameters.
Technology Suppliers and Manufacturers	Suppliers determine technology readiness and availability, performance characteristics (e.g. SEC efficiency, lifetime), and investment costs. Such data serves as an important input parameter in the model, which is not determined endogenously.
Energy Suppliers (Utilities)	Utilities determine the availability, reliability, and pricing of different energy carriers. As such, this is a critical element of the model. However, it is only considered in terms of price and availability.
Policymakers and Regulators	Policies set the external boundary conditions within scenario analyses, such as in emission targets, subsidies, carbon pricing schemes, and financial incentives, which influence the economic viability of technologies. Policies are only considered exogenously.

A.1.7 Activities of the sector addressed by the EU Taxonomy

Table 3: Activities of the taxonomy in the industry sector

Number	Activity	Example company	Consideration in the model
CCM 3.1	Manufacture of renewable energy technologies	All manufacturers likely need to report under the EU Taxonomy	Not considered
CCM 3.2	Manufacture of equipment for the production and use of hydrogen	See above	Not considered

Number	Activity	Example company	Consideration in the model
CCM 3.3	Manufacture of low carbon technologies for transport	See above	Not considered
CCM 3.4	Manufacture of batteries	See above	Not considered
CCM 3.5	Manufacture of energy efficiency equipment for buildings	See above	Not considered
CCM 3.6	Manufacture of other low carbon technologies	See above	Not considered
CCM 3.7	Manufacture of cement	See above	Partially considered
CCM 3.8	Manufacture of aluminium	See above	Partially considered
CCM 3.9	Manufacture of iron and steel	See above	Considered
CCM 3.10	Manufacture of hydrogen	See above	Not considered, in the model
CCM 3.11	Manufacture of carbon black	See above	Partially considered
CCM 3.12	Manufacture of soda ash	See above	Partially considered
CCM 3.13	Manufacture of chlorine	See above	Partially considered
CCM 3.14	Manufacture of organic basic chemicals	See above	Partially considered
CCM 3.15	Manufacture of anhydrous ammonia	See above	Partially considered
CCM 3.16	Manufacture of nitric acid	See above	Partially considered
CCM 3.17	Manufacture of plastics in primary form	See above	Not directly considered in the model
CCM 3.18	Manufacture of automotive and mobility components	See above	Not considered in the model
CCM 3.19	Manufacture of rail rolling stock constituents	See above	Not considered in the model
CCM 3.20	Manufacture, installation, and servicing of high, medium and low voltage electrical equipment for electrical transmission and distribution that result in or enable a substantial contribution to climate change mitigation	See above	Not considered in the model
CCM 3.21	Manufacturing of aircraft	See above	Not considered in the model

A.1.8 Approach to the analysis of EU Taxonomy alignment

Due to computational constraints for this modelling exercise, the model aggregates GHG emissions at a sector level; therefore, a direct evaluation of product-level emissions (e.g., per ton of cement or clinker) is not possible. As a result, alignment with taxonomy criteria cannot be assessed for any of the products except iron and steel, where the product definition matches the sector representation in the model. Furthermore, electricity generation is modelled separately as part of the conversion sector and lies outside the defined system boundaries of the industrial sector. Consequently, processes that rely primarily on electricity such as Electric arc Furnaces (EAF) in steel production are not directly linked to electricity emissions in the industry model. To approximate the impact of the associated indirect emission from electricity use, an EU average electricity emission factor was used where relevant. Table 4 lists contribution criteria that could be potentially considered if the level of detail would be increased in the model. However, for the reasons mentioned above, an evaluation at product level is not possible except for iron and steel.

For iron and steel, a simplified approach has been followed, which allows a first assessment of taxonomy alignment. It is verified whether the emission intensity meets the threshold in each Member State. Once the value is achieved, the member state is considered taxonomy conform. This way, the share of taxonomy alignment can be determined. In this approach, we do not distinguish between different types of final products, e.g. alloy steel and carbon Steel. A more complex analysis would require much more data. It would be necessary to assume a statistical distribution and estimate the share of production in a region that complies with the criterion. However, such data on the distribution is not available in the model. In this modelling exercise, only country-specific data are used; no results on NUTS 3 level or site level are provided.

Table 4: Taxonomy alignment analysis for the industry sector

No.	Activity	Contribution criteria considered	Contribution criteria outside scope	Relates to model variable	Evaluation approach
CCM 3.7	Manufacture of cement	Grey cement clinker where the specific GHG emissions are lower than 0,722 t CO2e Cement from grey clinker or alternative hydraulic binder, where the specific GHG emissions are lower than 0,469 tCO2e/t product	Screening criteria for CO2 underground storage Grey and white cement not differentiated in the model		Not evaluated, see above
CCM 3.8	Manufacture of aluminium	GHG emissions do not exceed 1,484 tCO2e/t Al The electricity consumption for the manufacturing process does not exceed 15.5 MWh/t Al.	The average carbon intensity for the indirect GHG emissions does not exceed 100g CO2e/kWh;		Not evaluated, see above
CCM 3.9	Manufacture of iron and steel	GHG emissions do not exceed: hot metal: 1,331 tCO2e/t product; sintered ore: 0,163 tCO2e/t product; coke (excluding lignite coke): 0,144 tCO2e/t product; iron casting: 0,299 tCO2e/t product; electric Arc Furnace (EAF) high alloy steel: 0,266 tCO2e/t product; electric Arc Furnace (EAF) carbon steel: 0,209tCO2e/t product.		Emissions and production volume, dividing one by the other gives the emission intensity	See above, using the EU average electricity factor for EAF steel
CCM 3.11	Manufacture of carbon black	GHG emissions from the carbon black production processes are lower than 1,141 tCO2e/t product.			Not evaluated, see above
CCM 3.12	Manufacture of soda ash	GHG emissions from the soda ash production processes are lower than 0,789 tCO2e/t product.			Not evaluated, see above
CCM 3.13	Manufacture of chlorine	Electricity consumption for electrolysis and chlorine treatment is equal or lower than 2.45 MWh/t product.	Average life cycle GHG emissions of the electricity used for chlorine production are at or lower than 100 g CO2e/kWh.		Not evaluated, see above
CCM 3.14	Manufacture of organic basic chemicals	GHG emissions do not exceed: for HVC: 0,693 tCO2e/t of HVC; for aromatics: 0,0072 tCO2e/t of complex weighted throughput;			Not evaluated, see above

No.	Activity	Contribution criteria considered	Contribution criteria outside scope	Relates to model variable	Evaluation approach
CCM 3.15	Manufacture of anhydrous ammonia		Ammonia is produced from hydrogen that complies with the technical screening criteria annex 3.10 Ammonia is recovered from wastewater.		Not evaluated, see above

A.1.9 Results of the EU Taxonomy alignment analysis

The compliance results shown in the tables below are based on detailed modelling for the iron and steel sector. Although the modelling is comprehensive, it is important to recognize that the EU Taxonomy criteria are highly specific and do not always align perfectly with the model boundaries. The compliance trend for the EAF is consistent across all scenarios. However, it is not expected to meet the required emissions thresholds by 2030, due to the carbon intensity of the grid. It is projected to achieve full compliance from 2040 onwards. For hot metal, there are more differences among scenarios. The EUBase scenario shows limited compliance by 2030, with improvement towards 2050, but without reaching full compliance. By contrast, the EU Target and EU Supreme achieve full compliance by 2050.

Table 5: Taxonomy alignment in the industry sector for the scenario EUBase

Activity	Criterion	2030	2040	2050
Manufacture of iron and steel	GHG emissions do not exceed EAF: 0,266tCO_2e/t (Compliance based on EU average electricity mix)	No compliance	Fully compliant All Countries are compliant	Fully compliant All Countries are compliant
	GHG emissions do not exceed hot metal: 1,331tCO_2e/t (BF-BOF route)	limited compliance 22% of the production	limited compliance 28% of the production	medium compliance 38% of the production

Table 6: Taxonomy alignment in the industry sector for the scenario EUTarget

Activity	Criterion	2030	2040	2050
Manufacture of iron and steel	GHG emissions do not exceed EAF: 0,266tCO_2e/t (Compliance based on EU average electricity mix)	No compliance	Full compliance All Countries are compliant	Full compliance All Countries are compliant
	GHG emissions do not exceed hot metal: 1,331tCO_2e/t (BF-BOF route)	limited compliance 22% of the production	Medium compliance 44% of the production	Full compliance All countries are compliant

Table 7: Taxonomy alignment in the industry sector for the scenario EUSupreme

Activity	Criterion	2030	2040	2050
Manufacture of iron and steel	GHG emissions do not exceed EAF: 0,266tCO_2e/t (Compliance based on EU average electricity mix)	No compliance	Full compliance All Countries are compliant	Full compliance All Countries are compliant
	GHG emissions do not exceed hot metal: 1,331tCO_2e/t (BF-BOF route)	limited compliance 22% of the production	Full compliance All countries are compliant	Full compliance All countries are compliant

A.2 Transport – Model *ALADIN*

A.2.1 Classification of the model

The ALADIN framework contains specialized modeling tools for five transport modes:

- **Passenger cars**: Logistic regression model
- **Trucks**: Agent-based simulation model
- **Railway, aviation, and navigation**: Top-down analysis

A.2.2 Short technical description

The modelling methodology applied within Aladin varies depending on subsector:

- **Passenger cars**: Depending on energy carrier prices, monetary incentives, and charging infrastructure availability, the model calculates a country-specific logistic curve, which determines the diffusion of battery electric vehicles (BEV) and plug-in hybrids (PHEV), into the national passenger car markets and the related phase-out of conventional internal combustion engine vehicles (ICEV).
- **Trucks**: The model simulates the purchase decision of individual users, differentiating five vehicle size classes and six powertrain options - Diesel engine, BEV, PHEV, fuel cell electric vehicles (FCEV), and two types of catenary hybrids. Each agent is characterized by a real-world driving profile and selects the powertrain option with minimum total cost of ownership. A stock model aggregates the individual purchase decisions for the German commercial vehicle market over time. Resulting energy demands and CO_2 emissions are transferred to other European countries according to today's national final energy demands for trucks and buses.
- **Rail**: Starting with today's situation on track electrification in each country, the model calculates electric rail transport performances for each country using a Lorenz curve, given assumptions on the target share of electrified tracks in the future. Given assumptions on passenger and freight rail transport activity growth rates and energy intensity reductions, it subsequently derives future demands for electricity and liquid fuels.
- **Aviation and navigation**: Starting from today's final energy demand in each country, the model calculates future fuel demands and related CO_2 emissions based on assumptions on transport activity development, energy intensity reductions, and quotas for non-fossil fuels.

A.2.3 Subsectors considered in the model

Subsectors are based on transport modes. Considered powertrain options and/or energy carriers per subsector are specified in parentheses.

1. **Road transport**
   a. Passenger cars (ICEV, BEV, PHEV; fossil fuel, biofuel, electricity)
   b. Trucks (Diesel, BEV, PHEV, FCEV, catenary hybrids; fossil diesel, biodiesel, electricity, H_2)
      i. Light duty: <3.5t

   ii. Medium duty: 3.5-7.5t and 7.5-12t
   iii. Heavy duty: rigid trucks >12t and tractor-trailers
2. **Rail transport** (fossil fuel, biofuel, electricity)
   a. Passenger rail transport
   b. Freight rail transport
3. **Aviation** (fossil fuel, biofuel, e-fuel, H_2)
   a. Domestic aviation
   b. International aviation
4. **Navigation** (fossil fuel, biofuel, e-fuel, H_2)
   a. Domestic navigation
   b. International navigation

A.2.4 Driving forces and exogeneous model variables

- **Passenger cars**: energy carrier prices, monetary incentives, charging infrastructure availability, average driving performances, specific energy consumption
- **Trucks**: energy carrier and CO_2 prices, battery and fuel cell prices
- **Rail**: Share of track electrification, transport activity development, energy efficiency improvements
- **Aviation + navigation**: Transport activity development, non-fossil fuel quotas, energy efficiency improvements

A.2.5 Relevant variables of the model to evaluate taxonomy alignment

Composition of the car and truck stocks, CO_2 emissions

A.2.6 Representation of actors in the model

Table 8: Actors considered in the model ALADIN

Description of actor	Is considered how?
Car users	Country specific car stocks and vehicle use (via average driving performance per country) are modeled. Individual car users are not explicitly considered, as the new car market in each country is modeled as a whole - the electric vehicle uptake follows a country-specific logistic curve.
Truck users	ALADIN models the individual purchase decision of truck users based on their total cost of ownership, comparing powertrain alternatives. The model only considers individual vehicles and does not model the truck-owning companies any further.

Description of actor	Is considered how?
Railway operators, railway infrastructure companies	The share of electric rail transport increases based on the electrification of rail tracks. The actors are only indirectly considered as individual rail tracks or rail vehicles are not modelled.
Airlines, jet fuel suppliers	The emission intensity of the fuel mix changes over time because the admixture of non-fossil jet fuel increases according to exogenously set quotas. Actors are only indirectly considered as individual aircraft or flights are not modeled.
Shipping companies, marine fuel suppliers	The emission intensity of the fuel mix in the model changes over time because the admixture of non-fossil fuel increases according to exogenously set quotas. The actors are only indirectly considered as individual companies, vessels or shipping routes are not modeled.

A.2.7 Activities of the sector addressed by the EU Taxonomy

Table 9: Activities of the taxonomy in the transport sector

Number	Activity	Example company	Activity considered in model?
CCM 6.1	Passenger interurban rail transport	Railway company	Considered as part of passenger rail transport activity in pkm but not differentiated from other forms of passenger rail. Individual actors (trains or their operators) are not modeled.
CCM 6.2	Freight rail transport	Railway company	Freight rail transport activity in tkm is considered in the rail transport model but individual actors (trains or their operators) are not modeled.
CCM 6.3	Urban and suburban transport, road passenger transport	Municipal transport company	Public transport is not modeled as a separate category. Buses are included in the calibration of the truck model. Individual actors (buses or their operators) are not modeled.
CCM 6.4	Operation of personal mobility devices, cycle logistics	Bike-sharing system operator	Not considered.
CCM 6.5	Transport by motorbikes, passenger cars and light commercial vehicles	Car rental agency	Yes, LCVs are considered as size class in the truck model, in which individual users are modeled. Passenger cars are considered in car model. Motorcycles are not modeled explicitly but their energy demand is included in calibration of the car model.
CCM 6.6	Freight transport services by road	Logistics company	Yes, differentiated in five size classes.
CCM 6.7	Inland passenger water transport	River cruise operator	Included in domestic navigation model but not considered separately from inland freight water transport. Individual actors (vessels or their operators) are not modeled.
CCM 6.8	Inland freight water transport	Shipping company	Included in domestic navigation model but not considered separately from inland passenger water transport or coastal shipping. Individual actors (vessels or their operators) are not modeled.
CCM 6.9	Retrofitting of inland water passenger and freight transport	Shipyard	Not considered.

Number	Activity	Example company	Activity considered in model?
CCM 6.10	Sea and coastal freight water transport, vessels for port operations and auxiliary activities	Container shipping company	Freight water transport is covered by domestic and international navigation models but not considered separately from passenger water transport. Individual actors (vessels or their operators) are not modeled.
CCM 6.11	Sea and coastal passenger water transport	Cruise line	Passenger water transport is covered by domestic and international navigation models but not considered separately from freight water transport. Individual actors (vessels or their operators) are not modeled.
CCM 6.12	Retrofitting of sea and coastal freight and passenger water transport	Shipyard	Not considered.
CCM 6.13	Infrastructure for personal mobility, cycle logistics	Municipality	Not considered.
CCM 6.14	Infrastructure for rail transport	Railway infrastructure manager	The share of electrified track-km in % per country is modeled. Individual actors (trains or their operators) are not modeled.
CCM 6.15	Infrastructure enabling low-carbon road transport and public transport		Charging infrastructure (cars and trucks) und hydrogen refueling stations (only trucks) are considered but roads are not modeled.
CCM 6.16	Infrastructure enabling low carbon water transport	Port operator	Not considered.
CCM 6.17	Low carbon airport infrastructure	Airport operator	Not considered.
CCM 6.18	Leasing of aircraft	Airline	Not considered.
CCM 6.19	Passenger and freight air transport	Airline	Yes, in aviation model. Freight air transport is not differentiated from passenger air transport. Individual actors (aircraft or their operators) are not modelled.
CCM 6.20	Air transport ground handling operations	Airport operator	Not considered.

A.2.8 Approach to the analysis of EU Taxonomy alignment

Table 10: Analysis of EU Taxonomy alignment in the transport sector

No.	Activity	Contribution criteria considered	Contribution criteria outside scope	Relates to model variable	Evaluation approach
CCM 6.5	Transport by motorbikes, passenger cars and light commercial vehicles	vehicles of category M1 and N1: from 2026, specific CO_2 emissions are zero.	▶ category L: zero tailpipe CO_2 emissions ▶ M1 and N1: until 2025, specific CO_2 emissions <50gCO_2/km	Result of market diffusion models: ▶ Cars: BEV stock ▶ Trucks: BEV and FCEV stocks <3.5 t	Share of vehicles in stock complying with taxonomy criteria. Separate evaluation for M1 (cars) and N1 (light-duty trucks)
CCM 6.6	Freight transport services by road	▶ vehicles of category N1 have zero tailpipe CO_2 emissions ▶ vehicles of category N2 and N3 <7.5 t are 'zero-emission heavy-duty vehicles' ▶ vehicles of category N2 and N3 > 7.5 t are 'zero-emission heavy-duty vehicles'	▶ Vehicles not dedicated to the transport of fossil fuels. ▶ vehicles of category N2 and N3 > 7.5 t are 'low-emission heavy-duty vehicles'	Result of market diffusion simulation for trucks for different size classes: ▶ BEV stocks, incl. all-electric catenary trucks ▶ FCEV stocks	Share of vehicles in the truck stock complying with the taxonomy criteria is evaluated. Separate evaluation for vehicles <3.5 t, 3.5-7.5t, and >7.5 t.

A.2.9 Results of the EU Taxonomy alignment analysis

The compliance of the three scenarios EUBase, EUTarget and EUSupreme with the EU Taxonomy criteria for road transport can be assessed by analysing the composition of the modeled car and truck stocks. Specifically, two activities are evaluated in parts:

- The activity “transport by motorbikes, passenger cars and light commercial vehicles”, which covers the purchase, financing, renting, leasing and operation of vehicles of the categories M1 (passenger car), N1 (light commercial vehicle, LCV), and L (two/three-wheelers), is evaluated by measuring the share of zero-emission vehicles, i.e., BEVs in the car stock as well as BEVs and FCEVs in the LCV stock. Vehicles of class L cannot be evaluated as their stock is not modeled separately.
- The activity “freight transport services by road”, which covers the purchase, financing, leasing, rental and operation of vehicles of categories N1, N2 and N3, is evaluated by measuring the share of zero-emission vehicles., i.e., BEVs and FCEVs. For N2 and N3 vehicles > 7.5 t, the EU Taxonomy additionally allows for “low-emission heavy-duty vehicles”, but this is not considered in the following assessment because it is unclear whether the modeled hybrid heavy-duty vehicles fit this classification.

The analysis shows that the three scenarios are fundamentally similar, reaching full compliance with the EU Taxonomy’s sustainability criteria for cars and LCVs and a near-full compliance across medium-duty and heavy-duty vehicles in 2050. In 2030 and 2040, the scenarios differ slightly, particularly in heavy-duty vehicles. See the result tables for details.

In the passenger car segment, where electric vehicles have already substantial market shares today, only about a third of the stock is battery electric, and therefore sustainable according to the EU Taxonomy in 2030. The limited compliance can be attributed to the comparatively long service life of cars and the resulting slow transformation of the car stock. By 2040, the share of BEVs in the car stock is already above 90%, and in 2050 their market diffusion is complete.

For commercial vehicles, the transformation varies between the size classes. In 2030, more than half of the LCVs are battery electric and medium-duty trucks under 7.5 tons are also already achieving medium compliance, whereas only a quarter to a third of heavy-duty vehicles over 7.5 t have zero direct emissions. In 2040, well above 90% of light and medium-duty trucks and 80-90% of heavy-duty vehicles are classified as sustainable by the EU Taxonomy. For all size classes and scenarios, the battery electric powertrain is the dominant sustainable technology while FCEVs make a minor contribution.

For the activities in aviation, navigation and rail transport, no assessment of the scenarios can be carried out with regard to their consistency with the criteria of the EU Taxonomy, as the subsector models do not cover the activities from an actor’s perspective. The subsectors are modeled in its entirety based on exogenous assumptions on transport activity development, efficiency improvements, and non-fossil fuel quotas, whereas the EU Taxonomy sets standards for individual system components, typically the vehicles (trains, aircraft, vessels) or infrastructures (e.g., rail tracks, airports, ports).

Table 11: Taxonomy alignment in the transport sector for the scenario EUBase

Activity	Criterion	2030	2040	2050
Transport by motorbikes, passenger cars and light commercial vehicles	Share of M1 vehicles (passenger cars) with zero specific CO_2 emissions	limited compliance 30% (30% BEV)	good compliance 91% (91% BEV)	Full compliance 100% (100% BEV)
	Share of N1 (light commercial vehicles) with zero specific CO_2 emissions	medium compliance 58% (58% BEV)	good compliance 97% (97% BEV, <1% FCEV)	Full compliance 100% (>99% BEV, <1% FCEV)
Freight transport services by road	Share of vehicles <3.5 t with zero tailpipe CO_2 emissions	medium compliance 58% (58% BEV)	good compliance 97% (97% BEV, <1% FCEV)	Full compliance 100% (>99% BEV, <1% FCEV)
	Share of vehicles 3.5-7.5 t that are classified as 'zero-emission heavy-duty vehicles'	medium compliance 37% (37% BEV, <1% FCEV)	good compliance 94% (92% BEV, 2% FCEV)	good compliance 99% (99% BEV, <1% FCEV
	Share of vehicles >7.5 t that are classified as 'zero-emission heavy-duty vehicles'	limited compliance 26% (26% BEV, <1% FCEV)	good compliance 79% (79% BEV, <1% FCEV)	good compliance 98% (97% BEV, <1% FCEV)

Table 12: Taxonomy alignment in the transport sector for the scenario EUTarget

Activity	Criterion	2030	2040	2050
Transport by motorbikes, passenger cars and light commercial vehicles	Share of M1 vehicles (passenger cars) with zero specific CO_2 emissions	limited compliance 32% (32% BEV)	good compliance 93% (93% BEV)	Full compliance 100% (100% BEV)
	Share of N1 (light commercial vehicles) with zero specific CO_2 emissions	medium compliance 58% (58% BEV, <1% FCEV)	good compliance 97% (97% BEV, <1% FCEV)	Full compliance 100% (>99% BEV, <1% FCEV)
Freight transport services by road	Share of vehicles <3.5 t with zero tailpipe CO_2 emissions	medium compliance 58% (58% BEV, <1% FCEV)	good compliance 97% (97% BEV, <1% FCEV)	Full compliance 100% (>99% BEV, <1% FCEV)
	Share of vehicles 3.5-7.5 t that are classified as 'zero-emission heavy-duty vehicles'	medium compliance 38% (37% BEV, 2% FCEV)	good compliance 96% (92% BEV, 4% FCEV)	good compliance 99% (99% BEV, <1% FCEV)

Activity	Criterion	2030	2040	2050
	Share of vehicles >7.5 t that are classified as 'zero-emission heavy-duty vehicles'	limited compliance 28% (26% BEV, 2% FCEV)	good compliance 84% (80% BEV, 3% FCEV)	good compliance 98% (97% BEV, <1% FCEV)

Table 13: Taxonomy alignment in the transport sector for the scenario EUSupreme

Activity	Criterion	2030	2040	2050
Transport by motorbikes, passenger cars and light commercial vehicles	Share of M1 vehicles (passenger cars) with zero specific CO_2 emissions	limited compliance 32% (32% BEV)	good compliance 92% (92% BEV)	Full compliance 100% (100% BEV)
	Share of N1 (light commercial vehicles) with zero specific CO_2 emissions	medium compliance 59% (58% BEV, <1% FCEV)	good compliance 98% (97% BEV, <1% FCEV)	Full compliance 100% (>99% BEV, <1% FCEV)
Freight transport services by road	Share of vehicles <3.5 t with zero tailpipe CO_2 emissions	medium compliance 59% (58% BEV, <1% FCEV)	good compliance 98% (97% BEV, <1% FCEV)	Full compliance 100% (>99% BEV, <1% FCEV)
	Share of vehicles 3.5-7.5 t that are classified as 'zero-emission heavy-duty vehicles'	medium compliance 40% (37% BEV, 2% FCEV)	good compliance 97% (93% BEV, 4% FCEV)	good compliance 99% (99% BEV, <1% FCEV)
	Share of vehicles >7.5 t that are classified as 'zero-emission heavy-duty vehicles'	limited compliance 31% (28% BEV, 3% FCEV)	good compliance 90% (87% BEV, 3% FCEV)	good compliance 98% (97% BEV, <1% FCEV)

A.3 Buildings – Model LCBE

A.3.1 Classification of the model

The Model LCBE is a stock exchange model driven by externally set variables. There is no optimization involved in the modelling process. Financial aspects are not considered directly.

A.3.2 Short technical description

The stock exchange of the LCBE Model considers the existing buildings, newly-built buildings, demolished buildings as well as retrofitted buildings, both for residential and non-residential buildings. The main drivers are the renovation rate, the rate at which new buildings are being built as well as the energy standards for new and retrofitted buildings. The energy carrier distributions are taken from the latest available Eurostat data. Data, where available, are considered per country, but clustered for implementing changes over time. Clusters are based on history and geography.

A.3.3 Subsectors considered in the model

The buildings sector is subdivided into residential and non-residential buildings. There is no further sub-division into categories like age classes or subtypes such as single-family house or multifamily house etc. Energy demand is subdivided into the following categories: space heating, hot water, cooling and ventilation.

A.3.4 Driving forces and exogeneous model variables

The main exogenous model variables are the renovation rate, the rate at which new buildings are being built, the demolition rate as well as the number of households. For each sub-sector (residential and non-residential) there are floor area-specific energy demands.

A.3.5 Relevant variables of the model for the taxonomy alignment analysis

Results: final energy demands, then split into energy carriers

A.3.6 Representation of actors in the model

Table 14: Actors considered in the model LCBE

Description of actor	Is considered how?
Landlords / Building owners / Building companies	Not directly considered; their investment decisions are indirectly addressed by the rate at which new buildings are being built, the renovation rate and changes in the energy carrier distribution (with associated heating system replacements)
Building occupants	Only considered as the total number of people / households per country
Producers of the technologies, manufacturers	Only indirectly addressed by the renovation rate (e.g. insulating material) and changes in the energy carrier distribution (with associated heating system)
Technology and efficiency equipment installers	Only indirectly addressed by the renovation rate and changes in the energy carrier distribution (with associated heating system)

A.3.7 Activities of the sector addressed by the EU Taxonomy

Table 15: Activities of the taxonomy in the buildings sector

Number	Activity	Example company	Activity considered in model?
CCM 7.1	Construction of new buildings	Building company, manufacturer	Both the rate at which new buildings are built and the energy standard realized are considered in the model

Number	Activity	Example company	Activity considered in model?
CCM 7.2	Renovation of existing buildings	Building company, manufacturer	Both the rate at which buildings are renovated and energy standard that is achieved are considered in the model
CCM 7.3	Installation, maintenance and repair of energy efficiency equipment	Building companies and technology installers	Installation considered indirectly via the renovation rate; maintenance and repair not considered
CCM 7.4	Installation, maintenance and repair of charging stations for electric vehicles in buildings (and parking spaces attached to buildings)	Local installers or distribution network operators	Not considered at all
CCM 7.5	Installation, maintenance and repair of instruments and devices for measuring, regulation and controlling energy performance of buildings	Local installers or distribution network operators	Not considered at all
CCM 7.6	Installation, maintenance and repair of renewable energy technologies	Local technology installers	Only indirectly considered by a pre-defined energy carrier distribution; maintenance and repair not considered
CCM 7.7	Acquisition and ownership of buildings	Landlords, building companies	Not considered at all

A.3.8 Approach to the analysis of EU Taxonomy alignment

The following table lists the contribution criteria considered for each of the seven activities in the buildings sector. For activities CCM 7.1, CCM 7.2, CCM 7.3, CCM 7.6 and CCM 7.7 only a theoretical approach is described in the table, since not all the information needed for a reliable evaluation can be found directly in the LBCE model. Rather a detailed search of energy standards in each Member State would be needed (NZEB levels, "major renovation" energy standards, etc.). Furthermore, assumptions on the distribution of actually used energy standards in both new and renovated buildings would be needed per Member State. All these data are not directly available, let alone are they implemented in the model. The results shown in Section A.3.9 below are therefore estimates based on our expertise in the field. They are nonetheless a good indicator of how well the individual scenarios align with the EU Taxonomy.

Table 16: EU Taxonomy alignment analysis for the buildings sector

No.	Activity	Contribution criteria considered	Contribution criteria outside scope	Relates to model variable	Evaluation approach
CCM 7.1	Construction of new buildings	Primary energy demand is at least 10% lower than the threshold set for the nearly zero-energy building (NZEB) requirements in national measures	Larger than 5000m2 air tightness text… not considered	Energy standard in new buildings	Theoretical approach: - assume a distribution of energy standards for new buildings in each country - research requirements for the NZEB standard in each country - calculate the share of buildings complying with the taxonomy
CCM 7.2	Renovation of existing buildings	The building renovation complies with the applicable requirements for major renovations; Alternatively, it leads to a reduction of primary energy demand (PED) of at least 30%	none	Energy standard for retrofitted buildings	Theoretical approach: - assume a distribution of energy standards for renovated buildings in each country - research requirements for major renovation standard per country - calculate the share of buildings complying with the taxonomy
CCM 7.3	Installation, maintenance and repair of energy efficiency equipment	Activity complies with minimum requirements set for individual components and systems in the applicable national measures implementing Directive 2010/31/EU: - addition of insulation to existing envelope components - replacement of existing external windows/doors with new energy-efficient windows/doors - installation, replacement, maintenance and repair of heating, ventilation and air-conditioning (HVAC) and water heating systems	none	Indirectly related to renovation rate/energy standard and changes in the energy carrier distribution	Theoretical approach: - research minimum requirements for individual components and systems in national legislation (e.g. in DE: regulation set out in GEG) - make assumptions about the share of taxonomy-conform implementation in each country (minimum compliance level may, e.g., be derived from the known number of cases supported by funding schemes)

No.	Activity	Contribution criteria considered	Contribution criteria outside scope	Relates to model variable	Evaluation approach
CCM 7.4	Installation, maintenance and repair of charging stations for electric vehicles in buildings (and parking spaces attached to buildings)	None	Installation, maintenance or repair of charging stations for electric vehicles.	N/A	Not considered at all
CCM 7.5	Installation, maintenance and repair of instruments and devices for measuring, regulation and controlling energy performance of buildings	None	installation, maintenance and repair of: - zoned thermostats, smart thermostat systems and sensing equipment, including. motion and daylight control. - building automation and control systems, building energy management systems (BEMS), lighting control systems and energy management systems (EMS); - smart meters for gas, heat, cool and electricity; - façade and roofing elements with a solar shading or solar control function, including those that support the growing of vegetation.	Installations could indirectly be related to overall efficiency gains made in buildings, that are included in the energy standards in new and retrofitted buildings	No reliable method to derive taxonomy-conformity, since none of the devices are represented in the model

No.	Activity	Contribution criteria considered	Contribution criteria outside scope	Relates to model variable	Evaluation approach
CCM 7.6	Installation, maintenance and repair of renewable energy technologies	Installation, maintenance and repair of: - solar hot water panels and the ancillary technical equipment; - heat pumps contributing to the targets for renewable energy in heat and cool in accordance with Directive (EU) 2018/2001 and the ancillary technical equipment; - heat exchanger/recovery systems.	Installation, maintenance and repair of: - solar photovoltaic systems and the ancillary technical equipment; - wind turbines and the ancillary technical equipment; - solar transpired collectors and the ancillary technical equipment; - thermal or electric energy storage units and the ancillary technical equipment; - high efficiency micro CHP (combined heat and power) plant;	Indirectly considered in energy carrier distributions	Theoretical approach: Make assumptions on the actual number of heat pumps and solar thermal devices installed in each country based on buildings stock characteristics (share of single- vs. multi-family houses) and their overall share in the total energy carrier distribution and per country
CCM 7.7	Acquisition and ownership of buildings	- For buildings built before 31 December 2020, the building has at least an Energy Performance Certificate (EPC) class A. As an alternative, the building is within the top 15% of the building stock. - For buildings built after 31 December 2020, the building meets the criteria specified in Section 7.1 of this Annex that are relevant at the time of the acquisition.	- Where the building is a large non-residential building it is efficiently operated through energy performance monitoring and assessment.	Economic transfer of building stock not considered in the model; EPC classes are related to the energy consumed in a building, which is determined by energy standards for new and renovated buildings.	Theoretical approach: For existing buildings: make assumptions on energy consumption distribution and put it into relation to class A EPCs in each country; for new buildings: check the specified criteria per country and compare it to the energy standard of new buildings as they are realized in the model.

A.3.9 Results of the EU Taxonomy alignment analysis

As mentioned above the results in the buildings sector are based on theoretical approaches, since a lot of the data required for addressing the taxonomy conformity thoroughly are not implemented in the model LCBE. The analysis nonetheless gives a rough indication of how taxonomy-conform each scenario is.

For the activity „Construction of new buildings“ a detailed analysis of the NZEB requirements in national regulations is needed in order to assess the conformity of new buildings with the taxonomy. Based on German regulation, we can assume that in both EUTarget and EUSupreme most new buildings are taxonomy-aligned. But it all depends on how NZEBs are defined in the first place and also over time.

„Renovation of existing buildings“ follows a similar logic as for the activity „Construction of new buildings“. In EUBase, the renovation standard is kept constant over time, whereas in EUTarget and EUSupreme the renovation standard increases in ambition starting already in the 2020s. This leads to higher taxonomy conformity in both target scenarios.

The activity "Installation, maintenance and repair of energy efficiency equipment" mainly relates to the energy standard of a renovated building and the components used for insulating the building. Since the energy standards in EUBase are less ambitious compared to the two target scenarios EUTarget and EUSupreme and do not improve over time, the taxonomy alignment in EUBase is rather low. EUTarget and EUSupreme with their more ambitious as well as increasing energy standards for renovated buildings are much more taxonomy-aligned.

For all three activities described above, EUBase moves from medium compliance in 2030 to limited compliance in both 2040 and 2050. This is due to the fact that EUBase standards are relatively good in 2030 when compared to EUTarget and EUSupreme, but since they do not improve over time, their relative compliance worsens in 2040 and 2050.

The activity "Installation, maintenance and repair of charging stations for electric vehicles in buildings (and parking spaces attached to buildings)" is not modelled at all, not even indirectly. Therefore, we cannot assess any taxonomy-conformity for this activity.

"Installation, maintenance and repair of instruments and devices for measuring, regulation and controlling energy performance of buildings" is only considered indirectly, if at all. We could assume that for the more ambitious energy standards in new buildings as well as renovated buildings it is a pre-condition to install instruments and devices for measuring, regulating and controlling the building's energy performance. Since both EUTarget and EUSupreme show very ambitious energy standards over time (especially from 2040 onwards) we can assume that they are more taxonomy-conform compared to EUBase.

The activity "Installation, maintenance and repair of renewable energy technologies" mainly addresses the installation of heat pumps and solar thermal hot water panels. In the model their respective share in the overall final energy demand can be assessed directly. Since other energy carriers such as district heating, electricity and biomass are still part of the mix at all times, the share of solar thermal plus ambient heat from heat pumps never exceeds 33% of the final energy demand, even in the EUSupreme scenario in 2050.

"Acquisition and ownership of buildings" are not taken into consideration in the buildings model at all. EPCs including their class distribution can only be derived indirectly, since the model only considers overall floor area-weighted energy consumption. Hence, the attempted assessment in the following tables is highly uncertain.

Table 17: EU Taxonomy alignment in the buildings sector for the scenario EUBase

Activity	Criterion	2030	2040	2050
Construction of new buildings	Primary energy demand is at least 10% lower than the threshold set for the nearly zero-energy building (NZEB) requirements in national measures	medium compliance (mid-level energy standards)	limited compliance (low-level energy standards)	limited compliance (low-level energy standards)
Renovation of existing buildings	The building renovation complies with the applicable requirements for major renovations; Alternatively, it leads to a reduction of primary energy demand (PED) of at least 30%	medium compliance (mid-level energy standards)	limited compliance (low-level energy standards)	limited compliance (low-level energy standards)
Installation, maintenance and repair of energy efficiency equipment	Activity complies with minimum requirements set for individual components and systems in the applicable national measures implementing Directive 2010/31/EU	medium compliance (mid-level energy standards)	limited compliance (low-level energy standards)	limited compliance (low-level energy standards)
Installation, maintenance and repair of instruments and devices for measuring, regulation and controlling energy performance of buildings	None	limited compliance (only implicitly addressed)	limited compliance (only implicitly addressed)	limited compliance (only implicitly addressed)
Installation, maintenance and repair of renewable energy technologies	Installation, maintenance and repair of: ▶ solar hot water panels ▶ heat pumps ▶ heat exchanger/recovery systems.	limited compliance (8% share of final energy demand)	limited compliance (12% share of final energy demand)	limited compliance (16% share of final energy demand)
Acquisition and ownership of buildings	For buildings built before 31 December 2020, the building has at least an Energy Performance Certificate (EPC) class A. As an alternative, the building is within the top 15% of the building stock. ▶ For buildings built after 31 December 2020, the building meets the criteria specified in Section 7.1 of this Annex that are relevant at the time of the acquisition.	limited compliance (rough estimate)	limited compliance (rough estimate)	limited compliance (rough estimate)

Table 18: Taxonomy alignment in the buildings sector for the scenario EUTarget

Activity	Criterion	2030	2040	2050
Construction of new buildings	Primary energy demand is at least 10% lower than the threshold set for the nearly zero-energy building (NZEB) requirements in national measures	Good compliance (ambitious energy standards)	Good compliance (ambitious energy standards)	Good compliance (ambitious energy standards)
Renovation of existing buildings	The building renovation complies with the applicable requirements for major renovations; Alternatively, it leads to a reduction of primary energy demand (PED) of at least 30%	Good compliance (ambitious energy standards)	Good compliance (ambitious energy standards)	Good compliance (ambitious energy standards)
Installation, maintenance and repair of energy efficiency equipment	Activity complies with minimum requirements set for individual components and systems in the applicable national measures implementing Directive 2010/31/EU	Good compliance (ambitious energy standards)	Good compliance (ambitious energy standards)	Good compliance (ambitious energy standards)
Installation, maintenance and repair of instruments and devices for measuring, regulation and controlling energy performance of buildings	None	Probably medium compliant (only implicitly addressed)	Probably good compliance (only implicitly addressed)	Probably good compliance (only implicitly addressed)
Installation, maintenance and repair of renewable energy technologies	Installation, maintenance and repair of: ▶ solar hot water panels ▶ heat pumps ▶ heat exchanger/recovery systems.	limited compliance (14% share of final energy demand)	medium compliance (22% share of final energy demand)	Medium compliance (28% share of final energy demand)

Activity	Criterion	2030	2040	2050
Acquisition and ownership of buildings	For buildings built before 31 December 2020, the building has at least an Energy Performance Certificate (EPC) class A. As an alternative, the building is within the top 15% of the building stock. ▶ For buildings built after 31 December 2020, the building meets the criteria specified in Section 7.1 of this Annex that are relevant at the time of the acquisition.	Probably medium compliance (rough estimate)	Probably good compliance (rough estimate)	Probably good compliance (rough estimate)

Table 19: Taxonomy alignment in the buildings sector for the scenario EUSupreme

Activity	Criterion	2030	2040	2050
Construction of new buildings	Primary energy demand is at least 10% lower than the threshold set for the nearly zero-energy building (NZEB) requirements in national measures	Good compliance (ambitious energy standards)	Good compliance (ambitious energy standards)	Good compliance (ambitious energy standards)
Renovation of existing buildings	The building renovation complies with the applicable requirements for major renovations; Alternatively, it leads to a reduction of primary energy demand (PED) of at least 30%	Good compliance (ambitious energy standards)	Good compliance (ambitious energy standards)	Good compliance (ambitious energy standards)
Installation, maintenance and repair of energy efficiency equipment	Activity complies with minimum requirements set for individual components and systems in the applicable national measures implementing Directive 2010/31/EU	Good compliance (ambitious energy standards)	Good compliance (ambitious energy standards)	Good compliance (ambitious energy standards)

Activity	Criterion	2030	2040	2050
Installation, maintenance and repair of instruments and devices for measuring, regulation and controlling energy performance of buildings	None	Probably medium compliant (only implicitly addressed)	Probably good compliance (only implicitly addressed)	Probably good compliance (only implicitly addressed)
Installation, maintenance and repair of renewable energy technologies	Installation, maintenance and repair of: ▶ solar hot water panels ▶ heat pumps ▶ heat exchanger/recovery systems.	medium compliance (21% share of final energy demand)	Medium compliance (28% share of final energy demand)	well compliant (32% share of final energy demand)
Acquisition and ownership of buildings	For buildings built before 31 December 2020, the building has at least an Energy Performance Certificate (EPC) class A. As an alternative, the building is within the top 15% of the building stock. ▶ For buildings built after 31 December 2020, the building meets the criteria specified in Section 7.1 of this Annex that are relevant at the time of the acquisition.	Probably medium compliant (rough estimate)	Probably good compliance (rough estimate)	Probably good compliance (rough estimate)

A.4 Energy supply – Model Enertile

A.4.1 Classification of the model

The Enertile model is primarily an optimization model focused on cost minimization from a system perspective for the supply of electricity, hydrogen, and district heating. Infrastructure costs are not considered, but costs associated with the expansion of electricity and hydrogen networks are included in the optimization process.

A.4.2 Short technical description

The Enertile model takes demand as input and incorporates both flexibility and load profiles. Energy balances are solved on a country-by-country and hourly basis. Techno-economic assumptions are made for both renewable and conventional technologies, with renewable potentials represented as cost-potential curves that include hourly profiles. Minimum and maximum restrictions govern certain aspects, such as the construction of specific technologies and the use of a limited amount of biomass. Additionally, greenhouse gas neutrality by 2050 is considered, which restricts the use of fossil fuels to waste by that year. The model assumes perfect foresight regarding prices and future demands, with no uncertainty in hourly or yearly demand. Capital costs are not considered, and a global interest rate of 2% is applied. The model exhibits a tendency to switch quickly between technologies, with necessary investments often made only at the very end when all other options have been exhausted.

Enertile is often used to evaluate which pathways are cost-efficient. If capital costs vary, the pathway would depend heavily on the assumed discount parameters.

A.4.3 Subsectors considered in the model

The model considers three main subsectors: electricity, hydrogen, and district heating, which are optimized together with full consideration of their interactions. All relevant technologies, including storage options (electricity, heat, hydrogen), are included. The endogenous demand for these three subsectors is also accounted for, recognizing for example, that electrolysis of hydrogen requires electricity.

A.4.4 Driving forces and exogeneous model variables

The primary driving force of the model is electricity, district heat and hydrogen demand. Exogenous variables include GHG targets and energy prices, which influence the model's outcomes.

A.4.5 Relevant variables of the model for taxonomy alignment analysis

Relevant variables encompass techno-economic parameters of the technologies considered, energy demands for secondary energy carriers, fuel prices, policy restrictions, availability, and other factors. The model incorporates all these variables into a cost function. The energy system under investigation is mathematically formulated as a linear problem, which includes hourly and regional energy balance constraints, along with additional global restrictions, integrating all relevant data.

For the activity "Electricity generation using solar photovoltaic technology" (CCM 4.1), the model considers capacity expansion and electricity generation as key contribution criteria. However, detailed criteria beyond electricity generation are outside the scope of the model. Similarly, "Electricity generation using concentrated solar power (CSP) technology" (CCM 4.2) and "Electricity generation from wind power" (CCM 4.3) follow the same logic, focusing on capacity expansion and electricity generation. Again, detailed criteria beyond electricity generation are not included. For "Electricity generation from hydropower" (CCM 4.5), the model considers capacity expansion and electricity generation, while life cycle GHG emissions criteria are outside its scope. The activity "Electricity generation from geothermal energy" (CCM 4.6) also aligns with capacity expansion and electricity generation, with life cycle GHG emissions criteria not being part of the model. In the case of "Electricity generation from bioenergy" (CCM 4.8), the model considers capacity expansion and electricity generation, but life cycle GHG emissions criteria are again outside its scope. For all criteria related to electricity generation from renewable sources, the evaluation approach involves scenario comparison based on the overall share of renewable energy sources in total electricity generation (RES-E Share).

For the activities "Transmission and distribution of electricity" (CCM 4.9), "Storage of electricity" (CCM 4.10), "Storage of thermal energy" (CCM 4.11), "Storage of hydrogen" (CCM 4.12), "Transmission and distribution networks for renewable and low-carbon gases" (CCM 4.14), and "Cogeneration of heat/cool and power from renewable non-fossil gaseous and liquid fuels" (CCM 4.19) capacity expansion and generation are part of the model, while regulatory criteria are outside of the model's scope. Taxonomy alignment is assessed based on capacity expansion for these technologies.

For the activities "Cogeneration of heat/cool and power from renewable non-fossil gaseous and liquid fuels" (CCM 4.19) and "Cogeneration of heat/cool and power from bioenergy" (CCM 4.20), the model considers capacity expansion and generation as the main contribution criterion. However, detailed criteria such as life cycle GHG emissions and compliance with sustainability requirements are not included in the model scope. Similarly, for "Production of heat/cool from solar thermal heating" (CCM 4.21), "Production of heat/cool from geothermal energy" (CCM 4.22), and "Production of heat/cool from renewable non-fossil gaseous and liquid fuels" (CCM 4.23), the model includes capacity expansion and heat generation, while specific criteria such as life cycle GHG emissions and other technical requirements are outside the scope of the model. Nevertheless, decarbonization of heat generation in district heating networks is mainly decarbonized

Finally, for "Construction and safe operation of new nuclear power plants" (CCM 4.27) and "Electricity generation from nuclear energy in existing installations" (CCM 4.28), both activities are assessed based on electricity generation (nuclear share), with regulatory criteria for nuclear safety and operations outside the model's scope.

A.4.6 Representation of actors in the model

Table 20: Actors considered in the model Enertile

Description of actor	Is considered how?
Well-tempered planner with perfect foresight	See above

Description of actor	Is considered how?
Energy suppliers	All the implicit actors optimize system costs, not personal benefits. Underlying assumption: The regulatory framework passes information on system costs to end users. Individual energy suppliers are not part of the model.

A.4.7 Activities of the sector addressed by the EU Taxonomy

Table 21: Activities of the EU Taxonomy in the energy supply sector

Number	Activity	Example company	Activity considered in model?
CCM 4.1	Electricity generation using solar photovoltaic technology		Technology is included
CCM 4.2	Electricity generation using concentrated solar power (CSP) technology		Technology is included
CCM 4.3	Electricity generation from wind power		Technology is included
CCM 4.4	Electricity generation from ocean energy technologies		Not considered in the model
CCM 4.5	Electricity generation from hydropower		Technology is included, but criteria not part of model (life cycle GHG emissions)
CCM 4.6	Electricity generation from geothermal energy		Technology is included, but criteria not part of model (life cycle GHG emissions)
CCM 4.7	Electricity generation from renewable non-fossil gaseous and liquid fuels		Not considered in the model as biogas only is not part of the activity
CCM 4.8	Electricity generation from bioenergy		Technology is included, but criteria not part of model
CCM 4.9	Transmission and distribution of electricity		Technology is included, but criteria not part of model
CCM 4.10	Storage of electricity		Technology is included
CCM 4.11	Storage of thermal energy		Technology is included
CCM 4.12	Storage of hydrogen		Technology is included
CCM 4.13	Manufacture of biogas and biofuels for use in transport and of bioliquids		Not considered in the model
CCM 4.14	Transmission and distribution networks for renewable and low-carbon gases		Technology is included

Number	Activity	Example company	Activity considered in model?
CCM 4.15	District heating / cooling distribution		Not considered in the model9
CCM 4.16	Installation and operation of electric heat pumps		For buildings: Only resulting electricity demand and flexibility potentials are included in the model For district heating: technology is included, but detailed criteria not part of model
CCM 4.17	Cogeneration of heat/cool and power from solar energy		Not considered in the model
CCM 4.18	Cogeneration of heat/cool and power from geothermal energy		Not considered in the model
CCM 4.19	Cogeneration of heat/cool and power from renewable non-fossil gaseous and liquid fuels		Technology is included, but criteria not part of model
CCM 4.20	Cogeneration of heat/cool and power from bioenergy		Technology is included, but criteria not part of model
CCM 4.21	Production of heat/cool from solar thermal heating		Technology is included, but criteria not part of model
CCM 4.22	Production of heat/cool from geothermal energy		Technology is included, but criteria not part of model
CCM 4.23	Production of heat/cool from renewable non-fossil gaseous and liquid fuels		Technology is included, but criteria not part of model
CCM 4.24	Production of heat/cool from bioenergy		Technology is included, but criteria not part of model
CCM 4.25	Production of heat/cool using waste heat		Not considered in the model
CCM 4.26	Pre-commercial stages of advanced technologies to produce energy from nuclear processes with minimal waste from the fuel cycle		Not considered in the model
CCM 4.27	Construction and safe operation of new nuclear power plants, for the generation of electricity and/or heat, including for hydrogen production, using best-available technologies		Technology is included, but criteria not part of model

[9] District heating is considered in the Pathways project, but the corresponding modelling activity is outside the scope of the EU Taxonomy analysis.

Number	Activity	Example company	Activity considered in model?
CCM 4.28	Electricity generation from nuclear energy in existing installations		Technology is included, but criteria not part of model
CCM 4.29	Electricity generation from fossil gaseous fuels		Not considered in the model (Technology only considered without fuel switch. Fossil gas power plants are replaced by hydrogen power plants.)
CCM 4.30	High-efficiency co-generation of heat/cool and power from fossil gaseous fuels		Not considered in the model (Technology only considered without fuel switch. Fossil gas power plants are replaced by hydrogen power plants.)
CCM 4.31	Production of heat/cool from fossil gaseous fuels in an efficient district heating and cooling system		Not considered in the model (Technology only considered without fuel switch. Fossil gas power plants are replaced by hydrogen power plants.)

A.4.8 Approach to the analysis of EU Taxonomy alignment

The analysis of EU Taxonomy alignment for the energy supply sector across all scenarios reveals several challenges. The EU Taxonomy primarily focuses on the provision of GHG-neutral electricity; however, the detailed criteria are not considered within the model, making them difficult to assess. Consequently, only the overarching objective of GHG-neutrality in energy supply sector can be evaluated. This overarching objective is achieved for the energy supply sector in all scenarios by 2050—including the EUBase scenario.

Additionally, the EU Taxonomy covers nearly all technologies necessary to achieve GHG-neutrality, but contributions of individual activities (e.g., renewable energy, nuclear, hydrogen) can vary significantly. While GHG-neutrality is reached. For example, a scenario with a high share of renewables but a low share of nuclear and hydrogen can be GHG-neutral as well as a scenario with less renewables but more nuclear. The required storage capacity also differs between these system configurations. Therefore, the highest share of renewables is not automatically an indicator of the best EU Taxonomy compliance, as different technology mixes can achieve the target.

Assuming that the technology mix achieved in the target year 2050 (and thus GHG neutrality) is EU Taxonomy-compliant, the scenarios provide different pathways towards this target. The assessment is based on the development of the technology shares and infrastructure expansion. The results for 2050 are always considered fully compliant; the values for previous years are mapped linearly onto a compliance scale.

It is assumed that all technologies and fuels used in the model also meet the detailed EU Taxonomy criteria (e.g., life-cycle emissions, sustainability requirements). Since these detailed criteria are not represented in the model, actual EU Taxonomy compliance in the scenarios may be lower if individual technologies or fuels do not meet the requirements.

Three criteria were used to analyze EU Taxonomy conformity: (1) electricity production shares, (2) heat production shares, and (3) capacity expansion pathways. The production shares analyzed include the share of electricity production from renewable energy sources (CCM 4.1, 4.2, 4.3, 4.5, 4.6, 4.8), the share of heat production from renewable energy sources (CCM 4.19, 4.21, 4.22, 4.23, 4.24), and the share of electricity generation from nuclear power (CCM 4.27, 4.28). None of these shares reaches 100%; instead, the share achieved in 2050 is considered fully EU Taxonomy-compliant, and the pathway towards this value is evaluated. This approach represents the upper limit of EU Taxonomy conformity, as not all detailed criteria may be met.

For infrastructure, the expansion of electricity transmission networks (CCM 4.9), non-fossil gas networks (CCM 4.14), and energy storage (CCM 4.10, 4.11, 4.12) were assessed. The required capacity in 2050 depends on the contributions of other decarbonization options. Here, the capacity reached in 2050 is assumed to be fully compliant, and the expansion pathway is evaluated.

The key assumption necessary to evaluate EU Taxonomy compliance over time is that the 2050 modelling results are assumed to be fully compliant, as they reach GHG- neutrality in the energy supply sector. The shares achieved in previous years are mapped linearly on a compliance scale. For example, if a technology's share in 2050 is 70%, a share of 35% in an earlier year would be rated as 50% compliant (medium compliance) on the final scale.

Table 22: Analysis of EU Taxonomy alignment in the energy supply sector

No.	Activity	Contribution criteria considered	Contribution criteria outside scope	Relates to model variable	Evaluation approach
CCM 4.1	Electricity generation using solar photovoltaic technology	Capacity expansion, electricity generation	Detailed criteria besides electricity generation	Capacity expansion, electricity generation	Scenario comparison, RES-Share
CCM 4.2	Electricity generation using concentrated solar power (CSP) technology	Capacity expansion, electricity generation	Detailed criteria besides electricity generation	Capacity expansion, electricity generation	Scenario comparison, RES-Share
CCM 4.2	Electricity generation using concentrated solar power (CSP) technology	Capacity expansion, electricity generation	Detailed criteria besides electricity generation	Capacity expansion, electricity generation	Scenario comparison, RES-Share
CCM 4.3	Electricity generation from wind power	Capacity expansion, electricity generation	Detailed criteria besides electricity generation	Capacity expansion, electricity generation	Scenario comparison, RES-Share
CCM 4.5	Electricity generation from hydropower	Capacity expansion, electricity generation	Life cycle GHG emissions criteria	Capacity expansion, electricity generation	Scenario comparison, RES-Share
CCM 4.6	Electricity generation from geo-thermal energy	Capacity expansion, electricity generation	Life cycle GHG emissions criteria	Capacity expansion, electricity generation	Scenario comparison, RES-Share
CCM 4.8	Electricity generation from bioenergy	Capacity expansion, electricity generation	Life cycle GHG emissions criteria	Capacity expansion, electricity generation	Scenario comparison, RES-Share
CCM 4.9	Transmission and distribution of electricity	Capacity expansion	Regulatory criteria for infrastructure development	Capacity expansion	Scenario comparison, capacity between countries
CCM 4.10	Storage of electricity	Capacity expansion	Regulatory criteria for energy storage systems	Capacity expansion	Scenario comparison, capacity
CCM 4.11	Storage of thermal energy	Capacity expansion	Regulatory criteria for thermal energy storage systems	Capacity expansion	Scenario comparison, capacity

No.	Activity	Contribution criteria considered	Contribution criteria outside scope	Relates to model variable	Evaluation approach
CCM 4.12	Storage of hydrogen	Capacity expansion	Regulatory criteria for hydrogen storage systems	Capacity expansion	Scenario comparison, capacity
CCM 4.14	Transmission and distribution networks for renewable and low-carbon gases	Capacity expansion	Regulatory criteria for gas infrastructure development	Capacity expansion	Scenario comparison, capacity between countries
CCM 4.16	Installation and operation of electric heat pumps	Capacity expansion, heat generation	global warming potential of refrigerant and life-cycle GHG emissions criteria	Capacity expansion, heat generation	Scenario comparison, RES-Share
CCM 4.16	Installation and operation of electric heat pumps	Capacity expansion, heat generation	global warming potential of refrigerant and life-cycle GHG emissions criteria	Capacity expansion, heat generation	Scenario comparison, RES-Share
CCM 4.19	Cogeneration of heat/cool and power from renewable non-fossil gaseous and liquid fuels	Capacity expansion, heat generation	Life cycle GHG emissions criteria	Capacity expansion	Scenario comparison, capacity
CCM 4.20	Cogeneration of heat/cool and power from bioenergy	Capacity expansion, heat generation	Life cycle GHG emissions criteria	Capacity expansion	Scenario comparison, capacity
CCM 4.21	Production of heat/cool from solar thermal heating	Capacity expansion, heat generation	Life cycle GHG emissions criteria	Capacity expansion, heat generation	Scenario comparison, RES-Share
CCM 4.22	Production of heat/cool from geothermal energy	Capacity expansion, heat generation	Life cycle GHG emissions criteria	Capacity expansion, heat generation	Scenario comparison, RES-Share
CCM 4.22	Production of heat/cool from geothermal energy	Capacity expansion, heat generation	Life cycle GHG emissions criteria	Capacity expansion, heat generation	Scenario comparison, RES-Share
CCM 4.23	Production of heat/cool from renewable non-fossil gaseous and liquid fuels	Capacity expansion, heat generation	Life cycle GHG emissions criteria	Capacity expansion, heat generation	Scenario comparison, RES-Share

No.	Activity	Contribution criteria considered	Contribution criteria outside scope	Relates to model variable	Evaluation approach
CCM 4.24	Production of heat/cool from bioenergy	Capacity expansion, heat generation	Life cycle GHG emissions criteria	Capacity expansion, heat generation	Scenario comparison, RES-Share
CCM 4.27	Construction and safe operation of new nuclear power plants	Capacity expansion, electricity generation	Regulatory criteria for nuclear safety	Capacity expansion, electricity generation	Scenario comparison, nuclear share
CCM 4.28	Electricity generation from nuclear energy in existing installations	Capacity expansion, electricity generation	Regulatory criteria for nuclear operations	Capacity expansion, electricity generation	Scenario comparison, nuclear share

A.4.9 Results of the EU Taxonomy alignment analysis

The scenario results provide a differentiated picture of taxonomy compliance across the key activities and infrastructure elements in the energy supply sector. The assessment applies the defined compliance categories—ranging from "no compliance" (< 20% of the 2050 value) to "full compliance" (>90% to 100% of the 2050 value or as required)—to each parameter and scenario year.

Electricity generation from renewable energy shows a high degree of compliance in all scenarios. In 2030, the share of renewables already reaches 89–95% of the 2050 value, corresponding to "good compliance" in all cases. By 2040, the share exceeds the 2050 value in EUBase and EUTarget (104%), which is still classified as "full compliance" under the applied scheme, while EUSupreme achieves 99% ("full compliance"). In 2050, the final shares (78–84%) are considered "full compliance" as they represent the scenario-specific share for the decarbonization target.

Heat generation from renewable energy also shows strong progress in all scenarios. In 2030 and 2040, the share ranges from 85% to 94% of the 2050 value, which is categorized as "good compliance" in all scenarios. By 2050, the share rises to 95–97%, meeting the "full compliance" threshold.

For electricity generation from nuclear power, the compliance pattern is more varied. In 2030, the share in all scenarios exceeds the 2050 value (104–167%), which is classified as "full compliance" according to the strict definition, as it surpasses the 2050 value. By 2040, the share declines to 79–100% of the 2050 value, reflecting both the phase-out of older plants and an increase in total electricity generation. This results in "good compliance" for EUTarget and "full compliance" for EUSupreme. In 2050, the final shares (9–15%) are again classified as "full compliance," as they represent the scenario-specific decarbonization mix.

The expansion of electricity transmission networks shows a more gradual progression. In 2030, all scenarios achieve 29% of the 2050 value, which is classified as "limited compliance." By 2040, the share increases to 69–73%, corresponding to "medium" or "good compliance" depending on the scenario. In 2050, all scenarios reach the target value, resulting in "full compliance."

A similar pattern is observed for the expansion of non-fossil gas transmission networks. In 2030, there is "no compliance" (0% of the 2050 value) in all scenarios. By 2040, EUBase reaches 43% ("medium compliance"), EUTarget achieves 83% ("good compliance"), and EUSupreme attains 94% ("full compliance"). In 2050, all scenarios reach the necessary scenario-specific target value, classified as "full compliance."

For energy storage expansion, the compliance trajectory is also scenario dependent. In 2030, all scenarios show "no compliance". By 2040, EUBase reaches 43% ("medium compliance"), while EUTarget and EUSupreme achieve 100% of the 2050 value, corresponding to "full compliance." In 2050, all scenarios meet the target, resulting in "full compliance."

Overall, the application of the strict compliance categories shows that most parameters and scenarios follow a consistent progression from limited or medium compliance in the early years to full compliance by 2050. However, for some parameters—particularly those where the share temporarily exceeds the 2050 value, such as nuclear power in 2030—the classification as "full compliance" results from the threshold-based approach, even if the absolute value is above the final target. This underlines the importance of interpreting the compliance categories within the context of scenario-specific decarbonization pathways and underlying system dynamics. In summary, the results demonstrate that all scenarios achieve full taxonomy compliance for the key parameters by 2050, albeit with different speeds and technology mixes along the transition pathway. The compliance categories provide a transparent and comparable framework for tracking progress, while also reflecting the diversity of decarbonization strategies across scenarios. The assessment of the three scenarios—EUBase, EUTarget, and EUSupreme—reveals similar but distinct trajectories towards full compliance. While all scenarios reach full decarbonization by 2050, EUSupreme demonstrates the strongest compliance across all criteria, particularly in infrastructure and energy storage. EUTarget shows proactive energy storage expansion but fluctuates in its reliance on nuclear power, as additional nuclear plants are only realized in the last decade. In contrast, EUBase shows the slowest progress

Table 23: EU Taxonomy alignment in the energy supply sector for the scenario EUBase

Activity	Criterion	2030	2040	2050
CCM 4.1, 4.2, 4.3, 4.5, 4.6, 4.8	Electricity generation share of renewable energy	Good compliance: 90% of 2050 share	Full compliance: 104% of 2050 share	Full compliance: 78%, as needed to decarbonize the energy supply sector
CCM 4.19, 4.20, 4.21, 4.22, 4.23, 4.24	Heat generation share of renewable energy	Good compliance: 91% of 2050 share	Good compliance: 93% of 2050 share	Full compliance: 97%, as needed to decarbonize the energy supply sector
CCM 4.27, 4.28	Electricity generation share of nuclear power	Full compliance: 127% of 2050 share	Good compliance: 87% of 2050 share	Full compliance: 15%, as needed to decarbonize the energy supply sector
CCM 4.9	Capacity expansion of electricity transmission networks	Limited compliance: 29% of 2050 share	Medium compliance: 69% of 2050 value	Full compliance: 100% or as needed to decarbonize the energy supply sector
CCM 4.14	Capacity expansion of non-fossil gas transmission networks	No compliance	Medium compliance: 43% of 2050 value	Full compliance: 100% or as needed to decarbonize the energy supply sector
CCM 4.10, 4.11, 4.12	Capacity expansion of energy storages	No compliance	Medium compliance: 43% of 2050 value	Full compliance: 100% or as needed to decarbonize the energy supply sector

Table 24: Taxonomy alignment in the energy supply sector for the scenario EUTarget

Activity	Criterion	2030	2040	2050
CCM 4.1, 4.3, 4.5, 4.6, 4.8	Electricity generation share of renewable energy	Good compliance: 95% of 2050 share	Full compliance: 104% of 2050 share	Full compliance: 79%, as needed to decarbonize the energy supply sector
CCM 4.19, 4.20, 4.21, 4.22, 4.23, 4.24	Heat generation share of renewable energy	Good compliance: 93% of 2050 share	Good compliance: 94% of 2050 share	Full compliance: 97%, as needed to decarbonize the transformation sector
CCM 4.27, 4.28	Electricity generation share of nuclear power	Full compliance: 104% of 2050 share	Good compliance: 79% of 2050 share	Full compliance: 14%, as needed to decarbonize the energy supply sector

Activity	Criterion	2030	2040	2050
CCM 4.9	Capacity expansion of electricity transmission networks	Limited compliance: 29% of 2050 value	Good compliance: 73% of 2050 value	Full compliance: 100% or as needed to decarbonize the energy supply sector
CCM 4.14	Capacity expansion of non-fossil gas transmission networks	No compliance	Good compliance: 83% of 2050 value	Full compliance: 100% or as needed to decarbonize the energy supply sector
CCM 4.10, 4.11, 4.12	Capacity expansion of energy storages	No compliance	Full compliance: 100% of 2050 value	Full compliance: 100% or as needed to decarbonize the energy supply sector

Table 25: Taxonomy alignment in the energy supply sector for the scenario EUSupreme

Activity	Criterion	2030	2040	2050
CCM 4.1, 4.3, 4.5, 4.6, 4.8	Electricity generation share of renewable energy	Good compliance: 89% of 2050 share	Full compliance: 99% of 2050 share	Full compliance: 84%, as needed to decarbonize the energy supply sector
CCM 4.19, 4.20, 4.21, 4.22, 4.23, 4.24	Heat generation share of renewable energy	Good compliance: 85% of 2050 share	Good compliance: 89% of 2050 share	Full compliance: 95%, as needed to decarbonize the energy supply sector
CCM 4.27, 4.28	Electricity generation share of nuclear power	Full compliance: 167% of 2050 share	Full compliance: 100% of 2050 share	Full compliance: 9%, as needed to decarbonize the energy supply sector
CCM 4.9	Capacity expansion of electricity transmission networks	Limited compliance: 29% of 2050 value	Good compliance: 73% of 2050 value	Full compliance: 100% or as needed to decarbonize the energy supply sector
CCM 4.14	Capacity expansion of non-fossil gas transmission networks	No compliance	Full compliance: 94% of 2050 value	Full compliance: 100% or as needed to decarbonize the energy supply sector
CCM 4.10, 4.11, 4.12	Capacity expansion of energy storages	No compliance	Full compliance: 100% of 2050 value	Full compliance: 100% or as needed to decarbonize the energy supply sector

A.5 Agriculture – Model LiSE

A.5.1 Classification of the model

LiSE is a bottom-up analytical deterministic model consisting of natural science sub-modules (animal, plant, energy). It is not coupled to an econometric model.

A.5.2 Short technical description

Activity variables and emission factors are extrapolated over time in five-year steps. The interaction with LULUCF is represented by an interface.

A.5.3 Subsectors considered in the model

LiSE considers all subsectors relevant to agriculture based on the UNFCCC inventory submission categories (Common Reporting Format (CRF 3) and energy (CRF 1.A.4.c) and it gives a detailed description of the following subsectors of the inventory categories: An enteric fermentation, B manure management and D agricultural soils. It also considers GHG emissions from the smaller subcategories 3.F to 3.J. There is also a module included in the LISE model on energy consumption, however within this project energy consumption from the agricultural sector is included in the modelling of the other sectors.

A.5.4 Driving forces and exogeneous model variables

The development of livestock numbers is based on exogenous model inputs. These inputs are derived either from external literature sources, such as the EU outlook, or from assumptions about dietary and demand changes. Typically, demand acts as an indirect driver, implemented alongside self-sufficiency targets.

Additionally, the implementation and adaptation rates of mitigation technologies are treated as exogenous model variables. However, in scenarios where price instruments, such as GHG pricing, are considered, the implementation of mitigation technologies is not an exogenous variable but rather depends on the level of the GHG price.

A.5.5 Relevant variables of the model for an analysis of taxonomy alignment

Agriculture is not directly affected by taxonomy regulation. Food industry – main customer of agricultural products – is also not covered. The only activities officially covered and related to the agricultural sector are:

- Peatland restoration: Environmental protection and restoration activities (CCM 2.1)

In addition, agriculture is indirectly affected via

- Activities of bioeconomy for energy and material use of biomass (CCM 4.8, CCM 4.13, CCM 4.20, CCM 4.24)

The activities assessed in the following are not included in the current version of the Taxonomy Regulation and are absent from the Taxonomy Navigator. The activities used for the assessment of taxonomy alignment for the agricultural sector and listed in the tables below were part of the draft of Annex I in 2020. Due to the lack of detailed information on activities under the EU Taxonomy for the agricultural sector, we refer to the 2020 draft of Annex I (European Commission 2020a) to determine which activities are included in the scenarios and which are not.

A.5.6 Representation of actors in the model

Table 26: Actors considered in the model LiSE

Description of actor	Representation in the model
Individual farmers and agricultural businesses	The model does not operate at the farm level but rather treats each EU member state as a single entity. Consequently, its scope is too broad to capture detailed farm-level activities. However, it includes activities that are concrete, measurable, and have available data on emission reductions.

A.5.7 Activities of the sector addressed by the EU Taxonomy

Table 27: Activities of the EU Taxonomy in the agricultural sector[10]

Number	Activity	Example company	Representation in the model
N/A	Growing of non-perennial crops	Farm level	Only partly represented N-fertilization (mineral and organic), spreading technology, use of nitrification inhibitors Land use aspects (change of SOC, change of land use categories) are addressed in the LULUCF sector
N/A	Growing of perennial crops	Farm level	Only partly represented AFS: "saved" N-fertilization (against reference case current fertilization/ future crop mix) Land use aspects (change of SOC, change of land use categories) are addressed in the LULUCF sector
N/A	Livestock production	Farm level	Only partly represented Digested manure: yield, animal numbers, grazing
CCM2.1	Peatland restoration: Environmental protection and restoration activities	Farm level	Yes, peatland restoration is considered in the model, but not on farm level

[10] Due to the lack of detailed information on activities under the EU Taxonomy for the agricultural sector, we refer to the 2020 draft of Annex I for this sector.

A.5.8 Approach to the analysis of EU Taxonomy alignment

Table 28: Approach to the analysis of EU Taxonomy alignment in the agricultural sector

No.	Activity	Contribution criteria considered	Contribution criteria outside scope	Relates to model variable	Evaluation approach
N/A	Growing of non-perennial crops		**Crop management:** ▶ -Crop rotation, 5 crops, including at least one legume or green manure ▶ At least 75% of living plant coverage on agricultural holding		Not considered (no farm level)
N/A	Growing of non-perennial crops/Growing of perennial crops/Animal husbandry	**Soil management:** ▶ protecting histosols and peatlands from nutrient leaching and decline in organic matter (rewetting peatlands, enlarging water storage etc.)	**Soil management:** The following practices are not covered: (a) practices that disturb histosols and organic soils; (b) artificially lowering water tables on histosols and organic soils; (c) mechanical weeding with inversion tillage between rows; (d) burning of crop residues (except where an exemption has been granted for plant health reasons) Good soil management practices in place, including: ▶ avoiding compaction from heavy machineries ▶ minimizing soil erosion (cover crops, strip cropping etc.) ▶ increase soil organic matter (crop residues, green manure etc.) ▶ preference to minimum or non-inversion tillage	Only criteria considered is the rewetting of peatland, which is reflected in the LULUCF model Model variable: area of agricultural land on drained organic soils, area of rewetted organic soils on agricultural land	Most activities are not considered in the model due to different scope of model (no farm level). Rewetting of peatland is considered in the LULUCF model (CO_2 emissions), but also in the LISE model due to reduction in agricultural used land and reduction in N_2O emissions, share of peatland rewetted is evaluated.

No.	Activity	Contribution criteria considered	Contribution criteria outside scope	Relates to model variable	Evaluation approach
N/A	Growing of non-perennial crops/Growing of perennial crops	**Nutrient management:** ▶ application techniques to reduce ammonia emissions (injection, timing, spreading rate) ▶ low emission nutrient storage (medium and high input farms): covering manure storage, fast incorporation into the soil etc.	**Nutrient management:** ▶ Implementation of crop nutrient and fertilization plan (testing of soil, budgeting nutrient inputs/outputs) ▶ low emission nutrient storage (medium and high input farms): cooling of liquid manure, slurry acidification,	Increasing N efficiency from manure	In the model the N efficiency of manure is increased by assuming a higher N- effectiveness of manure when accounting for the fertilizing effect of manure. This includes measures like the coverage of manure storage systems, direct incorporation into the soil, injection etc., N-effectiveness of organic fertilizer of the model is used for evaluation. Other measures like the cooling of manure and slurry acidification are not considered.
	Growing of non-perennial crops/Growing of perennial crops	High diversity landscape features – minimum share of 10% (hedges, non-productive area etc.)		Non- productive areas, agroforestry, unproductive grassland	This criterion is included in the LISE model by various area categories. These areas are not used or only partly used for agricultural production, which is reflected by a lower or no productivity, N-input and thus lower N_2O emissions. The share of agricultural area with agroforestry systems or area with high biodiversity value is evaluated.
	Growing of non-perennial crops/Growing of perennial crops/Animal husbandry		Energy efficiency		The energy consumption of the agricultural sector is part of the GHD sector and was not modelled with the LISE model.

No.	Activity	Contribution criteria considered	Contribution criteria outside scope	Relates to model variable	Evaluation approach
	Animal husbandry- Herd management	▶ Breed selection to increase resource efficient with higher yields and lower GHG intensity,	▶ animal health to reduce veterinary treatments and stock mortality ▶ optimize herd profile management to mitigation CH_4 emissions, increase productivity ▶ breed selection to adapt to local conditions	▶ Increase in yields ▶ reduction of CH_4 emissions from enteric fermentation by improved breeding	Increased yields are considered country specific level, increase in milk and carcass weight is evaluated. Reduction in CH_4 emissions by increased breeding is considered for a certain share of livestock population by using a reduced emission factor for CH_4 emissions from enteric fermentation
	Animal husbandry- feeding	Reduce GHG emissions by changes in feeding which impact nitrogen excretion Changes in feeding that reduce CH_4 emissions from enteric fermentation of ruminants, by increased forage digestibility, authorized feed additives	High sugar grasses or maize silage, phase feeding, low protein feed, etc. Sustainable procurement of feed, selecting feed that is sustainably sourced and certified	N-efficient feeding Use of feed additives	N-efficient feeding is reflected by reduced nitrogen excretion for a certain share of livestock population, reduction in N-excretion due to N-efficient feeding is evaluated. Use of feed additives is reflected for a certain share of livestock population by using a reduced emission factor for CH_4 emissions from enteric fermentation, share of livestock fed with feed additives to reduce CH_4 emissions is evaluated.
	Animal husbandry- manure management	Anaerobic digestion of slurries and manure for biogas to generate heat and electricity Application techniques to reduce ammonia emissions when slurry and manure is applied to soils (injection of slurry, banded spreading on grassland etc.) Nitrification inhibitors	Treatment of slurry and manure in on-farm facilities separation of slurries or digestates into solid and liquid fractions, use of manure additives Appropriate slurry processing including cooling of slurry, slurry acidification, storage systems reducing emissions from surface, adequate storage capacity	Share of manure and slurry which is anaerobic digested Nitrification inhibitors	Use of lower emissions factors for share of manure which is anaerobic digested Treatment of slurry is not reflected in such a detail in the model, by improving the N-efficiency of manure many activities (precision farming, application technologies, coverage of storage facilities etc.)

No.	Activity	Contribution criteria considered	Contribution criteria outside scope	Relates to model variable	Evaluation approach
			Fertilization plans Appropriate handling and storage of solid manure Precision farming		mentioned in the Annex are implicitly included. N-effectiveness of organic fertilizer is evaluated. Nitrification inhibitors are included and reflected by the use of lower emission factors for share of manure which contains nitrification inhibitors, Share of mineral and organic fertilizer with additives is evaluated.
	Animal husbandry – Soil management		Adjust stocking density to soil conditions to avoid compaction on wet soils Grassland management optimizing pasture growth and pasture quality and utilization by livestock (except in extensive grazing systems), optimum grazing times based on local circumstances, grassheight monitoring, rotational and strip grazing, pasture renovation		Grassland quality is not considered in the model
	CCM 2.1: Peatland restoration	Yes		Area of rewetted peatland	Area of rewetted peatland and emission factors

A.5.9 Results of the EU Taxonomy alignment analysis

Assessing compliance is difficult for the agricultural sector, as there are neither defined activities nor targets. In principle, a higher proportion of land treated in a way qualifying to be rated as taxonomy compliant or a higher penetration rate for the respective technologies rated higher. The scenarios differ in terms of the proportion of land or penetration rates.

In the EUBase scenario, both the proportion of land for peatland rewetting and agroforestry systems is low, as are the penetration rates for technical measures. Some technical measures, such as the addition of additives, are not taken into account at all in the EUBase scenario. The EUTarget scenario shows the highest penetration rates for technical mitigation measures (e.g. 70% digestion of animal manure). In addition, the reduction effects of additives are only taken into account in this scenario. Due to uncertainties regarding impacts on other environmental media and long-term mitigation effects, these are not considered in the EUSupreme scenario. In the EUSupreme scenario, the penetration rates for technical mitigation measures are lower in some cases (e.g. manure fermentation), mainly because the lower livestock density and smaller-scale structures make manure fermentation rather uneconomical. On the other hand, the share of rewetted areas and the areas for biodiversity and agroforestry systems continue to increase. The evaluation in the table is only based on the expert judgement of the authors and in some cases difficult to classify.

Table 29: EU Taxonomy alignment in the agricultural sector for the scenario EUBase

Activity	Criterion	2030	2040	2050
Animal Husbandry	Anaerobic digestion of slurries and manure for biogas	Limited compliance 10% of manure in stables	Limited compliance 16% of manure in stables	Limited compliance 22% of manure in stables
Animal husbandry	Breed selection to increase resource efficiency with higher yields and lower GHG intensity	Good compliance Increase in milk yield +8% compared to 2020	Good compliance Increase in milk yield +8% compared to 2020	Good compliance Increase in milk yield +8% compared to 2020
Animal Husbandry	Nitrification inhibitors	Not considered in the scenario	Not considered in the scenario	Not considered in the scenario
Animal Husbandry	Reduce GHG emissions by changes in feeding which impact nitrogen excretion	Medium compliance -1.5% nitrogen excretion due to increase in N-efficient feeding	Good compliance -3% nitrogen excretion due to increase in N-efficient feeding	Full compliance -5% nitrogen excretion due to increase in N-efficient feeding
Animal Husbandry	Changes in feeding that reduce CH4 emissions from enteric fermentation	Not considered in the scenario	Not considered in the scenario	Not considered in the scenario
High diversity landscape features	Minimum share of 10% of agricultural land covered with high-diversity landscape features	Limited compliance 5% of total UAA as fallow land or unproductive grassland 0.25% of total UAA as agroforestry system/fast growing trees	Limited compliance 5% of total UAA as fallow land or unproductive grassland 0.5% of total UAA as agroforestry system/fast growing trees	Limited compliance 5% of total UAA as fallow land or unproductive grassland, 1% of total UAA as agroforestry system/fast growing trees
CCM2.1: Peatland restoration/ Growing of non-perennial crops/Growing of perennial crops	Protecting histosols and peatlands	Limited compliance Rewetting of 7% of cropland, 11% of grassland	Limited compliance Rewetting of 14% of cropland, 22% of grassland	Medium compliance Rewetting of 20% of cropland, 33% of grassland

Activity	Criterion	2030	2040	2050
Growing of non-perennial crops/Growing of perennial crops/Animal Husbandry	Application techniques to reduce ammonia emissions Only implicit by increased N-efficiency of manure	Limited compliance 55%	Medium compliance 60%	Good compliance 65%
Growing of non-perennial crops/Growing of perennial crops/Animal Husbandry	Low emission nutrient storage (medium and high input farms) covering manure storage, fast incorporation into the soil etc. Only implicit by increased N-efficiency of manure	Limited compliance 55%	Medium compliance 60%	Good compliance 65%

Table 30: Taxonomy alignment in the agricultural sector for the scenario EUTarget

Activity	Criterion	2030	2040	2050
Animal Husbandry	Anaerobic digestion of slurries and manure for biogas	Limited compliance 15% of manure in stables	Medium compliance 35% of manure in stables	Good compliance 70% of manure in stables
Animal Husbandry	Breed selection to increase resource efficiency with higher yields and lower GHG intensity	Good compliance Increase in milk yield +8% compared to 2020	Good compliance Increase in milk yield +8% compared to 2020	Good compliance Increase in milk yield +8% compared to 2020
Animal Husbandry	Nitrification inhibitors	No compliance Not considered	Good compliance 50% of mineral fertilizer, 25% of manure with nitrification inhibitors	Full compliance 100% of mineral fertilizer, 50% of manure with nitrification inhibitors
Animal Husbandry	Reduce GHG emissions by changes in feeding which impact nitrogen excretion	Good compliance -3% nitrogen excretion due to increase in N-efficient feeding	Good compliance -4% nitrogen excretion due to increase in N-efficient feeding	Full compliance -5% nitrogen excretion due to increase in N-efficient feeding

Activity	Criterion	2030	2040	2050
Animal Husbandry	Changes in feeding that reduce CH4 emissions from enteric fermentation	Limited compliance 20% dairy cows, 10% other cattle fed with feed additives	Medium compliance 40% dairy cows, 20% other cattle fed with feed additives	Full compliance 100% of conventional dairy cows, 50% of conventional other cattle fed with feed additives
High diversity landscape features	Minimum share of 10% of agricultural land covered with high-diversity landscape features	Limited compliance 5% of total UAA as fallow land or unproductive grassland 0.25% of total UAA as agroforestry system/fast growing trees	Limited compliance 5% of total UAA as fallow land or unproductive grassland, 0.5% of total UAA as agroforestry system/fast growing trees	Limited compliance 5% of total UAA as fallow land or unproductive grassland 1% of total UAA as agroforestry system/fast growing trees
CCM2.1: Peatland restoration/Growing of non-perennial crops/Growing of perennial crops	Protecting histosols and peatlands	Limited compliance Rewetting of 16% of cropland, 20% of grassland	Medium compliance Rewetting of 33% of cropland, 40% of grassland	Good compliance Rewetting of 50% of cropland, 60% of grassland
Growing of non-perennial crops/Growing of perennial crops/Animal Husbandry	Application techniques to reduce ammonia emissions Only implicit by increased N-efficiency of manure	Medium compliance 60%	Good compliance 65%	Full compliance 70%
Growing of non-perennial crops/Growing of perennial crops/Animal Husbandry	Low nutrient emission storage (medium and high input farms) covering manure storage, fast incorporation into the soil etc. Only implicit by increased N-efficiency of manure	Medium compliance 60%	Good compliance 65%	Full compliance 70%

Table 31: Taxonomy alignment in the agricultural sector for the scenario EUSupreme

Activity	Criterion	2030	2040	2050
Animal Husbandry	Anaerobic digestion of slurries and manure for biogas	Limited compliance 15% of manure in stables	Limited compliance 25% of manure in stables	Medium compliance 50% of manure in stables
Animal husbandry	Breed selection to increase resource efficiency with higher yields and lower GHG intensity	Medium compliance Increase in milk yield +2% compared to 2020, due to higher share of organic farming and large share of pastures	Medium compliance Increase in milk yield +2% compared to 2020, due to higher share of organic farming and large share of pastures	Medium compliance Increase in milk yield +2% compared to 2020, due to higher share of organic farming and large share of pastures
Animal Husbandry	Nitrification inhibitors	Not considered in the scenario	Not considered in the scenario	Not considered in the scenario
Animal Husbandry	Reduce GHG emissions by changes in feeding which impact nitrogen excretion	Medium compliance -1.5% nitrogen excretion due to increase in N-efficient feeding	Good compliance -3% nitrogen excretion due to increase in N-efficient feeding	Full compliance -5% nitrogen excretion due to increase in N-efficent feeding
Animal Husbandry	Changes in feeding that reduce CH4 emissions from enteric fermentation	Not considered	Not considered	Not considered
High diversity landscape features	Minimum share of 10% of agricultural land covered with high-diversity landscape features	Full compliance 10% of total UAA as fallow land or unproductive grassland, 2,5% of total UAA as agroforestry system/fast growing trees	Full compliance 10% of total UAA as fallow land or unproductive grassland, 5% of total UAA as agroforestry system/fast growing trees	Full compliance 10% of total UAA as fallow land or unproductive grassland, 10% of total UAA as agroforestry system/fast growing trees
CCM2.1: Peatland restoration/Growing of non-perennial crops/Growing of perennial crops	Protecting histosols and peatlands	Medium compliance Rewetting of 22% of cropland, 26% of grassland	Good compliance Rewetting of 44% of cropland, 52% of grassland	Full compliance Rewetting of 67% of cropland, 78% of grassland

Activity	**Criterion**	**2030**	**2040**	**2050**
Growing of non-perennial crops/Growing of perennial crops/Animal Husbandry	Application techniques to reduce ammonia emissions Only implicit by increased N-efficiency of manure	Medium compliance 60%	Good compliance 65%	Full compliance 70%
Growing of non-perennial crops/Growing of perennial crops/Animal Husbandry	Low emission nutrient storage (medium and high input farms) covering manure storage, fast incorporation into the soil etc. Only implicit by increased N-efficiency of manure	Medium compliance 60%	Good compliance 65%	Full compliance 70%

A.6 Forestry and land use – Model FABio-Land

A.6.1 Classification of the model

The Forest and Agriculture Biomass – Land use (FABio-Land) model is a simulation tool based on information on area shares of different land use categories and emission factors for activities and processes on these areas.

A.6.2 Short technical description

FABio-Land projects GHG emissions from sources and carbon removals by sinks in the LULUCF sector. It covers all land use categories included in GHG reporting under the UNFCCC, i.e. forest land, cropland, grassland, wetlands, settlements, and other land as well as harvested wood products. Land use categories are further differentiated by mineral and organic soils, as well as sub-categories for land in transition between land use categories.

The model uses historical emission factors and land transition coefficients for each category derived from GHG inventories and National Inventory Documents (NIDs) of EU countries. The model considers the EU countries as one and does not differentiate individual Member States. Based on historic data extracted from the EU inventory, area changes and associated emissions and removals are extrapolated (e.g. mean of the last 10 years).

Historic data are used to describe a business-as-usual projection, assuming continuation of land use policies and demand for agricultural goods and forestry products. Mitigation measures in the model are described as change factors for area transitions and/or as change factors for emission factors deviating from the baseline. For example, for simulating afforestation measures, the area entering the sub-category “Land converted to forest land” is increased. For simulating short rotation coppice plantations, the emission/removal factor for cropland is adapted for the respective share of area.

A model interface exchanges data on area development of cropland, grassland and wetland with the agricultural model to ensure consistency between the sectors. Calculations in FABio-Land are done with a temporal resolution of one year and extend up to the year 2050.

FABio-Land considers land management agents that represent a combination of decisions by landowners, land use policies, demand for products, and other drivers. For a more detailed consideration of drivers, other modelling approaches could be useful:

- Partial equilibrium models like GLOBIOM (IIASA 2025), Landshift (Alcamo and Schaldach 2006), Magpie (Dietrich et al. 2025) etc. consider economic aspects of land use decisions, i.e. markets for agricultural goods and forestry products. However, they rely on assumptions about rational decision making in the sector that can also be questioned. CAPRI is another partial equilibrium model, designed for assessing economic and environmental impacts on agriculture at more regional level (Gocht 2025).
- Agent-based models like CRAFTY consider characteristics of landowners or managers and their behavior. In CRAFTY land manager agents make management decisions explicitly on the basis of the supply and demand for ecosystem services, and the interventions of institutional agents with specific land use or ecosystem service-related objectives (Brown et al. 2018).

FABio-Land does not consider all activities addressed by the EU Taxonomy in the land sector. To increase the coverage of activities, restoration would have to be considered by modelling tools. This requires also the coverage of natural disturbances and extreme events, a major reason for implementing restoration activities.

Other required data include information on ownership, size and type (private, public), and other economic indicators of landowners. There is also a lack of information on structure and size of management actors operating in forests and on agricultural areas that are often different from landowners.

A.6.3 Subsectors considered in the model

FABio-Land considers all IPCC reporting categories of the LULUCF sector. These are: forest land, cropland, grassland, wetlands, settlements, other lands, and harvested wood products. Moreover, it differentiates transition classes between categories. After land use change, e.g. from cropland to forest land, the area is traced in the category "cropland converted to forest land". The model applies a transition period of 20 years (according to IPCC rules) before converted land is entered into the new land use category (e.g. forest land). This differentiation reflects that on newly converted areas often other processes and management apply.

A.6.4 Driving forces and exogeneous model variables

FABio-Land is explicitly driven by assumed projected area transitions between land use categories and assumptions on the timing and extension of specific land management activities on the areas. Management changes such as changes in the intensity of forest management, introduction of short rotation plantations on cropland etc. result in altered emission factors for the respective land use categories.

Implicitly assumed are policies that are incentivizing changes in land management, such as payments for ecosystem services or rewetting of organic soils used for crop production. They drive change in the behavior of land managers. Demand for agricultural crops is considered by the agriculture model that provides constraints for required cropland and grassland areas.

Biomass production is not an exogenous variable to the FABio-Land model but is estimated by the area available for biomass supply. The model estimates the amount of biomass from cropland areas (short rotation plantations), from forests (fellings for timber production, fuelwood, and primary forestry residues), as well as wood waste, i.e. recovered post-consumer wood. The latter is considered constant over time.

A.6.5 Representation of actors in the model

FABio-Land considers assumptions on farmers' and foresters' activities on land management, i.e. on how land is used and for what products. Their activities are embedded in land use policies that constrain land conversion and management changes. Forestry and agriculture markets also influence land management to some degree.

Therefore, emissions and removals estimated by FABio-Land are not directly controlled by forest owners and farmers. It is the complex interaction of land managers (often not the owners of the land), policies, market forces and natural processes that are affecting the results. These influencing factors are recorded in historic data of GHG emissions and removals in the sector.

However, their individual contributions cannot be differentiated in the reported data and therefore also not explicitly modelled in projections.

Table 32: Actors considered in the model FABio-Land

Description of actors	Is considered how?
Explicitly: land management assumptions	Drivers of area changes for different land reporting categories and changes in land management, reflected by changes in emission factors for each category
Implicitly: Farmers and forest owners differentiated by land reporting categories	Homogenous groups in each land reporting category and homogenous across EU countries
Implicitly: Land use policies and demand for agricultural goods and forestry products	Reflected in historic development of land area development used as basis for the projection and in measures addressing changes of land-use management

A.6.6 Activities of the sector addressed by the EU Taxonomy

The EU Taxonomy addresses the following activities attributed to the LULUCF sector:

- Afforestation. The EU Taxonomy defines afforestation as the establishment of forest through planting, deliberate seeding or natural regeneration on land that was under a different land use or not used. The most relevant contribution criteria are 1) an afforestation plan, 2) a climate benefit analysis, and 3) a guarantee of permanence. In FABio-Land the activity is considered as a transformation of land use from a non-forest category (e.g. cropland) to the forest category. Afforestation is implemented by either the public or private owner of the land area. It can also occur naturally, following the abandonment of agricultural use of land.
- Rehabilitation and restoration of forests. The definition of the EU Taxonomy also includes activities of reforestation and natural forest regeneration after an extreme event. Compared to afforestation, this activity does not imply a change in land use but a restoration of the forest cover on formerly forested areas. The most relevant contribution criteria are 1) a management plan, 2) a climate benefit analysis, and 3) a guarantee of permanence. The activity is not considered by FABio-Land because natural disturbances and forest degradation are not explicitly modelled.
- Conservation forestry. This activity includes forest management activities with the objective of preserving one or more habitats or species. As restoration, conservation forestry assumes no change in land category and occurs on land. The most relevant contribution criteria are 1) a management plan, 2) a climate benefit analysis, and 3) a guarantee of permanence. Conservation forestry is an activity of private and public forest owners. The activity is not explicitly considered in FABio-Land because fit does not differentiate explicitly between protected and unprotected areas. The activity can be modelled implicitly by constraining wood supply from forest areas.
- Forest management. This activity corresponds to any economic activity resulting from a system applicable to a forest that influences the ecological, economic or social functions of the forest. The most relevant contribution criteria are 1) a management plan, 2) a climate benefit analysis, and 3) a guarantee of permanence. Forest management assumes no change

in land use. It is carried out by forest managers that can be owners of the land or manage the forest based on contracting and concessions. The activity is considered in the model FABio-Land.

- Restoration of wetlands. The EU Taxonomy defines wetland restoration as economic activities that promote a return to original conditions of wetlands and economic activities that improve wetland functions without necessarily promoting a return to pre-disturbance conditions. The most relevant contribution criteria are 1) a restoration plan, 2) a climate benefit analysis, and 3) a guarantee of permanence. It is unclear whether the activity implies a land-use change, as rewetted land can sometimes still be used for agricultural activities, e.g. paludiculture on cropland. It is carried out by private and public owners of the land. The activity is considered in the model FABio-Land.

Table 34 below presents an overview of the activities and their consideration in the model. Restoration activities are not considered by FABio-Land. Conservation forestry can only be considered implicitly.

When looking at the detailed contribution criteria to be considered for compliance with the EU Taxonomy in the land sector (Table A.6.3), there are uncertainties about the share of the activities which could potentially meet the criteria. While management plans are likely to be in place for most forestry activities, climate benefit analyses are not typically included in forestry planning. This is the case for activities that are related to the voluntary carbon market where such requirements, depending on the standards applied, often exist already.

In FABio-Land there is no differentiation between public and private landowners. The differentiation is relevant for the EU Taxonomy that addresses private companies. However, a large share of land sector mitigation activities in the scenarios are expected to be implemented by public owners, such as national state, Federal state actors, or communities.

Table 33: Activities of the EU Taxonomy in the forestry sector

Number	Activity	Example actor	Activity considered in model?
CCM 1.1	Afforestation	Public or private landowners	Yes
CCM 1.2	Rehabilitation and restoration of forests, including reforestation and natural forest regeneration after an extreme event		No
CCM 1.3	Forest management	Forest managers, concession holders, public or private landowners	Yes
CCM 1.4	Conservation forestry	Public or private landowners	(No)
CCM 2.1	Restoration of wetlands	Public or private landowners	Yes

A.6.7 Approach to the analysis of EU Taxonomy alignment

Table 34: Approach to the analysis of EU Taxonomy alignment in the forestry sector

No.	Activity	Contribution criteria considered	Contribution criteria outside scope	Relates to model variable	Evaluation approach
CCM 1.1	Afforestation	Afforestation plan		None	Is required by many national land use policies in case of intended land use change. Could be assumed for 100% of activities
		Climate benefit analysis		None	Is included in voluntary carbon market projects. Could be assumed for activities under a voluntary carbon market scheme. Share of forest land affected unknown.
		Guarantee of permanence		None	Is given by national forest laws. Could be assumed for 100% of activities
		An audit is required		None	Is included in voluntary carbon market projects. Could be assumed for activities under a voluntary carbon market scheme. Share of forest land affected unknown.
CCM 1.3	Forest management	Forest management plan		None	Is required by many national forest laws for larger owners. Could be assumed for 100% of activities
		Climate benefit analysis		None	Is typically not part of forest management plan. Share of forest land affected unknown.
		Guarantee of permanence		None	Can be challenging for some activities under climate change. Share of forest land affected unknown.
		Audit		None	Is often required if subsidies are being received. Share of forest land affected unknown.
CCM 1.4	Conservation forestry	A forest management plan		None	Is required by many national forest laws for larger owners. Could be assumed for 100% of activities
		Climate benefit analysis		None	Is part of management plan. Could be assumed for 100% of activities
		Guarantee of permanence		None	Can be challenging for some activities under climate change. Share of forest land affected unknown.

No.	Activity	Contribution criteria considered	Contribution criteria outside scope	Relates to model variable	Evaluation approach
		Audit		None	Is required if part of payment scheme. Share of forest land affected unknown.
CCM 2.1	Restoration of wetlands	Restoration plan		None	Is required by land use policies. Could be assumed for 100% of activities
		Climate benefit analysis		None	Is often part of restoration projects. Could be assumed for 100% of activities
		Guarantee of permanence		None	Is assumed to be provided by national laws. Could be assumed for 100% of activities
		Audit		None	Is often required if subsidies are being received. Could be assumed for 100% of activities

A.6.8 Results of the EU Taxonomy alignment analysis

Due to the limitations described above, no taxonomy alignment analysis was carried out for this sector.

A.7 Waste – Model Waste_Mod

A.7.1 Classification of the model

Analytical model for emission development in CRF category 5, consisting of different modules for each of the subcategories.

A.7.2 Short technical description

1. 5.A: Solid waste disposal:
    a. IPCC Waste Models used for larger countries
    b. Use of Eurostat data on waste treatment on Member State level to implement changes in waste treatment routes
2. 5.B: Biological treatment of solid waste
    a. Use of Eurostat data on waste treatment on Member State level to implement changes in waste treatment routes
3. 5.C: Incineration and open burning of waste (outside energy supply sector)
    a. Emissions from waste incineration for power & heat generation are not reported in this category, they are treated in the energy supply sector.
    b. Use of Eurostat data on waste treatment on Member State level to implement changes in waste treatment routes
    c. Only a few countries use uncoupled incineration and open burning.
4. 5.D: Wastewater treatment and discharge
    a. Activity variables and emission factors are combined with population development and extrapolated using assumptions on technical development, depending on underlying scenario.
    b. Countries with similar characteristics are grouped together in the assessment.
5. 5.E Other
    a. Only a few countries report data in this category. Historical emissions are extrapolated using population development

A.7.3 Subsectors considered in the model

The model is structured along the 5 subcategories of CRF category 5 in the GHG inventories as described above:

1. 5.A: Solid waste disposal

2. 5.B: Biological treatment of solid waste
3. 5.C: Incineration and open burning of waste (outside energy supply sector)
4. 5.D: Wastewater treatment and discharge
5. 5.E Other

A.7.4 Driving forces and exogeneous model variables

The following driving forces are considered in modelling the waste sector:

- Historic developments and resulting emissions influence future emissions through ongoing organic processes
- Waste policies on landfilling and recycling and wastewater management influence the development of emissions in the waste sector
- The development of population directly influences the amount of waste and wastewater formed and thus in the necessity of treatment
- Amounts of industrial waste can be influenced by industrial activity and thus GDP development, however, this coupling is not implemented in the model.

A.7.5 Relevant variables of the model for EU Taxonomy alignment analysis

- Waste treatment – recycling, land filling, biological treatment
- Emission factors change over time and could be used for an assessment of the successful implementation of measures.

A.7.6 Representation of actors in the model

No single actors are explicitly considered in the model since the model treats each EU member state as one entity with no further subdivisions into lower levels.

There are actors whose actions influence the developments represented in the model. For the developments to take place, it can be implicitly assumed that the actors will have to behave in a specific way, e.g. along with the rules laid out in the EU Taxonomy. These actors are listed and discussed in the following table.

Table 35: Actors considered in the model Waste_mod

Description of actor	Is considered how?
Municipal waste collection and treatment companies	Not directly modelled, their actions are reflected in the developments modelled. Companies are assumed to comply with EU and national regulations.
Municipal wastewater treatment	Not explicitly modelled, their actions are implicitly represented in the model. Companies are assumed to comply with EU and national regulations.
State owned companies or companies directly working for the municipality	Optimization of private companies to earn money is not modelled, they are assumed to comply with regulations.
Recycling companies	Not directly considered in the model. Their actions are considered implicitly since recycling can reduce the amount of waste in landfills and treated in MBT facilities.

A.7.7 Activities of the sector addressed by the EU Taxonomy

Table 36: Activities of the EU Taxonomy in the waste sector

Number	Activity	Example company	Activity considered in model?
CCM 5.1	Construction, extension and operation of water collection, treatment and supply systems	Municipal entities or companies working as contractors for those entities	Implicitly assumed to be the case in the model, but not explicitly model, energy demand is not part of this model
CCM 5.2	Renewal of water collection, treatment and supply systems	Municipal entities or companies working as contractors for those entities	Implicitly assumed to be the case in the model, but not explicitly model, energy demand is not part of this model
CCM 5.3	Construction, extension and operation of wastewater collection and treatment	Municipal entities or companies working as contractors for those entities	Possibly also for other criteria: per se covered, energy demand is not covered in the waste model. Likely energy demand in buildings model but not linked and therefore out of scope
CCM 5.4	Renewal of wastewater collection and treatment	Municipal entities or companies working as contractors for those entities	Implicitly assumed to be the case in the model, but not explicitly model, energy demand is not part of this model

Number	Activity	Example company	Activity considered in model?
CCM 5.5	Collection and transport of non-hazardous waste in source segregated fractions	N/A	Not part of the model
CCM 5.6	Anaerobic digestion of sewage sludge	Municipal entities or companies working as contractors for those entities	Yes
CCM 5.7	Anaerobic digestion of bio-waste	Municipal entities or companies working as contractors for those entities	Yes
CCM 5.8	Composting of bio-waste	Municipal entities or companies working as contractors for those entities Private individuals	Yes
CCM 5.9	Material recovery from non-hazardous waste	N/A	Not part of the model
CCM 5.10	Landfill gas capture and utilization	Municipal entities or companies working as contractors for those entities	Yes
CCM 5.11	Transport of CO_2	N/A	Not part of the model
CCM 5.12	Underground permanent geological storage of CO_2	N/A	Not part of the model

A.7.8 Approach to the analysis of EU Taxonomy alignment

Table 37: Analysis of EU Taxonomy alignment in the waste sector

No.	Activity	Contribution criteria considered	Contribution criteria outside scope	Relates to model variable	Evaluation approach
CCM 5.6	Anaerobic digestion of sewage sludge	2 (produced biogas is captured and used)	Monitoring plan	Not modeled directly. Emission factors of wastewater treatment are reduced by	Implicit assumption: emissions are falling, so biogas is treated and not emitted. Emission factor drops.

No.	Activity	Contribution criteria considered	Contribution criteria outside scope	Relates to model variable	Evaluation approach
				capture of biogas to be used elsewhere.	However, other factors like connection rate to sewage system also influence emissions from wastewater treatment. Since detailed data on different factors is not available, only a combined quantitative assessment of all measures implemented in wastewater treatment is possible
CCM 5.7	Anaerobic digestion of bio-waste	2 (produced biogas is captured and used), 3 (bio-waste is source segregated and collected separately)	Monitoring plan	Model contains information on amounts of biowaste collected separately and treated in biogas plants.	Higher amounts of biowaste collected and treated separately lead to higher emissions in this category (CRF 5.B). Share of fermentation vs. composting influences emission factors.
CCM 5.8	Composting of bio-waste	1 (bio-waste is source segregated and collected separately)	Compost use	Model contains information on amounts of biowaste collected separately and composted.	See CCM 5.7
CCM 5.10	Landfill gas capture and utilization	3 Landfill gas is captured to be used elsewhere	Information on Landfill operation times. Monitoring.	Capture of landfill gas to be used elsewhere reduces emissions from landfills.	Increase in landfill gas capture is reflected in the model

A.7.9 Results of the EU Taxonomy alignment analysis

The taxonomy criteria for the waste sector are mostly included implicitly in the model. In scenarios where emission factors are improving and emission reductions are achieved; the criteria will be met in the model. However, the scope of the model does not cover all aspects listed in the criteria for taxonomy alignment. It is thus not possible to provide an absolute ranking of taxonomy alignment for the criteria included in the assessment. The ranking provided in the tables below for the three scenarios is thus a relative compliance ranking, comparing the three scenarios and the temporal development within the scenarios. To indicate this, (R) is given in brackets behind the assessment.

For activities CCM5.7 and CCM5.8, concerning anaerobic digestion and composting of bio-waste, the overall amount of bio-waste collected separately is increasing over time, indicating efforts in waste collection in all three scenarios. While in the EUBase scenario, the share of composted bio-waste is higher than the amount of bio-waste undergoing anaerobic digestion, this changes for the EUTarget scenario and is even more pronounced in the EUSupreme scenario. This development is to be considered positive, since increased anaerobic digestion of bio-waste allows for the resulting methane gas to be used for energy generation.

A similar development can be observed for landfill gas capture and utilization, the rates are increasing over time in the EUBase scenario, but the more ambitious scenarios EUTarget and EUSupreme show higher rates of landfill gas capture. This allows for this gas to be used in energy generation.

Generally, it can be observed that in the EUBase scenario, which follows current EU policies, the alignment of the development in the waste sector with taxonomy criteria is good. In the scenarios EUTarget and EUSupreme, where a higher level of ambition in terms of emission reductions is implemented, the criteria set out in the taxonomy are met at an even higher rate. Close alignment with taxonomy criteria thus supports a climate-friendly development of the waste sector.

Table 38: EU Taxonomy EU Taxonomy alignment in the waste sector for the scenario EUBase

Activity	Criterion	2030	2040	2050
CCM5.7	Anaerobic digestion of bio-waste	Limited compliance (R) 19.9 Mt dry matter	Medium compliance (R) 24.0 Mt dry matter	Medium compliance (R) 23.4 Mt dry matter
CCM5.8	Composting of bio-waste	Medium compliance (R) 33.8 Mt dry matter	Medium compliance (R) 33.2 Mt dry matter	Medium compliance (R) 32.3 Mt dry matter
CCM5.10	Landfill gas capture and utilization	Limited compliance (R) 31%	Limited compliance (R) 32%	Limited compliance (R) 33%

Table 39: EU Taxonomy alignment in the waste sector for the scenario EUTarget

Activity	Criterion	2030	2040	2050
CCM5.7	Anaerobic digestion of bio-waste	Limited compliance (R) 22.0 Mt dry matter	Medium compliance (R) 27.1 Mt dry matter	Medium compliance (R) 31.0 Mt dry matter
CCM5.8	Composting of bio-waste	Medium compliance (R) 33.0 Mt dry matter	Medium compliance (R) 29.1 Mt dry matter	Medium compliance (R) 23.9 Mt dry matter
CCM5.10	Landfill gas capture and utilization	Medium compliance (R) 36%	Good compliance (R) 42%	Good compliance (R) 47%

Table 40: EU Taxonomy alignment in the waste sector for the scenario EUSupreme

Activity	Criterion	2030	2040	2050
CCM5.7	Anaerobic digestion of bio-waste	Medium compliance (R) 28.9 Mt dry matter	Good compliance (R) 34.7 Mt dry matter	Good compliance (R) 40.2 Mt dry matter
CCM5.8	Composting of bio-waste	Medium compliance (R) 28.9 Mt dry matter	Medium compliance (R) 23.1 Mt dry matter	Medium compliance (R) 17.2 Mt dry matter
CCM5.10	Landfill gas capture and utilization	Medium compliance (R) 36%	Good compliance (R) 42%	Good compliance (R) 47%