Institute for Sustainable Futures

One Earth Climate Model 2024

Science-based Target Setting for the Finance Industry

Implementation of the EU Taxonomy with GICS based Net-Zero Sectoral 1.5°C Pathways for Real Economy Sectors

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The Institute for Sustainable Futures (ISF) was established by the University of Technology Sydney in 1996 to work with industry, government, and the community to develop sustainable futures through research and consultancy. Our mission is to create change toward sustainable futures that protect and enhance the environment, human wellbeing, and social equity. We seek to adopt an inter-disciplinary approach to our work and engage our partner organisations in a collaborative process that emphasises strategic decision-making.

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All conclusions and any errors that remain are the authors' own.

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The latest available scientific information is contained in the International Panel on Climate Change's (IPCC's) Sixth Assessment Report Climate Change 2021: The Physical Science Basis [1]. According to the IPCC definition, 67% likelihood of a 1.5°C increase in global temperature is 'good', whereas 50% likelihood is 'fair'. The One Earth Climate Model (OECM) aims to limit the global mean temperature rise to 1.5°C with 'good' likelihood. Therefore, the 'science-based target' for the OECM 1.5°C pathway, in terms of the global carbon budget between 2020 and 2050, is set between 400 Gt CO_2 (67% likelihood) and 425 Gt CO_2 (60% likelihood). The development of sectoral targets to meet the requirements of specific countries or industries will ensure that the sum of all energy-related CO_2 emissions for all countries or industry sectors does not exceed the global budget. Therefore, any approach undertaken in isolation, such as for a single industry sector, will involve the risk that one industry sector will demand a high CO_2 budget and push the responsibility to reduce CO_2 emissions onto other sectors.

The One Earth Climate Model

The OECM is an integrated energy assessment model that was originally developed in an interdisciplinary research project between the University of Technology Sydney (UTS), the German Aerospace Centre (DLR), and the University of Melbourne between 2017 and 2019. The task was to develop detailed 1.5°C-targeting energy-related greenhouse gas (GHG) emissions trajectories for 10 world regions. OECM 1.0 was developed based on established DLR and UTS energy models.

Based on the OECM, the Institute for Sustainable Futures, UTS (UTS/ISF), in close co-operation with the UN-convened Net Zero Asset Owners Alliance, developed the advanced One Earth Climate Model (OECM 2.0), which has been applied to all member states of the G20 and the EU27 region, to develop energy scenarios and fair carbon budgets for each country, as well as detailed carbon budgets for key industries in each country.

The Global Industry Classification Standard (GICS) was used in OECM 2.0 to allow the design of energy and emissions pathways for clearly defined industry sectors (sectoral pathways). Developing pathways via which to reduce the CO_2 emissions of industry sectors requires very high technical resolution in the calculation and projection of the future energy demand for and supply of the electricity, (process) heat, and fuels that are necessary for (for example) the steel and chemical industries. An energy model with high technical resolution must be able to calculate the energy demand based on either projections of the sector-specific gross domestic product (GDP) or market forecasts of material flows, such as the demand for steel, aluminium, or cement in tonnes per year.

Carbon budget for the EU27 member states

The EU27 carbon budget of about 32 $GtCO_2$ (2020–2050) has been broken down further by developing an OECM 1.5°C pathway for each of the member states. The scenario data for all individual countries are available on the open-access project webpage (www.uts.edu.au/oecm). In this section, we present the distribution of the EU27 carbon budgets. Figure E1 shows the carbon budget for each country between 2020 and 2050 in million tonnes of carbon dioxide (CO_2) and each country's share (as a percentage) of the overall EU carbon budget of 32.1 $GtCO_2$.

The CO_2 budgets must be related to the population shares within the European Community to ensure the fairness of this distribution.

1 IPCC (2021) Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Edited by S.L. Masson-Delmotte, V., P. Zhai, A. Pirani, J.B.R. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, and B.Z. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu. Cambridge University Press. Available at: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Full_Report.pdf

The ratio of the CO_2 budget share to the population share is similar across most EU countries, within a ± 20% margin. However, some countries emit significantly higher proportions of global CO_2 relative to their populations, whereas others emit lower proportions.

The 'high-carbon' countries, with carbon budgets 30%–50% greater than their population shares, are Cyprus, Czechia, Finland, Luxembourg, the Netherlands, and Poland.

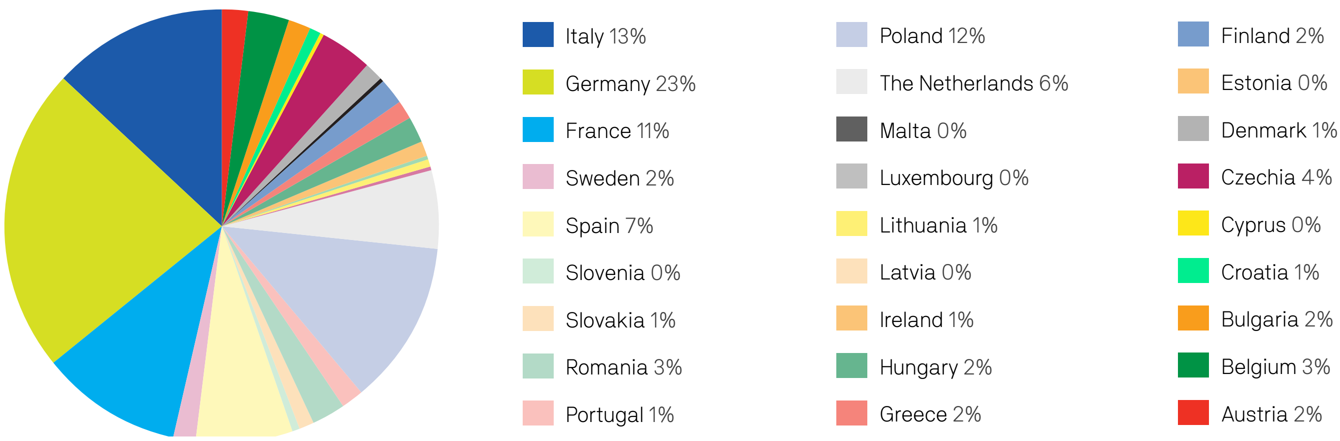
Cyprus has an extremely carbon-intensive power-generation mix, based almost entirely on diesel and oil generators. This is not only the most polluting fossil-fuel-based technology for electricity generation but also one of the most expensive. The transition to renewables-based generation – mainly solar photovoltaic – with battery storage is expected to take more than 10 years, which explains the high carbon budget of Cyprus. Power generation in Czechia and Poland is heavily dependent on coal. Therefore, both countries start with a carbon-intensive power supply that significantly exceeds the EU average. Luxembourg and Finland have very high per capita GDPs, and relatively high energy demands per capita as well. The Netherlands has a significant chemical industry, which is a very energy-intensive industry.

The carbon shares of Germany and Italy are within ± 15% of their population shares, so they represent countries with balanced carbon budgets.

Portugal has among the lowest carbon budgets relative to its population size due to its already large share of renewable power generation.

Figure E1: EU27 – the remaining carbon budget and its distribution by member states

Remaining carbon budget EU27: 32.1GtCO_2 (2020-2050) distribution by member state – country CO_2 budgets in MtCO_2 (2020-2050)



The OECM takes the current situation of the energy demands for industries and service-based economies, the building stock, and the transport sector of each country into account and includes the status quo of the energy supply. Therefore, the carbon budgets of economies with already low carbon intensities will be smaller. However, this is not a disadvantage, but actually an advantage insofar as those countries are ahead on the road to decarbonisation of countries with higher carbon intensities. Therefore, the energy transition of advanced countries and their decarbonisation can be reached more rapidly.

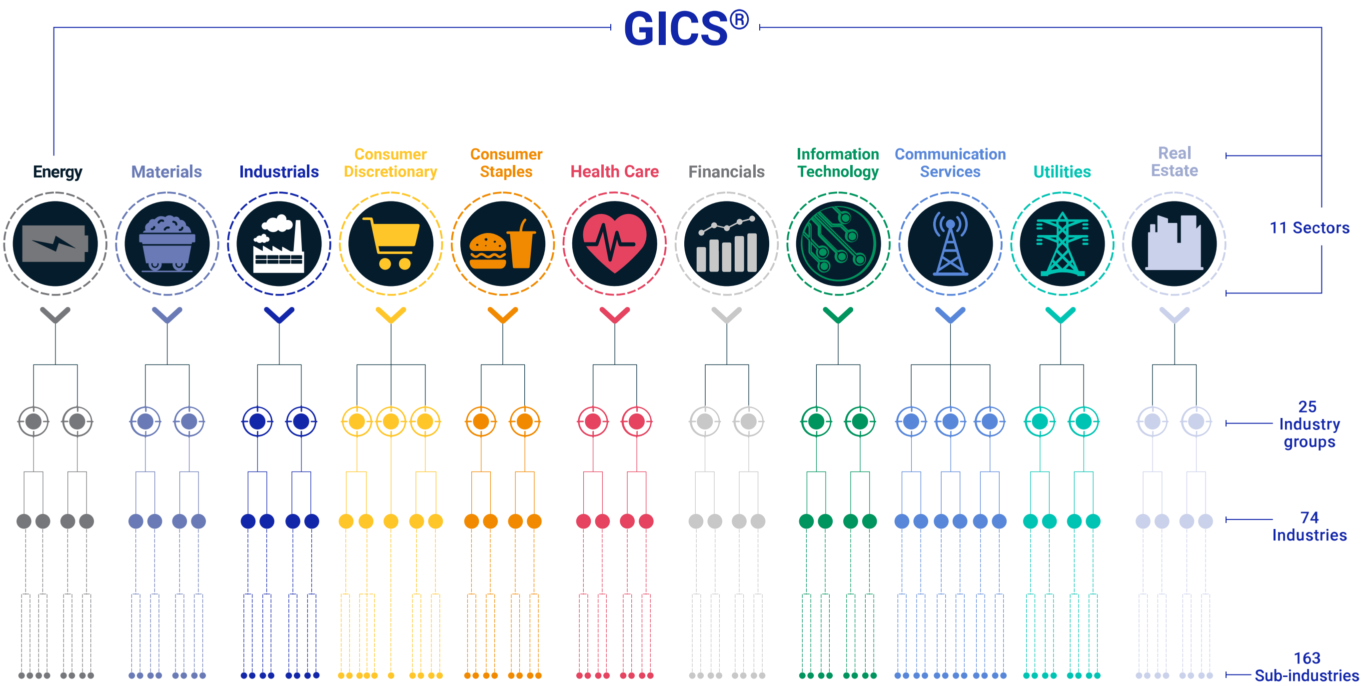
The results of the OECM scenario for the EU27 (as a region) are compared with the EU Taxonomy. The following sections document a detailed analysis of the EU Taxonomy and how the OECM pathways can be utilised to implement and advance it in the future.

The EU taxonomy and the One Earth Climate Model

The EU Taxonomy was introduced as a classification system to help companies and investors classify sustainable investment decisions. It does not set mandatory targets, but companies falling under the Corporate Sustainability Directive (CSRD) must disclose their alignment with the Taxonomy in their annual reports.

In this research, we present the congruence between the current European Taxonomy and the 1.5°C pathways of the OECM, to provide decarbonisation pathways for real economic sectors. By integrating OECM data with the EU Taxonomy, we aim to help EU member states set ambitious targets to meet a 1.5°C global temperature increase and to improve the reporting of their achievements, and to develop an international context for countries outside the EU.

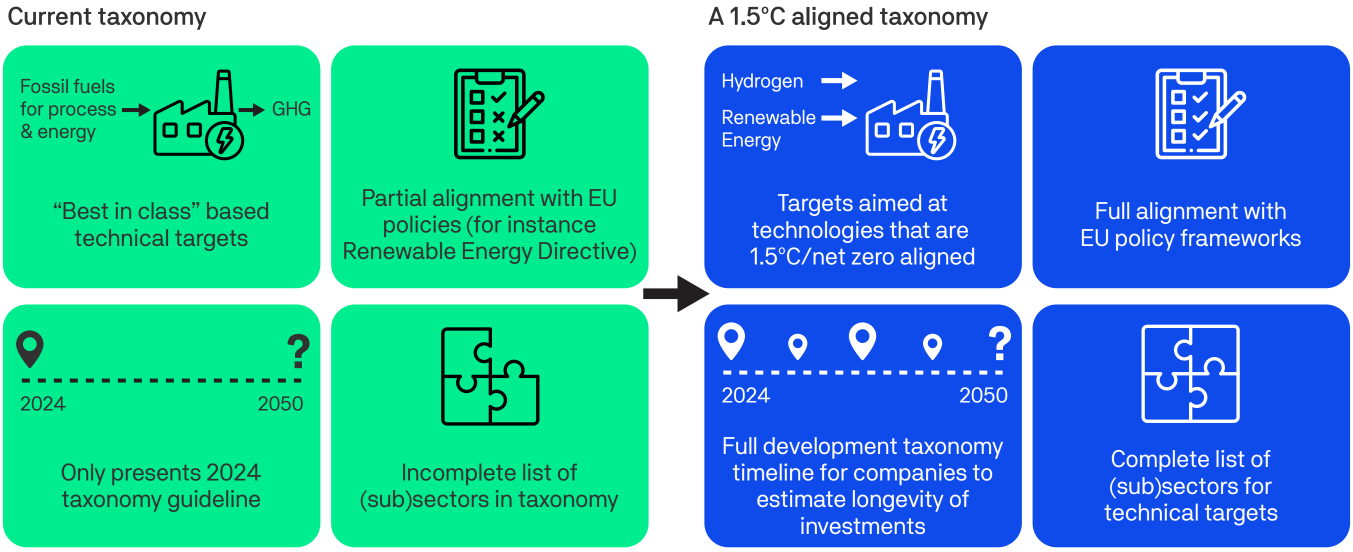
Figure E2: Overview of the Global Industry Classification Standard (GICS). MSCI (2024)



To achieve this goal, the EU Taxonomy targets were systematically categorised within the framework of the GICS (Figure E2). Previous work has matched the GICS classes and the OECM 1.5°C pathways.

As a result of this study, key strategies have been identified to 'future proof' the EU Taxonomy and make it capable of supporting a truly sustainable 1.5°C energy pathway that is compatible with the Paris Climate Agreement.

Figure E3: Comparison of content covered in the EU Taxonomy (current taxonomy) and a taxonomy compatible with the Paris Agreement (1.5°C-aligned), as outlined in the One Earth Climate Model (OCEM)



EU taxonomy – Economic Activities

The EU Taxonomy consists of 16 industry sectors and 150 economic activities and is numbered according to the industry standard classification system (NACE system). Some industry sectors have only a single defined economic activity, e.g., Education, whereas other industry sectors have many activities associated with them. Sectors with the largest numbers of defined economic activities include Energy, with 31 economic activities; Manufacturing, with 26 economic activities; and Transport, with 23 economic activities.

To allocate the Taxonomy Economic Activities (TEA) to the GICS sectors, the numbering of the TEA has been greatly simplified. The first number describes the alphabetical order of the main TEA sector, and the number after the dot is the serial number of the associated economic activity. Based on the TEA allocation to all GICS sectors documented in Section 3, the economy-wide coverage of the TEA is calculated. This calculation provides an estimate of the entire coverage of specific economic activities relative to the overall economic activity. Based on these data, the GHG emissions covered by the TEA are calculated. Two examples are given below.

Taxonomy Economic Activities that cover an entire GICS class: The total GDP of the EU27 in 2020 was US$15.1 trillion. As a contributing component, GICS class 55 Utilities accounted for around US$800 billion. The economic activities defined under the EU Taxonomy that were allocated to the GICS 55 Utilities sector cover all the economic activities of this class. Therefore, 100% of the Utilities sector is covered by the EU Taxonomy in terms of both its economic value (in US$) and the emissions for which it is responsible in tonnes of CO_2 per year.

Taxonomy Economic Activities that do not cover an entire GICS class: Sector 30 Consumer Staples contributed around US$850 billion (5.6%) to the entire GDP of the EU27 in 2021. The economic activities defined under the EU Taxonomy that were allocated to the GICS sector 30 Consumer Staples covered only a small fraction of the sector. Within the entire GICS class 30, only '302020 2010 Agricultural Products' was allocated by the TEA. The economic value attributed to this sub-sector was US$331 million – 2% of the overall value of GICS class 30. Therefore, 2% of the annual CO_2 emissions of GICS 30 Consumer Staples was allocated by TEA. Like GICS class 30, many sectors are yet to be fully defined by their economic activities in the EU Taxonomy.

Calculation method used to determine the economy-wide coverage of TEA

Table 1 provides the summary results of the analysis of the economy-wide coverage of TEA. The following list identifies the content of the table (by columns) and explains the calculation method:

- **Column A:** Name of the GICS class
- **Column B:** Coverage of TEA by GICS class – red, no coverage; green, high coverage
- **Column C:** Number of TEA allocated to 8-digit GICS sectors for each 2-digit GICS class
- **Column D:** Shares of TEA allocated to 8-digit GICS sectors for each 2-digit GICS class
- **Column E:** Total value of all 8-digit GICS sectors that are covered by TEA within the 2-digit GICS class
- **Column F:** Total share of economic value covered by TEA within a 2-digit GICS class
- **Column G:** Total energy-related CO_2 emission covered by TEA within a 2-digit GICS class
- **Column H:** Total share of energy-related CO_2 emission covered by TEA within a 2-digit GICS class
- **Column I:** Economic value of the 2-digit GICS class
- **Column K:** Energy-related CO_2 emission of the 2-digit GICS class
- **Column L:** Assignment of the GICS class – supply (primary and secondary energy) or demand (end-use).

The calculation of the emissions in column G is based on the emissions in column k and the economic coverage of the TEA in column F.

Table 1: Economic-wide coverage of the Taxonomy Economic Activities regarding GDP and total energy-related CO_2 emissions – for 2020

A	B	C	D	E	F	G	H	I	K	L
GICS		Economic Activities (TEA) Number & coverage		GDP share of GICS sector covered by Taxonomy Economic Activities		Energy-related CO_2 covered by allocation of the TEA		GDP by GICS class	Energy-related CO_2 by GICS sector	
		[1]	[%]	[million $]	[%]	[$MtCO_2$/a]	[%] of total emissions	[million $]	[$MtCO_2$/a]	
10 Energy		3	2%	2,497	0.02%	0.39	0.02%	33,207	2,518	Primary
55 Utilities		55	36%	804,456	5.04%	70.18	5.04%	804,456	1,391	Secondary
Supply		58	38%	806,953	5.06%					Supply
15 Materials		16	11%	913,058	5.73%	19.64	5.73%	1,607,092	343	End-use
20 Industrials		48	32%	1,615,494	10.13%	68.23	10.13%	3,033,857	674	
25 Consumer Discretionary		9	6%	193,799	1.22%	1.88	1.22%	1,496,348	155	
30 Consumer Staples		1	1%	331,556	2.08%	2.70	2.08%	850,753	130	
35 Health Care		3	2%	215,801	1.35%	1.46	1.35%	1,034,875	108	
40 Financials		2	1%	185,833	1.17%	1.00	1.17%	1,765,410	86	
45 Information Technology		10	7%	168,923	1.06%	2.62	1.06%	731,999	247	
50 Communication Services		3	2%	198,070	1.24%	4.28	1.24%	990,352	345	
60 Real Estate		1	1%	199,984	1.25%	4.84	1.25%	3,599,714	386	
End-use		93	62%	4,022,518	26.62%	106.644	4.31%	15,110,400	2,473	
Total		151	100%	4,829,471	30.35%	176.827	7.2%		2,473	

Based on this methodology – and if the EU Taxonomy were fully implemented for the entire EU economy – the economic activities defined by the EU Taxonomy would cover 30% of the EU's GDP, but would only cover 7.2% of all the energy-related CO_2 emissions of the European Community (EU27).

Key actions required to align the current EU taxonomy with 1.5°C pathways

1. Improve the technology targets to steer towards long-term sustainable investments

The current EU Taxonomy is largely based on a "best-in-class" approach: economic activities focus on the most efficient performers in the current state of the industry. The EU Taxonomy, as it is currently set up (based on 2024 data), does not consider the contributions of disruptive technologies in manufacturing processes, such as in the chemical industry, that will be required to achieve the 1.5°C target. Companies and investors require visibility in the technology targets up to 2050, so that investments made today will result in industry assets with lifetimes that extend to 2050.

2. Align the Taxonomy with existing EU policies

In the EU, there is an existing framework for sustainability policy, which is leading the global stage. Currently, the EU Taxonomy only partly accommodates the sustainability guidelines from other policy frameworks, including policies captured in the 'Fit for 55' policy packages, such as (but not limited to) [2]:

- Renewable Energy Directive (promotes the shift towards renewable electricity)
- Energy Efficiency Directive (promotes improvements in final energy consumption)
- European Green Deal (promotes the circular economy, with a focus on materials and resources)
- ReFuel EU Aviation (promotes the shift to sustainable aviation fuels to reduce emissions in the aviation sector).

The harmonisation of policies, regulations, and directives will create a more complete and more accurate EU Taxonomy.

3. Develop a taxonomy timeline

A complete timeline of taxonomy targets will allow companies and investors to steer assets towards long term financial investments and will avoid stranded assets and wasting assets.

4. Complete the taxonomy for all (sub)sectors

Some sectors are only partially covered in the current EU taxonomy. An illustrative example is the chemical sector where only 5 chemical feedstocks (hydrogen, ammonia, ethylene, propylene and chlorine) have been partly but other parts of the chemical industry – such as electrical steam cracker that can be operated by renewable electricity – are not even mentioned.

2 European Green Deal Renewable Energy Directive (), Energy Efficiency Directive, ReFuel EU Aviation (promotes shift to sustainable aviation fuels to reduce aviation emissions), and the FulEU Maritime Regulation (promotes the use of renewable, low-carbon bunker fuels and clean energy technologies for the shipping sector).

Recommendation

The EU Taxonomy provides a framework with which to capture and assess the GHG emissions from sectors across the EU economy. These sectors range from industry to the service and transport sectors, including sub-sectors. The EU Taxonomy offers an opportunity to monitor, encourage, and innovate operational and strategic changes at the sector level, which are required to shift towards more sustainable energy use, resourcing, and long-term financial decisions (Pettingale et al., 2022)[3].

This report has assessed the EU Taxonomy framework by comparing it with other quantitative models that capture economic activities and calculate CO_2 emissions on a sector-by-sector basis. As a result, we have identified knowledge gaps and provides suggestions on how to improve the assessment of GHG emissions from a sector perspective. The OECM has been used as the key reference tool for this comparison. The OECM has been selected for its highly ambitious emissions reduction target – it assesses sector-based transitions within the framework of the Paris Climate Agreement to limit the global temperature increase to well below 2°C above pre-industrial levels. Furthermore, the OECM provides a highly comprehensive and bottom-up database of energy consumption, energy intensities, and CO_2 emissions by economic activity, based on the global industry standard classification system (GICS), as used by the finance industry.

The rationale of this report is to ensure that the EU Taxonomy's assessment of the entire EU economy is as comprehensive and accurate as possible, including all (relevant) sub-sectors and the resulting GHG emissions, within a context that reflects developments in technology innovation and policy, and acknowledges the relevance of milestones. It highlights the urgency of decarbonising rapidly to reach net zero emissions by 2050.

We compare of EU Taxonomy sector benchmarks with the OECM sector decarbonisation pathways for 11 real economic sectors (GICS classes): Energy, Utilities, Materials, Industrials, Consumer Discretionary, Consumer Staples, Health Care, Financials, Information Technology, Communication Services, and Real Estate. Our findings show that for most sectors, the EU Taxonomy benchmarks align with the OECM pathways until 2030, but not beyond then (Table 2). After 2030, the EU Taxonomy benchmarks do not reach the values required to meet the OECM decarbonisation pathways, which are necessary to maintain the global temperature increases well below 2°C by 2050. Table 2 provides a summary of the alignment between the EU Taxonomy benchmarks and the OECM sector decarbonisation pathways across sectors.

3 Pettingale, H., de Maupeou, S, Reilly, P. (2022) EU Taxonomy and the Future of Reporting. FTI Consulting. https://corpgov.law.harvard.edu/2022/04/04/eu-taxonomy-and-the-future-of-reporting/

Table 2 Alignment of decarbonisation pathways based on carbon intensity benchmarks for energy-intensive sectors comparing EU Taxonomy and OECM

Sectors and sub-sector	Activity	Unit	EU Taxonomy vs. OECM sector decarbonisation pathways	EU taxonomy aligned with OECM until [year] 2025	2030	2050
Steel	Carbon intensity	[tCO_2e/tonne steel]	EU Taxonomy has two sets of emission intensities (climate mitigation and climate adaption). Mitigation benchmarks are aligned with OECM until 2025.	✅	❌	❌
Aluminium	Carbon intensity	[tCO_2e/tonne aluminium]	EU Taxonomy does not present benchmarks for bauxite (raw material for aluminium production); EU Taxonomy process emissions for aluminium are lower than those of OECM, but specific energy emissions are 3x higher than those of OECM.	⊖	⊖	❌
Cement	Carbon intensity	[tCO_2/tonne clinker OR cement]	EU Taxonomy has two sets of emission intensities for clinker and cement (climate mitigation and climate adaption). Mitigation benchmarks for clinker and cement are aligned with OECM until 2035, but not thereafter.	✅	✅	❌
Chemicals			EU Taxonomy coverage of the chemical sector is incomplete.			
- Hydrogen	Carbon intensity	[tCO_2e/tonne H2]	Both EU Taxonomy and OECM consider ammonia produced from renewable hydrogen sustainable. However, there is no long-term alignment of decarbonisation pathways until 2050.	✅	⊖	❌
	Carbon intensity		Organic chemicals in the base hydrocarbon category produced from renewable feedstock have lower carbon intensities than those manufactured from fossil fuels. The definition of 'sustainable biomass' for agricultural forest biomass is unclear.	✅	✅	❌
- Ethylene	Carbon intensity	[tCO_2e/tonne ethylene]	EU Taxonomy aligns with the OECM pathway. Phase-out of fossil-fuel-based ethylene production is required to reduce carbon intensity further. EU Taxonomy does not define a %-target or timeline (date) to shift to renewable feedstock.	✅	✅	❌
- Propylene	Carbon intensity		EU Taxonomy aligns with the OECM pathway. Phase-out of fossil-fuel-based propylene production is required to reduce carbon intensity further. EU Taxonomy does not define a %-target or timeline (date) to shift to renewable feedstock.	✅	✅	❌
- Ammonia	Carbon intensity	[tCO_2e/tonne NH3]	EU Taxonomy aligns with OECM pathway until 2035. EU Taxonomy does not shift to renewable feedstock after 2035.	✅	✅	❌
- Chlorine	Carbon intensity (electricity)	[gCO_2/a]	EU Taxonomy aligns with OECM pathway until 2025.	✅	❌	❌
Real estate/ Buildings	Carbon intensity	[$kgCO_2$/kWh]	EU Taxonomy aligns with OECM pathway until 2035.	✅	✅	❌
Transport						
- Aviation	Carbon intensity	[gCO_2/tkm]	EU Taxonomy align with OECM pathway until 2030. By 2040, a fuel switch from fossil to organic kerosine generated from renewable energy is required.	✅	✅	❌
-Shipping	Carbon intensity	[gCO_2/tkm]	EU Taxonomy aligns with OECM pathway until 2035. A fuel switch from fossil fuel to bio-fuel is required by 2040 to achieve carbon neutrality.	✅	✅	❌
- Road transport	Carbon intensity	[gCO_2/tkm]	EU Taxonomy aligns with OECM pathway until 2030. By 2040, passenger and freight transport will be electrified and will reach carbon neutrality.	✅	✅	❌
Energy Supply	Carbon intensity	[tCO_2/PJ]	EU Taxonomy aligns with RE Directive, which requires an increase in the renewables share to 42.5% by 2030. Therefore, the EU Taxonomy aligns with the OECM pathway until 2030, but not thereafter.	✅	✅	❌
Electricity	Carbon intensity (electricity)	[gCO_2/kWh]	EU Taxonomy aligns with the REPowerEU Plan, which requires an increase in the renewable electricity to at least 45% by 2030. This aligns the Taxonomy with the OECM pathway until 2030, but not thereafter.	✅	✅	❌

Legend:

✅ EU Taxonomy benchmark(s) and OECM pathway is **ALIGNED**

⊖ EU Taxonomy benchmark(s) and OECM pathway are **PARTIALLY ALIGNED**
(not all OECM parameters/sub-sectors are aligned, or covered by the Taxonomy)

❌ EU Taxonomy benchmark(s) and OECM pathway are **NOT ALIGNED**

This report has identified four key knowledge and policy gaps, and suggests the following corresponding actions (Table 3)

Table 3: Gaps identified during the comparison of the EU Taxonomy and the OECM and suggested actions

	Consideration	Gap	Suggested Action
1	**Technologies**	Currently, the EU Taxonomy considers a wide range of technologies, including the use of fossil fuels ('best in class' technologies)	The framework must ensure that the technologies used between now and 2050 are compatible with the Paris Climate Agreement and are aligned with 1.5°C decarbonisation pathways, including renewable electricity, renewable hydrogen, and other fuel sources, such as sustainable biofuels (while avoiding biodiversity loss).
2	**Policies**	Currently, the EU Taxonomy does not consider all key policies framing the EU energy transition.	The framework must ensure that all relevant sustainability, energy, climate, and other sector-specific policies are included. The overarching EU legislation – the 'Fit for 55' package – aims to reduce GHG emissions by at least 55% by 2030 relative to 1990 levels, and by 100% by 2050. Relevant sector-specific policies that provide the legislative pillars of the 'Fit for 55' package include the European Green Deal (focuses on material, resources, and circular economy), Renewable Energy Directive (focuses on renewable electricity), Energy Efficiency Directive (focuses on final energy consumption and improvements), ReFuel EU Aviation (promotes shift to sustainable aviation fuels to reduce aviation emissions), and the FulEU Maritime Regulation (promotes the use of renewable, low-carbon bunker fuels and clean energy technologies for the shipping sector). The harmonisation of the EU Taxonomy with sector-specific EU policies, directives, and regulations will result in a more comprehensive framework that can provide more-accurate guidelines for investors and companies.
3	**Temporal Dimension**	Currently, the EU Taxonomy does not consider the temporal milestones and dynamics of the energy transition.	The framework must ensure that it follows a strict timeline to support the energy transition. Key milestones and technology changes due to technological breakthroughs and innovations must be reflected in its structure. As an example, the phase-out of fossil fuels for the Energy and Transport sectors should be incorporated and highlighted. Following a strict timeline will improve the Taxonomy's accuracy, and more importantly, the milestones will guide sector-based capital investment and ultimately avoid stranded assets. A strict timeline will also highlight the Taxonomy's understanding of the need to transition rapidly, because any temporal delay will result in the greater accumulation of GHG emissions.
4	**Sub-sector Coverage**	Some sectors are only partially covered in the current EU Taxonomy. The Taxonomy for all (sub)sectors must be completed.	The breakdown of the industry, service, and transport sectors according to the GICS standard classification system shows that the limited granularity of the Taxonomy and the breakdown of sectors into sub-sectors results in the incomplete coverage of GHG emissions at the sector level. An example is the Chemical sector, for which the Taxonomy recognises only eight economic activities for a sector that covers a very large number of products (more than 10,000 products). The framework must ensure that the coverage of economic activities by sector strives for the highest accuracy as possible, ensuring there are no (sub)sector gaps.

These actions have broader implications for the EU Taxonomy, and will significantly increase:

- its relevance in the industry and policy space by demonstrating a deep understanding and consideration of the dynamics and pace that characterise the transition, including the impact of any temporal delays;
- the accuracy of its sector and sub-sector coverage of CO_2 emissions; and
- its longevity as a financial guidance instrument.

1 The one earth climate model – 1.5°C pathways for Europe

1.1 The Carbon budget and 1.5°C

The latest available scientific information is contained in the IPCC's Sixth Assessment Report *Climate Change 2021: The Physical Science Basis*[4]. According to the IPCC definition, 67% likelihood is 'good', whereas 50% likelihood is 'fair' (Table 4). The One Earth Climate Model (OECM) aims to limit the global mean temperature rise to 1.5°C with 'good' likelihood. Therefore, the 'science-based target' for the OECM 1.5°C pathway, in terms of the global carbon budget between 2020 and 2050, is set between 400 Gt CO_2 (67% likelihood) and 425 Gt CO_2 (60% likelihood).

Table 4: Carbon budget and likelihood of limiting global warming to temperature targets – IPCC AR6, 2021

Global warming between 1850-1900 and 2010-2019 [°C]		Historical cumulative CO_2 emissions from 1850 to 2019 [$GtCO_2$]					
1.07 (0.8-1.3: likely range)		2,390 (+/- 240; likely range)					
Approximate global warming relative to 1850-1900 until temperature limit [°C]	Approximate global warming relative to 2010-2019 until temperature limit [°C]	Estimated remaining carbon budgets from the beginning of 2020 [$GtCO_2$] Likelihood of limiting global warming to temperature limit					Variations in reductions in non-CO_2 emissions
		17%	33%	50%	67%	83%	Higher or lower in accompanying non-CO_2 emissions can increase or decrease the values on the left by 220$GtCO_2$ or more
1.5	0.43	900	650	500	400	300	
1.7	0.63	1,450	1,050	850	700	550	
2.0	0.93	2,300	1,700	1,350	1,150	900	

The development of sectoral targets to meet the needs of specific countries or industries will ensure that the global sum of all energy-related CO_2 emissions for all countries or industry sectors does not exceed the global budget. Therefore, any approach undertaken in isolation, such as for a single industry sector, will involve the risk that one industry sector will demand a high CO_2 budget and push the responsibility to reduce CO_2 emissions onto other sectors.

What is the international process regarding carbon budgets?

Achieving the goal of the Paris Climate Agreement (2015) will require the total decarbonisation of the global energy system by 2050, with an emissions peak between 2020 and 2025[5] and a drastic reduction in non-energy-related GHGs, including land-use-related emissions[6]. Based on the Agreement, countries have agreed to regularly report their GHG emissions and submit their 'nationally determined contributions' (NDC), describing their planned measures to reduce GHG emissions. In 2021, the 'Global Stocktake' process began to collect the latest data on emissions and to assess future developments based on NDCs already commenced. According to the United Nations Framework Convention on Climate Change (UNFCCC), the Global Stocktake '*enables countries and other stakeholders to see where they're collectively making progress toward meeting the goals of the Paris Agreement – and where they're not. It's like taking inventory*'[7].

4 IPCC (2021) Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Edited by S.L. Masson-Delmotte, V., P. Zhai, A. Pirani, J.B.R. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, and B.Z. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu. Cambridge University Press. Available at: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Full_Report.pdf

5 Ibid – see above.

6 Rogelj, J. et al. Paris Agreement climate proposals need a boost to keep warming well below 2 °C. Nature 2016;534(7609):631–639. Available at: https://doi.org/10.1038/nature18307

7 UNFCCC (2023a) Global Stocktake, United Nations Climate Change. Available at: https://unfccc.int/topics/global-stocktake (accessed: 20 March 2024).

Fair distribution of the remaining carbon budgets for the industrialised G20 and EU27 countries

The One Earth Climate Model methodology was developed to design mitigation pathways for countries in line with the remaining carbon budget to limit global mean temperature rise to +1.5°C. The methodology is documented in detail in section 7.

Figure 1 shows the historic cumulative energy-related CO_2 emissions in 1750–2019, and the calculated CO_2 emissions under the OECM 1.5°C pathways in 2020–2050. The historic and projected energy-related CO_2 emissions in 2020–2050 for each G20 country are divided by the current population to determine the country-specific emissions index. The Per Capita Carbon Index (PCCI) is introduced as a benchmark with which to compare cumulative historic and projected emissions. However, the PCCI is a simplified calculation because historic and future population developments are not included. Therefore, the index is only an indication. The global OECM 1.5°C pathway calculation in this analysis resulted in total cumulative energy-related CO_2 emissions of 426 $GtCO_2$ (2020–2050). The maximum value of 500 $GtCO_2$ was deliberately undercut in order to maximise the probability of achieving the 1.5°C target.

Carbon budgets

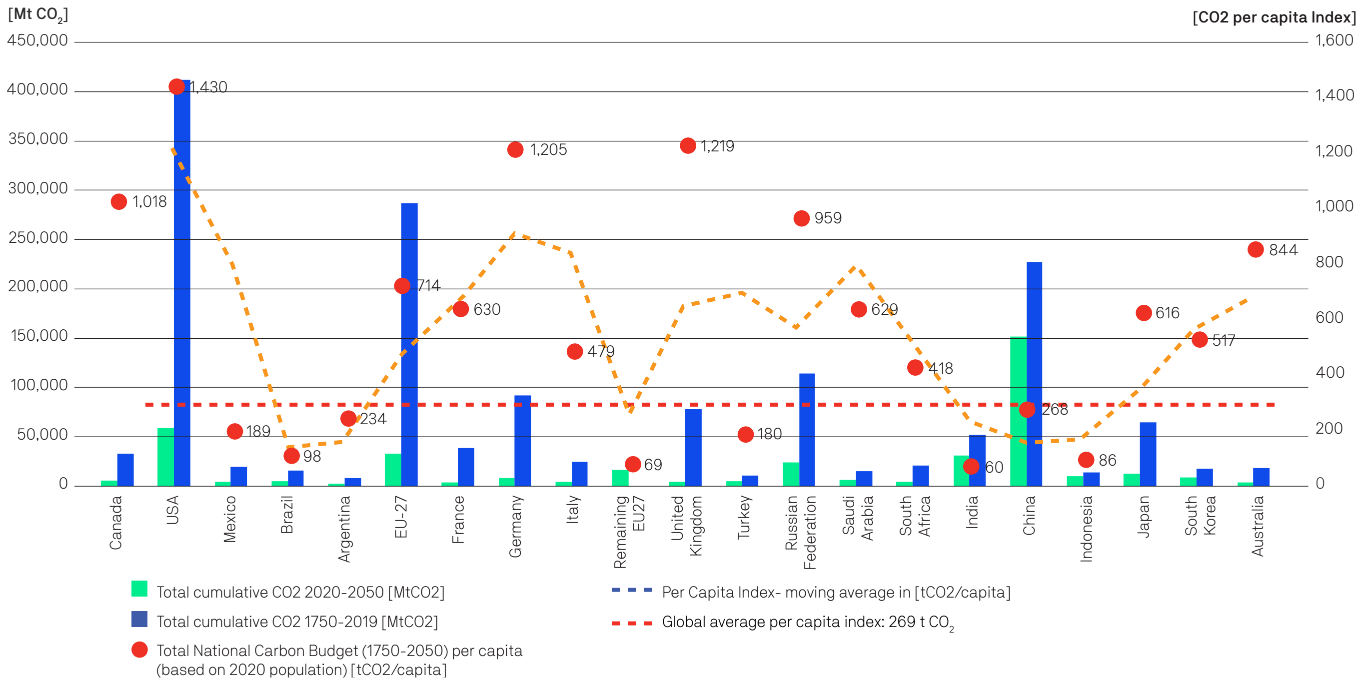
Historic (1750–2019) and 1.5°C pathway emissions (2020–2050) will lead to total global emissions of 2,091 $GtCO_2$, 75% (1,570 $GtCO_2$) of which will be emitted by the G20 countries. In terms of the overall emissions, the USA is by far the greatest emitter, with 471 $GtCO_2$ – 87% are historic emissions and the future emissions allowance under the OECM pathway is 58.9 $GtCO_2$. The second greatest emitter is the 27 countries of the European Union (EU27), with 286 $GtCO_2$ of historic emissions, 30% less than the USA.

Under the OECM 1.5°C pathway, the EU27 will decarbonise with a total remaining carbon budget of 32.9 $GtCO_2$, 44% less than the USA, even though the EU27 population is 448 million, 26% larger than the USA. The European economy is significantly more energy efficient than the US economy, and the renewable energy share (final energy) in 2020 was 28%, more than twice that of the USA (11%). Therefore, the faster decarbonisation of Europe's energy system is assumed. China is the third greatest emitter, with 227 $GtCO_2$ of historic emissions and a projected remaining carbon budget of 151 $GtCO_2$.

The USA, EU27, and China represent 28% of the global population (in 2020) and are responsible for 56% of historic emissions (926 $GtCO_2$). The 1.5°C OECM decarbonisation pathways for these three regions lead to a remaining carbon budget of 243 $GtCO_2$, 57% of the total global carbon budget of 426 $GtCO_2$. China is assumed to require the largest carbon budget to reach decarbonisation. Under the national OECM 1.5°C decarbonisation pathway, China – with a population of 1.4 billion people, compared with 0.8 billion for the EU27 and USA combined – will cumulatively emit 151 $GtCO_2$ in 2020–2050, more than 1.5 times the remaining carbon budget of the EU27 and USA combined.

In terms of the total combined historic and projected emissions, the fourth largest emitter is Russia, with 138.2 $GtCO_2$, followed by Germany (100.3 $GtCO_2$). All other G20 countries – including populous India – have significantly lower cumulative emissions, although some had significantly higher per capita emissions in 2020.

Figure 1: G20 Carbon Stocktake: cumulative energy-related CO_2 emissions in 1750–2020 and 2020–2050 under the OECM 1.5°C pathways and the Per Capita Carbon Index (PCCI)



Per Capita Carbon Index

The total carbon emitted will determine the increase in global temperature, so an increase in global CO_2 emissions, and consequently the global carbon budget, will inevitably cause us to miss the 1.5°C target. Therefore, increasing the carbon budgets of countries with low historic emissions is not possible. To determine CO_2 budgets that are still fair for developing countries with little responsibility for climate change, the *Per Capita Carbon Index* (PCCI) is introduced. The historic emissions and future emissions under the OECM 1.5°C pathway for each G20 member are divided by the country's population in 2020. The '*historic PCCI*' shows the level of responsibility and the '*1.5°C PCCI*' provides a way to compare the remaining carbon budgets. In combination, the '*total PCCI*' provides a way to compare emissions, as required in the *Global Stocktake*. The overall PCCI for each country is compared with the global PCCI under the global OECM 1.5°C scenario plus the global historic emissions.

G20 countries are the world's major economies, representing 85% of the global GDP, 75% of international trade, and two-thirds of the global population[8]. However, the national historic emissions of the G20 member countries vary significantly, and their individual PCCIs differ greatly: India has the lowest, with only 60 tCO_2 per capita, whereas the USA has the highest, with 1,430 tCO_2 per capita – almost 24 times higher. The United Kingdom, Germany, and Canada have PCCIs > 1,000 tCO_2 per capita. The global average PCCI is calculated to be 269 tCO_2 per capita – almost exactly the PCCI of China (268 tCO_2 per capita). The results for all other developing countries are below the global average.

8 Australian Government (2023) The G20, Department of Foreign Affairs and Trade. Available at: https://www.dfat.gov.au/trade/organisations/g20 (Accessed: 11 July 2023).

Carbon budget by industry sector

The 1.5°C carbon budgets (2020–2050) for the 16 main industry sectors are shown in Table 2. Each sectoral carbon budget is presented as the sum for G20 and the EU27 member countries and compared with the results for the global pathway. The difference between the global and G20 emissions represents the carbon budget for all the remaining countries. The OECM 1.5°C pathways for all G20 countries reflect the current distribution of industry sectors. The G20 steel industry, for example, represents almost 90% of the current production capacity of the global steel industry, and is assumed to do so until 2050. The carbon budget for the EU27 represents 7.5% of the global carbon budget while global the population share is 5.46%. The carbon is slightly higher than the population share due to the high industrialisation which requires a significant transition as opposed to countries how can leapfrog directly in energy efficient applications and production methods and a low-cost renewable energy supply structure.

Table 5: Cumulative energy-related CO_2 emissions by sector (2020–2050) for the OECM 1.5°C pathways all G20 member countries compared with the remaining global budgets and the remaining carbon budgets for Australia

Sector	Industry	G20	G20 share	EU-27 (2024)	EUI27 share	Global
Cement (process heat, fuels, & electricity)	Industry	8,534	88%	476	4.94%	9,653
Steel (process heat, fuels, & electricity)	Industry	27,173	98%	1,605	5.76%	27,841
Chemical Industry (process heat, fuels & electricity)	Industry	19,012	97%	1,173	5.99%	19,579
Textiles & Leather (process heat, fuels, & electricity)	Industry	3,880	84%	145	3.15%	4,621
Aluminium (process heat, fuels, & electricity)	Industry	5,266	95%	227	4.09%	5,553
Buildings, commercial, residential, & construction (heat, fuels, & electricity)	Services	60,003	95%	7,553	11.92%	63,341
Fisheries (fuels & electricity)	Services	411	67%	112	18.17%	614
Agriculture & Food Processing (heat, fuels, & electricity)	Services	13,668	99%	1,192	8.62%	13,830
Forestry & Wood (heat, fuels, & electricity)	Services	8,364	92%	871	9.59%	9,086
Water Utilities (heat, fuels, & electricity)	Services	305	69%	15	3.39%	438
Aviation – Transport Services	Transport	6,118	34%	269	1.51%	17,743
Aviation Industry Direct (fuels & electricity)	Transport	349	24%	17	1.19%	1,464
Navigation – Transport Services	Transport	2,077	17%	177	1.46%	12,160
Navigation Industry Direct (fuels & electricity)	Transport	495	28%	25	1.44%	1,762
Road Transport – Transport Services	Transport	55,937	76%	8,376	11.42%	73,334
Road Transport Industry Direct (fuels & electricity)	Transport	3,033	67%	244	5.36%	4,554
All Other Sectors	Other	155,545	97%	9,652	6.02%	160,417
Total cumulative CO_2 2020–2050	[$MtCO_2$]	370,169	87%	32,131	7.54%	425,990
Total cumulative CO_2 1750–2020		1,407,519		286,967		1,664,542
Total CO_2 budget from beginning to end of fossil fuel era		1,777,689		319,098		2,090,532
2020–2050 carbon budget per capita (2020 population)		77		76		55
Carbon budget (1750–2050) per capita index (based on 2020 population)	[tCO_2/capita 1750–2050]	291		677		269
Global CO_2 share (2020-2050)	[%]	86.90%		7.54%		100.00%
Global Population share	[%]	62.30%		5.46%		100.00%
Population in 2020	[million]	4,836		424		7,762

Impact of implementation delay of the 1.5°C OECM pathways:

The total remaining global carbon budget required to limit the temperature increase to 1.5°C (with 67% likelihood) is 400 $GtCO_2$. An increased carbon budget of 500 $GtCO_2$ will reduce the likelihood to 50%, and a carbon budget of 650 $GtCO_2$ will reduce it to only 33%, according to the IPCC. The impacts of delaying the implementation of the 1.5°C pathways by 5 or 7 years are shown, by sector, in Table 6.

A delay of 5 years – across all sectors and countries – will increase the global carbon emissions from 426 $GtCO_2$ under the 1.5°C OECM scenario to 585 $GtCO_2$, and the likelihood of meeting the +1.5°C target will decrease to < 50%. A delay of 7 years will increase the total emissions to 649 $GtCO_2$ in 2020–2050, reducing the likelihood of achieving the target to 33%.

A closer look at the development of sector-specific emissions and the increase in emissions if implementation is delayed shows that those of the *Transport* sector and *Building* sector will be significant. A 7-year delay in the *Road Transport* sector alone will increase emissions in 2020–2050 by 39 $GtCO_2$.

Every 3 months delay in implementing the OECM pathways will reduce the likelihood of achieving the 1.5°C target by 1%.

Table 6: Total cumulative energy-related CO_2 emissions (2020–2050) Global and all G20 and EU 27 member states with a 5-year or 7-year delay in implementing the 1.5°C pathway [$MtCO_2$]

	5-year delay [$MtCO_2$]			7-year delay [$MtCO_2$]		
Sector	**G20**	**EU-27 (2024)**	**Global**	**G20**	**EU-27 (2024)**	**Global**
Cement	12,305	706	13,819	13,814	798	15,485
Steel	34,815	2,115	35,699	37,872	2,320	38,842
Chemical Industry	25,505	1,754	26,558	28,102	1,985	29,350
Textiles & Leather	5,442	205	6,318	6,067	228	6,997
Aluminium	8,191	359	8,374	9,362	411	9,503
Buildings – commercial, residential, & construction	88,376	11,223	94,364	99,725	12,691	106,774
Fisheries	518	140	777	560	152	842
Agriculture & Food Processing	19,953	1,795	20,418	22,466	2,035	23,053
Forestry & Wood	12,036	1,283	13,207	13,505	1,448	14,855
Water Utilities	451	22	670	509	24	763
Aviation – Transport Services	8,423	334	23,799	9,345	359	26,221
Aviation Industry Direct	429	25	1,522	461	29	1,545
Navigation – Transport Services	2,732	213	16,358	2,995	229	18,038
Navigation Industry Direct	601	37	1,840	643	42	1,871
Road Transport – Transport Services	77,170	11,618	102,223	85,662	12,913	113,779
Road Transport Industry Direct	4,034	335	5,232	4,434	372	5,503
All Other Sectors	206,553	13,516	213,642	226,984	15,089	234,932
Total cumulative energy-related CO_2 emissions (2020–2050)	507,533	45,679	584,821	562,506	51,126	648,353

Is it already too late to achieve the 1.5°C target?

No. Whereas limiting the global mean temperature rise to a maximum of 1.5°C with 100% certainty is virtually impossible, because this would require the complete decarbonisation of the global economy by 2030, to achieve this target with > 60% likelihood is still within reach. It is essential to implement all known GHG emissions reduction measures as fast as possible. It will be essential to remain within a global carbon budget well under 500 $GtCO_2$ if we are to meet the Paris Climate Agreement target of maintaining '*the global temperature rise this century well below 2 degrees Celsius above pre-industrial levels*'[9]. The IPCC 6th Assessment Report (AR6) stressed that a global temperature rise of 1.5°C will still have significant climate impacts.

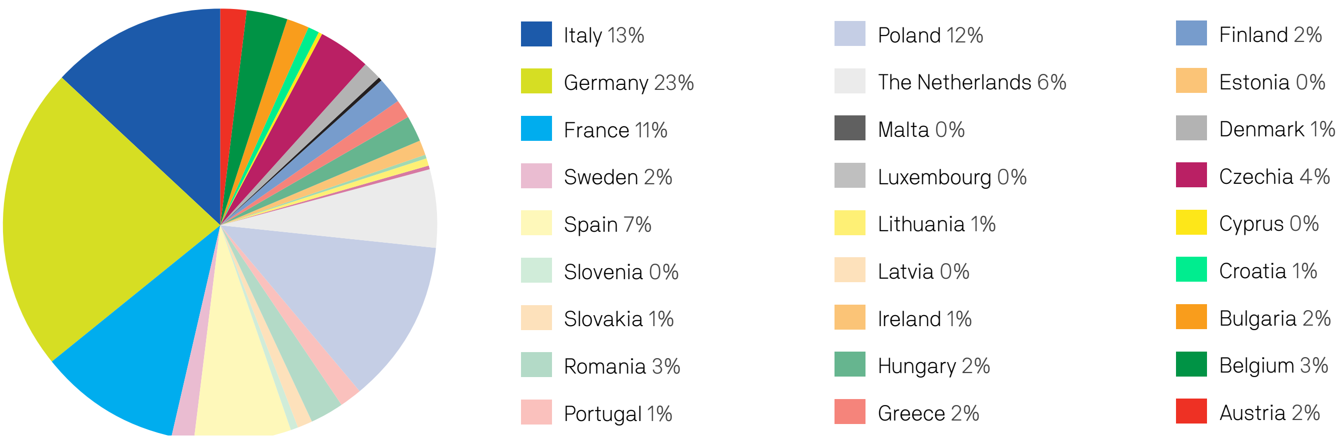
Therefore, the OECM pathways aim to stay within a carbon budget that will limit the global temperature rise to 1.5°C with ≥ 50% probability.

Financial institutions around the world have committed to the 1.5°C target. This research aims to support the implementation of that target.

1.2 Carbon budget for the EU27 member states

In the next step, the EU27 carbon budget of about 32 $GtCO_2$ (2020-2050) has been broken down further by developing an OECM 1.5°C pathway for each of the member states. The scenario data for all individual countries are available on the open access project webpage (www.uts.edu.au/oecm). In this section, we focus on presenting the distribution of the EU27 carbon budgets. Figure 2 shows the carbon budget for each country between 2020 and 2050 in million tonnes of carbon dioxide (CO_2) and the share (as a percentage) of the overall EU carbon budget of 32.1 $GtCO_2$.

Figure 2: EU27 – the remaining carbon budget and its distribution by member states



The CO_2 budgets must be related to the population share within the European Community to judge the degree of fairness of this distribution. For most EU countries, the ratios of the CO_2 budget share to the population shares are similar, within a ± 20% margin. However, there are countries with significantly higher CO_2 shares relative to their populations, whereas others have the reverse situation.

The 'high-carbon' countries, with carbon budgets 30%–50% greater than their population shares, are Cyprus, Czechia, Finland, Luxembourg, the Netherlands, and Poland.

9 UNFCCC (2023b) Key aspects of the Paris Agreement, United Nations Climate Change. Available at: https://unfccc.int/most-requested/key-aspects-of-the-paris-agreement

Cyprus has an extremely carbon-intensive power-generation mix, based almost entirely on diesel and oil generators. Not only is this the most polluting fossil-fuel-based technology for electricity generation but also one of the most expensive. The transition to renewables-based generation – mainly solar photovoltaic – with battery storage is expected to take more than 10 years, which explains the high carbon budget. Power generation in Czechia and Poland is heavily dependent on coal. Therefore, both countries start with a carbon-intensive power supply that significantly exceeds the EU average. Luxembourg and Finland have very high per capita gross domestic products (GDPs), and relatively high energy demands per capita as well. The Netherlands has a significant chemical industry, which is a very energy-intensive industry.

The carbon shares of Germany and Italy are within ± 15% of their population shares, so they represent countries with balanced carbon budgets. Portugal has among the lowest carbon budgets relative to its population size due to its already large share of renewable power generation.

The OECM takes the current situation regarding the energy demands for industries and the service-based economy, its building stock and the transport sector into account and includes the status quo of the energy supply. Therefore, the carbon budgets of economies with already low carbon intensities will be smaller. However, this is not a disadvantage, but an advantage insofar as those countries are ahead of countries with higher carbon intensities. The energy transition of advanced countries and their decarbonisation can be reached more rapidly.

The results of the OECM scenario for the EU27 (as a region) are compared with the EU Taxonomy. The following sections document a detailed analysis of the EU Taxonomy and how the OECM pathways can be utilised to implement and advance it in the future.

2 Background: EU taxonomy

2.1 What is the EU Taxonomy?

According to European Commission communications[10], the *'EU Taxonomy is a classification system that helps companies and investors identify "environmentally sustainable" economic activities to make sustainable investment decisions. Environmentally sustainable economic activities are described as those which "make a substantial contribution to at least one of the EU's climate and environmental objectives, while at the same time not significantly harming any of these objectives and meeting minimum safeguards."*

The EU Taxonomy is not a mandatory list for investors to invest in. It does not set mandatory requirements on environmental performance for companies or for financial products. Investors are free to choose what to invest in. However, it is expected that over time, the EU Taxonomy will encourage a transition towards sustainability to achieve the EU's climate and environmental goals.'

Figure 3: EU Taxonomy, defined by the EU Commission

What the EU Taxonomy is:

- ✓ A classification system to establish clear definitions of what is an environmentally sustainable economic activity.
- ✓ Tool to help investors and companies to make informed investment decisions on environmentally sustainable activities for the purpose of determining the degree of sustainability of an investment.
- ✓ Reflecting technological and policy developments: The Taxonomy will be updated regularly.
- ✓ Facilitating transition of polluting sectors.
- ✓ Technology neutral.
- ✓ Fostering transparency by disclosures for financial market participants and large companies related to the Taxonomy.

What the EU Taxonomy is not:

- ✗ It's not a mandatory list to invest in.
- ✗ It's not a rating of the "greenness of companies.
- ✗ It does not make any judgement on the financial performance of an investment.
- ✗ What's not green is not necessarily brown. Activities that are not on the list, are not necessarily polluting activities. The focus is simply on activities that contribute substantially to environmental objectives.

10 EU Taxonomy online information – official website of the European Union: https://ec.europa.eu/sustainable-finance-taxonomy/ and https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities_en

2.2 What are the disclosure obligations related to the EU Taxonomy?

Companies that fall under the scope of the Corporate Sustainability Reporting Directive (CSRD)[11] must report annually the extent to which their activities are covered by the EU Taxonomy (Taxonomy eligibility) and comply with the criteria set in the Taxonomy-delegated acts (Taxonomy alignment). Other companies that do not fall under the scope of CSRD can disclose this information on a voluntary basis to access sustainable financing or for other business-related reasons.

The reporting obligations and timelines (Figure 4) for undertakings are set out in the Disclosures Delegated Act, supplementing Article 8 of the Taxonomy Regulation. The Disclosures Delegated Act specifies the content, methodology, and presentation of information to be disclosed by financial and non-financial undertakings concerning the proportion of environmentally sustainable economic activities in their business, investments, and lending activities.

Figure 4: EU Taxonomy – reporting timeline according to the EU Commission

As of January 2022	• Non-financial entities report Taxonomy eligibility for the previous calendar year* • Financial entities report Taxonomy eligibility for the previous calendar year*
As of January 2023	• Non-financial entities report Taxonomy eligibility and alignment for the previous calendar year* • Financial entities report Taxonomy eligibility and alignment for the previous calendar year*
As of January 2024	• Non-financial entities report Taxonomy eligibility and alignment for the previous calendar year* • Financial entities report Taxonomy eligibility and alignment for the previous calendar year*
As of January 2025	• Financial entities may include estimates on Taxonomy alignment for DNSH assessments of third-country exposures subject to the 2024 review period
As of January 2026	• Credit institutions include Taxonomy alignment of their trading book and fees and commissions for non-banking activities

11 There are also disclosure obligations for sustainable financial products (SFDR): https://finance.ec.europa.eu/sustainable-finance/disclosures_en

2.3 Taxonomy objectives and eligibility criteria

The EU Taxonomy covers seven economic sectors in the category ‘contribution to climate mitigation’: addressing agriculture and forestry; manufacturing; energy (electricity, gas, steam, and air-conditioning supply); transport; buildings; water, waste and sewage remediation; and information and communication technologies (ICT) (Schütze and Stede, 2024)*12*. Economic activities must provide a significant contribution to one of the following six environmental objectives:

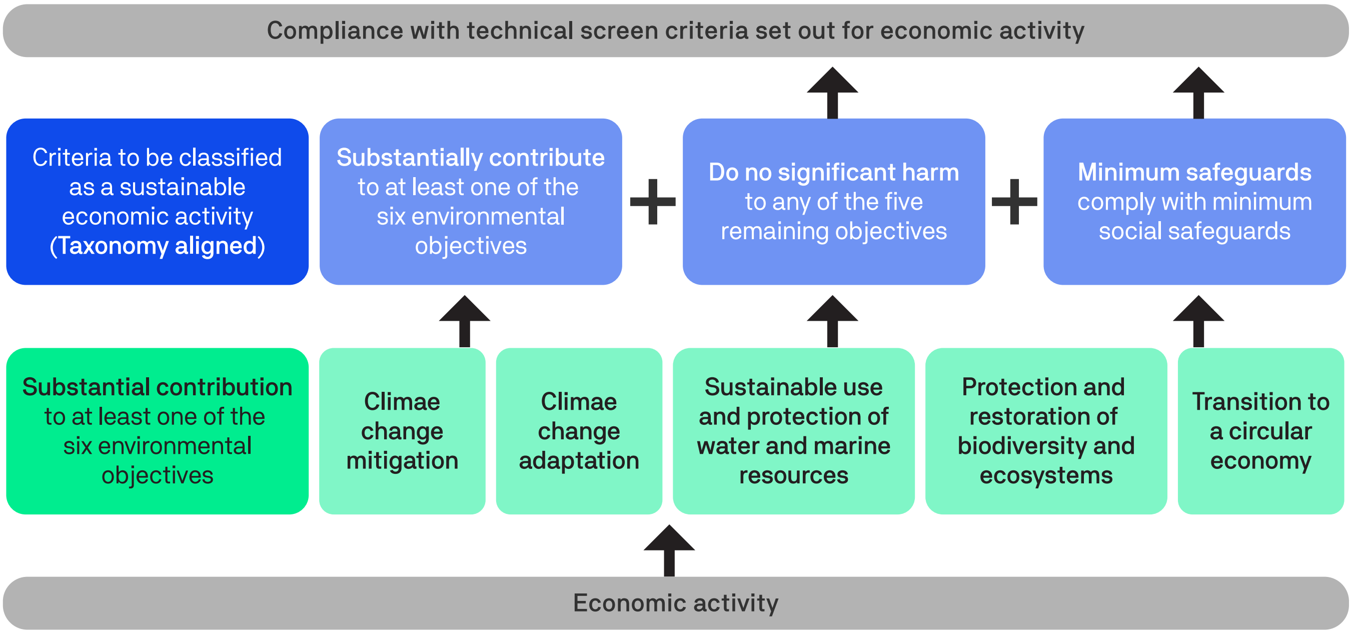
1. Climate change mitigation
2. Climate change adaptation
3. Sustainable use and protection of water and marine resources
4. Transition to a circular economy
5. Pollution prevention and control
6. Protection of healthy ecosystems.

Furthermore, to make a substantial contribution to at least one of these six objectives, the economic activity – to be classified as sustainable economic activity – must meet the following technical screening criteria (Figure 5):

- Substantially contribute to one or more of the six environmental objectives, and comply with the relevant technical and/or sector-specific screening criteria;
- Do no significant harm (DNSH) to any other environmental objective;
- Comply with minimum social safeguards.

The economic activity must not harm any of the remaining objectives. Another criterion that must be met is that the activity must comply with minimum social safeguards. These are related to UN-based human rights and International Labour Organisation (ILO) employment principles that ensure that workers’ rights are not violated in any form. If these criteria are met, the activity is considered taxonomy-aligned.

Figure 5: EU Taxonomy framework and assessment steps

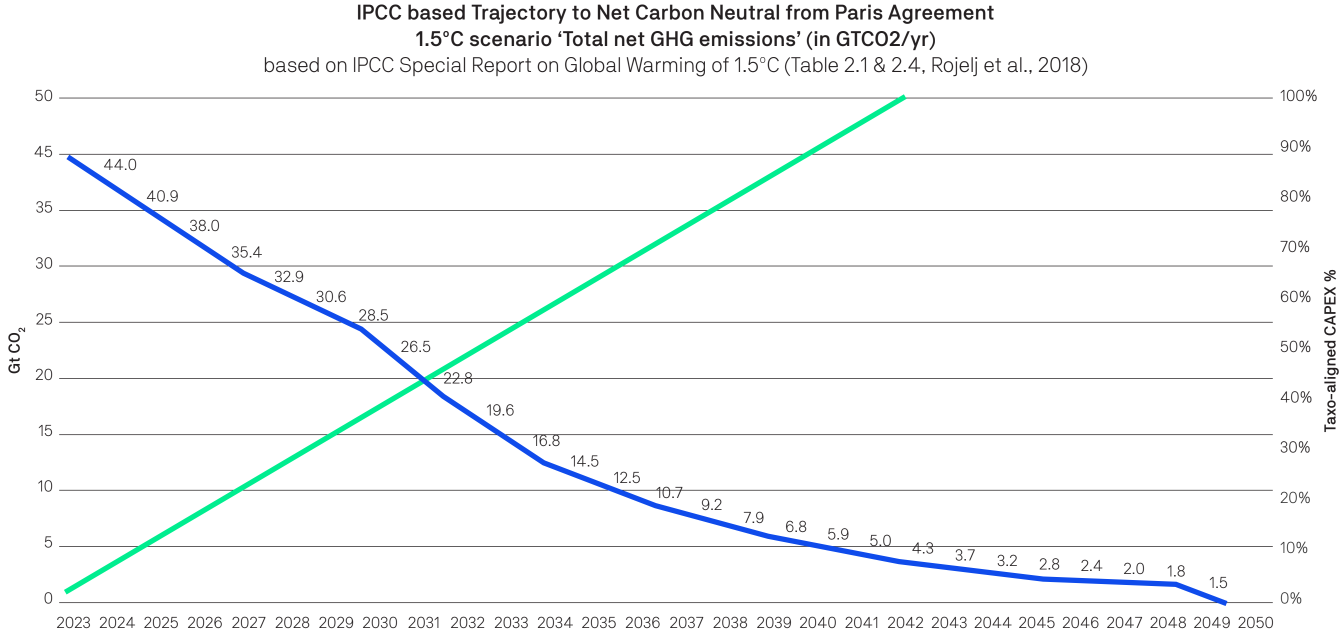


12 Schütze, F. & Stede, J. (2024) The EU sustainable finance taxonomy and its contribution to climate neutrality, Journal of Sustainable Finance & Investment 14(1):128–160, DOI: 10.1080/20430795.2021.2006129

2.4 Economic coverage of the Taxonomy

The EU Taxonomy, adopted in 2022, establishes a list of environmentally sustainable economic activities. These activities present sustainable investment benchmarks for all EU member countries, with special consideration of the reporting obligations of national and international financial institutions. The main objective of the EU Taxonomy is to re-direct investments from high-emissions (fossil-fuel-based) economic activities to the development of activities with low- to near-zero emissions by 2050 (Figure 6).

Figure 6: EU Taxonomy approach to doubling objectives: increasing greening capital expenditure and decarbonising the economy. Source: EC (2023)[13]



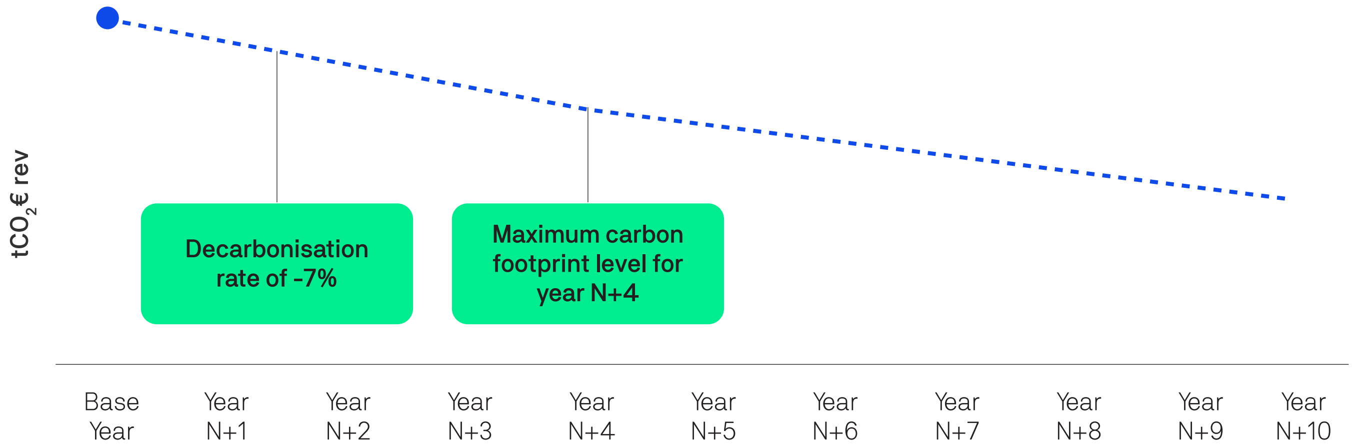
Whereas the key purpose of the 2022 Taxonomy is to green financial investments, in the past, EU Directives primarily focussed on monitoring economic activities and reporting greenhouse gas (GHG) emissions. In 2014, the European Non-financial Reporting Directive (Directive 2014/95/EU, the NFRD) was amended, which involved the revision of the Accounting Directive, which was then adopted. As part of the 2020 European Green Deal, the European Commission's commitment included a proposal to revise the NFRD and its 2020 Work Program. Since January 2023, the environmental objectives – disclosure of the remaining four environmental objectives – are mandatory for companies.

13 EC (2023) Climate Change Taxonomy and the EU Regulatory Response: EU Taxonomy-Aligning Benchmarks (TABs) Report – EU Platform on Sustainable Finance. 12 Dec. 2023. https://finance.ec.europa.eu/system/files/2023-12/231213-sustainable-finance-platform-draft-report-eu-taxonomy-aligning-benchmarks_en.pdf

2.5 Taxonomy Climate Benchmark – decarbonisation trajectory

The EU Taxonomy recommends *a 'resulting yearly geometric average decarbonisation rate of at least 7%. The points are calculated with scientific data (IPCC and IEA for past and current emissions, IPCC for future emissions), and the trajectory uses a simple geometric progression, justified by the fact that no technological breakthrough is likely to reduce worldwide emissions at a point in time, but a sum of several actions leading to the reduction of emissions will occur continuously in time, and the fact that the first reductions are easier and cheaper than the last ones, thus an annual constant decrease rate applies'* (EU TABs[10]).

Figure 7: Year-on-year decarbonisation trajectory of a climate benchmark



Although the EU Taxonomy includes a 7% annual reduction rate on CO_2 emissions, there are no specific benchmarks for the majority of industry sectors. Minimum energy and/or emissions standards for (for example) buildings per square meter are not part of the Taxonomy benchmarks. However, the EU Taxonomy information refers to all legally binding and/or voluntary EU energy efficiency standards for buildings, vehicles, appliances, etc.

In this research, an annual reduction rate of 7%, which leads to a total reduction of 48.4% after 10 years due to compounding effects, has been used to calculate the climate benchmarks for the year 2035 (see Chapter 5).

2.6 New opportunities to arise from the EU Taxonomy

The rules of the EU Taxonomy require large companies and listed companies (including listed Small and Medium Enterprises (SMEs) to report on sustainability in accordance with the European Sustainability Reporting Standards (ESRS)[14] and to disclose industrial activities and finances, and will require entire industry sectors to undertake operational and strategic changes. This shift towards sustainable and climate-compatible development will create an opportunity for companies to re-think their business models and to future-proof their financial investments. '*In a world where a range of stakeholders – customers, suppliers, financiers, investors, among others – are increasingly concerned about the genuine sustainability profile of a business and its products/services, the 'Taxonomy' should be seen as an opportunity*' (Pettingale et al., 2022).[15] From the perspective of responsible investors, there is a preference for companies with high scores in environmental, social, and governance (ESG) practices. Businesses with high ESG ratings show higher shareholder wealth (Parikh et al., 2023).[16] The EU Taxonomy is likely to show similar trends. Key advantages for high-performing organisations may include offers of '*lower rate loans if they are to be used to finance Taxonomy-aligned activities or investments*' (Lodh, 2020).[17]

Our findings demonstrate that currently, only a very small share of EU securities is used to finance environmentally sustainable activities. We estimate that only 1.3% of EU bond and equity markets, corresponding to €290 billion, are currently financing activities aligned with the Taxonomy with the objective of climate change mitigation. At the same time, around 15% of the market currently finances "eligible" activities, i.e., activities that could become green but are not there yet. These activities that must transition include some that are particularly harmful. Investors' exposure to activities of this type, and to activities generally related to fossil fuels, carry a so-called "transition risk". We estimate such exposure to transition risk to be around 5% overall. Looking ahead, we calculate that green loans and bonds could increase to around 10% of total debt financing. This points to an enormous growth potential for green financial instruments, starting from our status-quo assessment, in sectors such as *Transport* and *Buildings*. At the same time, greening 10% of financial markets appears feasible, meaning that the achievement of EU climate targets could be within reach from a financial perspective[18].

In short, a company will work to map its economic activities against the Taxonomy's relevant sector criteria (eligibility). It will then analyse those eligible activities for alignment with the Taxonomy. That second step involves a set of screening criteria and the assessment of harms and safeguards. That analysis results in a set of comparable key performance indicators (KPIs) in terms of the percentage of a company's revenue, operating expenditure (OPEX), and capital expenditure (CAPEX) that comes from, or is related to, sustainable activities judged against the EU's largely science-based Taxonomy criteria[19].

Institutional investors have started to identify Taxonomy disclosures as a rich source of comparable forward signals. For example, a small proportion of a company's revenue may be assessed as sustainable today (in low single figures), but may show a CAPEX figure a quarter of which is assessed as sustainable (i.e., consistent with the applicable Taxonomy criteria for that activity). That gap between the alignment of revenues and the alignment of CAPEX may provide a strong signal about the future direction of a company's business model, i.e., the volume of sustainable CAPEX over time will re-direct a company's core activities toward generating sustainable future revenues. Some companies that provide products directly linked to sustainable activities (e.g., wind turbine manufacturers) may discover that 100% of their revenues are already assessed as sustainable.

14 https://finance.ec.europa.eu/capital-markets-union-and-financial-markets/company-reporting-and-auditing/company-reporting/corporate-sustainability-reporting_en

15 Pettingale, H., de Maupeou, S, Reilly, P. (2022) EU Taxonomy and the Future of Reporting. FTI Consulting. https://corpgov.law.harvard.edu/2022/04/04/eu-taxonomy-and-the-future-of-reporting

16 Parikh, A., Kumari, D., Johann, M., & Mladenovic, D. (2023). The impact of environmental, social and governance score on shareholder wealth: A new dimension in investment philosophy. Cleaner and Responsible Consumption, 8, 100101. https://doi.org/10.1016/j.clrc.2023.100101

17 Lodh (2020) ESG and the cost of capital. https://www.msci.com/www/blog-posts/esg-and-the-cost-of-capital/01726513589

18 *https://www.ecb.europa.eu/press/financial-stability-publications/macroprudential-bulletin/html/ecb.mpbu202110_2~ea64c9692d.en.html*

19 https://www.financialexecutives.org/FEI-Daily/June-2023/The-EU-Taxonomy-Sustainability-And-The-Forward-Sto.aspx

2.7 Context of this research: Linking the European Taxonomy with the OECM

In this research, we aim to link the European Taxonomy with OECM data to allow reporting and ambitious target setting by EU member states and to develop an international connection for countries outside the EU.

The EU Taxonomy – a classification system that establishes a list of environmentally sustainable economic activities – must relate to 1.5°C-compatible sustainable investment benchmarks for all EU member countries, with special consideration of the reporting obligations of national and international financial institutions. In this research, we aim to develop detailed short-term (2025), medium-term (2030), and long-term (2050) emissions reduction targets based on the EU Taxonomy system.

Data from the OEC) is useful here. The OECM, through detailed country-specific KPIs for 13 Global Industry Classification Standard (GICS)-based industry sectors, provides the foundation for emissions-intensive industry sectors to implement the 1.5°C goal set out in the Paris Climate Agreement, under the EU Taxonomy data structure.

Analysis of EU taxonomy data requirements

A finance taxonomy is a classification system for identifying activities or investments that allow specific targets related to priority environmental objectives to be met. The standardisation of definitions for sustainable investments to achieve climate and other sustainable environmental goals is crucial and aims to:

- Limit the potential for "green washing" in the marketplace.
- Ensure the quality and sustainability credentials of different assets;
- Facilitate the tracking and reporting of public and private expenditure, for transparency and international alignment;
- Identify opportunities and areas of underinvestment.

Interface development between OECM data and EU taxonomy format

The EU committed itself to proposing a revision of the Non-Financial Reporting Directive in the European Green Deal and its 2020 Work Program. Since January 2023, the Environmental objectives – Disclosure of the remaining four environmental objectives are mandatory for companies. The OECM calculates sectoral data and decarbonisation pathways for the current and future emissions of real-economy industry sectors. The existing EU Taxonomy data:

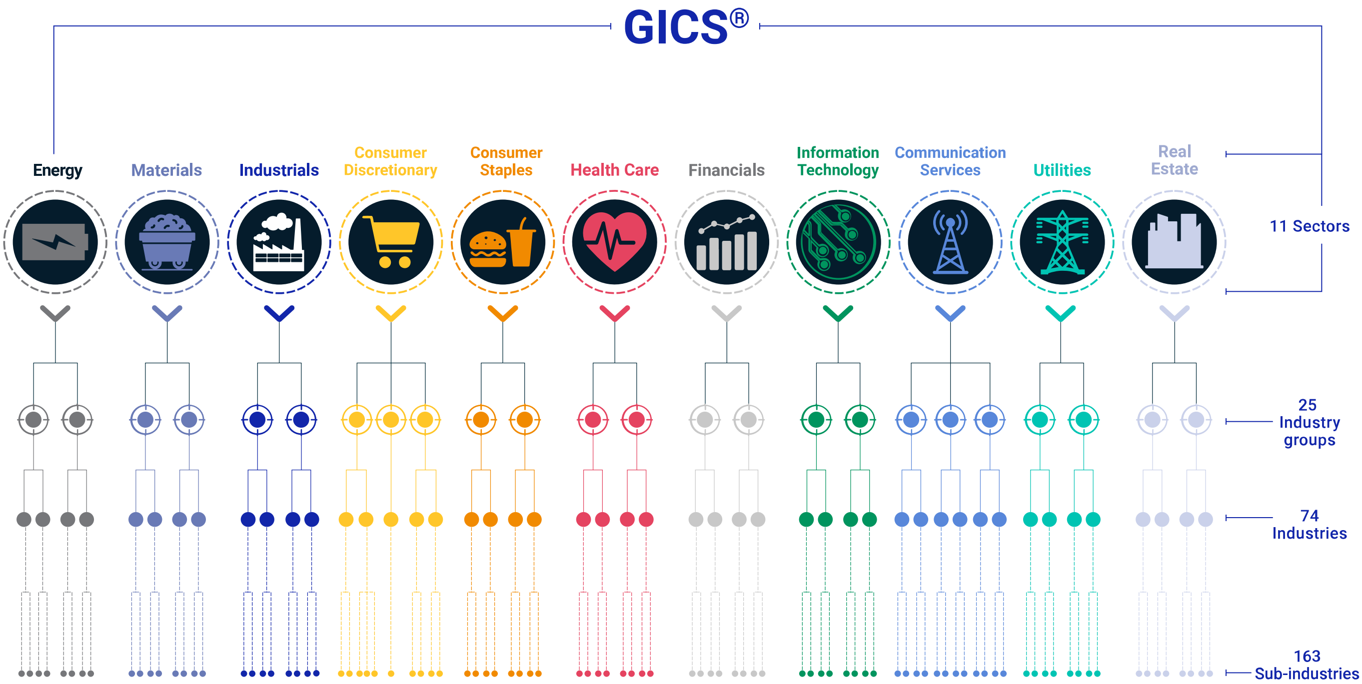
1. Classify economic activities,
2. Identify environmental contributions to climate mitigation, and
3. Identify environmental contributions to climate adaptation.

Currently, the report structures of the Taxonomy and the OECM differ. The first part of this report (Sections 2–4) documents the process used to develop a methodology to align the Taxonomy reporting structure with the OECM sector and industry classification structure. The second part (Section 5) outlines the methodological development of an 'OECM GICS-based Taxonomy', aligning the OECM model with the EU Taxonomy data and requirements.

Global Industry Classification Standard (GICS)

The Global Industry Classification Standard (GICS) was first developed in 1999 by the US-based investment research firm Morgan Stanley Capital International (MSCI) together with Standard & Poor (S&P), a finance data and credit ratings company. According to MSCI, the GICS was designed to define specific industry classifications for reporting, comparison, and investment transaction processes[20]. The GICS has four classification levels and includes 11 sectors, 24 industry groups, 69 industries, and 158 sub-industries. The 11 GICS sectors are: Energy, Materials, Industrials, Consumer Discretionary, Consumer Staples, Health Care, Financials, Information Technology, Communication Services, Utilities, and Real Estate (Figure 8).

Figure8: Overview of the Global Industry Classification Standard (GICS); MSCI (2024)



Investment decisions, such as the decarbonisation target of the Net-Zero Asset Owner Alliance, are highly complex processes. In November 2020, the European Central Bank published a *Guide on climate-related and environmental risks*, which maps out a detailed process for undertaking "climate stress tests" for investment portfolios. To achieve the Paris Climate Agreement goals in the global finance industry, decarbonisation targets and benchmarks for industry sectors are required.

The OECM is an integrated assessment model for climate and energy pathways that focuses on 1.5°C-directed scenarios[21], and has been further improved to meet the requirements for sector decarbonisation. To develop energy scenarios for the industry sectors classified under the GICS, the technological resolution of the OECM required significant improvement. Furthermore, all energy-related demand and supply calculations had to be broken down to the industry-sector level before the individual pathways could be developed.

20 MSCI. Global Industry Classification Standard (GICS®) Methodology. Guiding Principles and Methodology for GICS. 2020.

21 Teske, S., Pregger, T., Naegler, T., Simon, S., Pagenkopf, J., van den Adel, B., et al. (2019) Energy Scenario Results. In: Achieving the Paris Climate Agreement Goals: Global and Regional 100% Renewable Energy Scenarios with Non-Energy GHG Pathways for +1.5°C and +2 °C. 1st edition. New York, NY, USA: Springer International Publishing; 2019

2.8 The European NACE system

The Statistical Classification of Economic Activities in the European Community, commonly referred to as NACE (an acronym of the French term “nomenclature statistique des activités économiques dans la Communauté européenne”), is the standard industry classification system used in the EU. The current version (revision 2) was established by Regulation (EC) No. 1893/2006[22], which is the European implementation of the UN classification ISIC, revision 4. There is a correspondence between NACE and the UN’s International Standard Industrial Classification of all Economic Activities[23]. NACE is similar in function to the Standard Industrial Classification (SIC) and the North American Industry Classification System (NAICS) systems and uses four hierarchical levels[24]:

- **Level 1:** 21 sections identified by alphabetical letters A–U;
- **Level 2:** 88 divisions identified by a two-digit numerical code (01–99);
- **Level 3:** 272 groups identified by a three-digit numerical code (01.1–99.0);
- **Level 4:** 615 classes identified by a four-digit numerical code (01.11–99.00).

The first four digits of the code refer to the first four levels of the classification system, and the code is adopted by all European countries. National implementation may introduce additional levels. The fifth digit may vary from country to country and further digits are sometimes included by suppliers of databases.

Table 7: NACE – main sectors

NACE Code	NACE – Economic Areas (21)
A	Agriculture, Forestry, and Fishing
B	Mining and Quarrying
C	Manufacturing
D	Electricity, Gas, Steam, and Air-Conditioning Supply
E	Water Supply; Sewerage, Waste Management, and Remediation Activities
F	Construction
G	Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles
H	Transportation and Storage
I	Accommodation and Food Service Activities
J	Information and Communication
K	Financial and Insurance Activities
L	Real Estate Activities
M	Professional, Scientific, and Technical Activities
N	Administrative and Support Service Activities
O	Public Administration and Defence; Compulsory Social Security
P	Education
Q	Human Health and Social Work Activities
R	Arts, Entertainment, and Recreation
S	Other Service Activities
T	Activities of Households as Employers; Undifferentiated Goods and Services Producing Activities of Households for Own Use
U	Activities of Extraterritorial Organisations and Bodies

22 Regulation (EC) No. 1893/2006 of the European Parliament and of the Council of 20 December 2006 establishing the statistical classification of economic activities NACE Revision 2 and amending Council Regulation (EEC) No. 3037/90 as well as certain EC Regulations on specific statistical domains. OJ L 393, 30.12.2006, p. 1–39.

23 United Nations Statistics Division – Classifications Registry. unstats.un.org. Archived from the original on 14.10.2015.

24 https://ec.europa.eu/eurostat/web/metadata/classifications

2.9 Comparison of GICs and NACE

The breakdown of the GICS system is, in parts, similar to NACE and in other parts significantly different. Whereas the GICS system only has 11 main sectors, the NACE system has almost twice as many sectors (see Table 8 for the 21 sectors). Table 9 provides an overview of the main sectors of GICS and NACE. Similar sectors are marked with similar colours. However, there are several NACE sectors that correspond to more than one GICS sector and vice versa.

Table 8: GICS versus NACE – main sectors

GICS Codes	GICS Main Sectors (11)	NACE Codes	NACE–Economic Areas (21)
10	Energy	A	Agriculture, Forestry, and Fishing
55	Utilities	B	Mining and Quarrying
15	Materials	C	Manufacturing
20	Industrials	D	Electricity, Gas, Steam, and Air-Conditioning Supply
25	Consumer Discretionary	E	Water Supply; Sewerage, Waste Management, and Remediation Activities
30	Consumer Staples	F	Construction
35	Health Care	G	Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles
40	Financials	H	Transportation and Storage
45	Information Technology	I	Accommodation and Food Service Activities
50	Communication Services	J	Information and Communication
60	Real Estate	K	Financial and Insurance Activities
		L	Real Estate Activities
		M	Professional, Scientific, and Technical Activities
		N	Administrative and Support Service Activities
		O	Public Administration and Defence; Compulsory Social Security
		P	Education
		Q	Human Health and Social Work Activities
		R	Arts, Entertainment, and Recreation
		S	Other Service Activities
		T	Activities of Households as Employers; Undifferentiated Goods and Services Producing Activities of Households for Own Use
		U	Activities of Extraterritorial Organisations and Bodies

Table 9 compares the most GHG relevant industries as well as the primary and secondary energy supply sectors categorisation under the NACE and GICS system.

Table 9: Industry sectors most relevant to GHG emissions – NACE versus GICS

Financial Sector	NACE	GICS
Energy / Oil & Gas	B – Mining and quarrying B5 – Mining of coal and lignite B6 – Extraction of crude petroleum and natural gas	10. Energy 101020 Oil, Gas, & Consumable Fuels 1010 20 Integrated Oil & Gas 1010 2020 Oil & Gas Exploration & Production 1010 2050 Coal & Consumable Fuels
Utilities Electricity generation & distribution Gas distribution	D – Electricity, gas, steam and air-conditioning supply D35.1 – Electric power generation, transmission and distribution	55. Utilities 5510 1010 Electric Utilities 5510 2010 Gas Utilities 5510 3010 Multi Utilities 5510 4010 Water Utilities
Transport	H – Transporting and storage H50 – Water transport H51 – Air transport C – Manufacturing C29.1 – Manufacture of motor vehicles C30.1 – Building of ships and boats C30.3 – Manufacture of air- and spacecraft and related machinery	20 Industrials 2030 Transportation 2030 50 Transportation Infrastructure 2030 5030 Marine Ports & Services
Materials / Steel	C – Manufacturing C 24.1 – Manufacture of basic iron, steel, and of ferro-alloys C 24.2 – Manufacture of tubes, pipes, hollow profiles, and related fittings, from steel C 24.3 – Manufacture of other products of first processing of steel	15. Materials 1510 40 Metals & Mining 1510 4020 Diversified Metals & Mining 1510 4010 Aluminium 1510 4050 Steel
Materials & Cement	C – Manufacturing C23.5.1 – Manufacture of cement	15. Materials 1510 2010 Construction Materials (including cement)

3 Development of a Methodology for ‘OECM GICS-Based Taxonomy’

Section 1 described the basic structure of the international GICS classification system and the European NACE system. The EU Taxonomy is based on the NACE system, whereas the sectoral breakdown of industry sectors in the OECM to develop mitigation pathways and calculate the current and future Scope 1, 2, and 3 emissions is based on the GICS system.

This section provides an overview of the main steps used to develop the methodology for a 'GICS-based Taxonomy' structure matching the OECM structure. Transferring the EU Taxonomy's economic activities from NACE to GICS is necessary because:

1. the OECM model architecture is based on the GICS classification system;
2 a GICS-based Taxonomy structure will facilitate the transfer of the European Taxonomy to the international level, and allow other regions and/or countries to develop similar policies.

3.1 Overview of Methodology development

The OECM GICS-based Taxonomy was developed in the following four steps:

Step 1: Taxonomy Economic Activities (TEA)

(see section 2.2)

- All 'economic activities' listed under the *EU Taxonomy Navigator* were downloaded.
- An overview of all main sectors and their sector-specific economic activities was developed.
- The TEA were divided into 16 sectors and 150 economic activities and numbered according to the NACE system.
- To allocate the TEA to the GICS sectors, the numbering of the TEA was greatly simplified. The first number describes the alphabetical order of the TEA main sector, and the number after the dot is the serial number of the associated economic activity.

Step 2: Taxonomy Economic Activities (TEA) are allocated to GICS sectors and sub-sectors

(section 3)

- GICS classes (8-digit) were compared with all economic activities.
- Taxonomy activities that could be allocated to several GICS sectors were identified.
- A traffic light code for GICS classes included/not included in TEA was developed.

RED	**Not included**
YELLOW	**Relevant** – 1 or 2 matching economic activities
GREEN	**Increased relevance** – up to 5 matching economic activities
BLUE	**GICS sectors that are entirely covered by TEA**

Step 3: Economy-wide TEA coverage was determined (GDP–GICS–TEA)

(section 4)

- The GDP shares for all 8-digit GICS classes were allocated
- The TEA shares for each 8-digit GICS class were allocated
- Results for all main GICS classes were summarised (2-digit level).

Step 4: The EU Taxonomy benchmarks and the OECM mitigation pathways were consolidated

(section 5)

- Overview EU Benchmark emissions for all sectors
- Energy-related CO_2 emissions by sector
- Scope 1, 2, and 3 emissions for all GICS classes.

3.2 EU Taxonomy – Economic Activities

The EU Taxonomy consists of 16 industry sectors and 150 economic activities, which are numbered according to the NACE system. Some industry sectors have only a single defined economic activity, e.g., *Education,* whereas other industry sectors have many associated activities. Sectors with the most identified economic activities include *Energy* with 31 economic activities, *Manufacturing* with 26 economic activities, and *Transport* with 23 economic activities.

To allocate the TEA to the GICS sectors, the numbering of the TEA has been greatly simplified. The first number describes the alphabetical order of the main TEA sector, and the number after the dot is the serial number of the associated economic activities.

4 Allocation Of GICS Classes to Taxonomy Economic Activities

In a third step, the GICS classes are allocated to all Taxonomy Economic Activities (TEA). A traffic light code allows the qualitative assessment of all GICS classes in terms of their correspondence to TEAs.

Colour code:

RED	**Not included**
YELLOW	**Relevant** – 1 or 2 matching economic activities
GREEN	**Increased relevance** – up to 5 matching economic activities
BLUE	**GICS sectors that are entirely covered by TEA**

4.1 GICS Classes with allocated economic activities

The following section documents the allocation of all GICS sectors and sub-sectors (165 in total) to the *Taxonomy Economic Activities* (150 in total). The GICS system has 11 main sectors and the TEA has 16 main sectors.

Whereas the GICS classes have dedicated 2-digit numbers for the main sectors, with 4–8-digit numbers for the sub-sectors, the EU TEA sectors were given a 1- or 2-digit number for the main TEA sectors, and a 2-digit number for the economic activities of each of the TEA sectors (see section 2.2). The *Energy* sector in the TEA system, for example, is number 6, whereas the economic activities of this sector range from 6.1 to 6.31.

Table 10: Main sectors of the Global Industry Categorisation Standard versus Taxonomy Economic Activities

GICS Main Sectors	TEA Main Sectors	TEA numbering (assigned by author)
10 Energy	Accommodation activities	1
55 Utilities	Arts, entertainment, and recreation	2
15 Materials	Construction and real estate	3
20 Industrials	Disaster risk management	4
25 Consumer Discretionary	Education	5
30 Consumer Staples	Energy	6
35 Health Care	Environmental protection and restoration activities	7
40 Financials	Financial and insurance activities	8
45 Information Technology	Forestry	9
50 Communication Services	Human health and social work activities	10
60 Real Estate	Information and communication	11
	Manufacturing	12
	Professional, scientific, and technical activities	13
	Services	14
	Transport	15
	Water supply, sewerage, waste management, and remediation	16

4.2 Challenges in allocating GICS to TEA

The economic activities of the EU Taxonomy are not as prescriptive and unique to one specific industry sector as those in the GICS system and have no defined system boundaries. For example,, under the TEA sector *Construction and real estate* (3), activity 3.4 *Installation, maintenance, and repair of charging stations for electric vehicles in buildings (and parking spaces attached to buildings)* could be categorised under *Power Utility* (GICS 5510) or *20103010 Construction & Engineering* in the GICS sector (*20 Industrials).*

Therefore, allocation is not exact. However, the allocation of a TEA to more than one GICS class has been avoided in order to assign a defined amount of CO_2 and financial investment to each TEA.

4.3 Allocation of GICS to TEA

This section documents the allocation of the TEA to all GICS classes. Each of the 11 main GICS sectors, from 2-digit to 8-digit sub-sectors, and the specific TEA are provided, and the assignment was designated '12'.

GICS 10: Energy

The TEA for the primary *Energy* sector are limited to the transport of CO_2 and the 'manufacture' of hydrogen. Technically, hydrogen cannot be 'manufactured' but is generated, either with electricity and water using the electrolysis process or by chemical separation from fossil fuels.

GICS Sector Definition: Energy Sector: 25

The Energy sector comprises companies engaged in exploration and production, refining and marketing, and storage and transportation of oil, gas, coal, and consumable fuels. It also includes companies that offer oil and gas equipment and services.

25 S&P Global, Global Industry Classification Sector (GICS)–Definition of GICS Sectors, effective close 17 Match 2023, https://www.msci.com/documents/1296102/11185224/GICS+Sector+Definitions+2023.pdf/822305c6-f821-3d65-1984-6615ded81473?t=1679088764288

Table 11: GICS class 10: Energy

				Sector No.	Sector	Matching EU Taxonomy Activities	Not included	Relevant (<2)	Increased R£relevance (£ 5)	High Relevance (> 5/sector)
10 Energy								2		
1010 Energy	101010	Energy Equipment & Services	10101010 Oil & Gas Drilling							
			10101020 Oil & Gas Equipment & Services	12	Manufacturing,	12.12		1		
				16	Water supply, sewerage, waste management, and remediation	16.22		1		
	101020	Oil, Gas, & Consumable Fuels	10102010 Integrated Oil & Gas							
			10102020 Oil & Gas Exploration & Production							
			10102030 Oil & Gas Refining & Marketing							
			10102040 Oil & Gas Storage & Transportation							
			10102050 Coal & Consumable Fuels							

Table 12: GICS-specific Taxonomy Economic Activities

12	Manufacturing	12.12	Manufacture of hydrogen
16	Water supply, sewerage, waste management, and remediation	16.22	Transport of CO_2

GICS 55: Utilities

The *Utilities sector* (55) has by far the most economic activities matching those of the EU Taxonomy (55).

Therefore, the secondary energy sector is defined as the conversion of primary energy into electricity, heat, gaseous, liquid or solid fuels for the supply of energy to commercial and residential customers (= the *End-use* sector).

The *Utilities* sector covers the generation of electricity and heat, the distribution of electricity, gas, liquids, and water, and the treatment of water and soil.

The *Utilities* sector (55) represents the secondary energy supply, whereas the *Energy'* sector (10) represents primary energy.

All other sectors represent the *End-use* sector. The clear separation of energy supply and demand is crucial for the allocation of Scope 1, 2, and 3 emissions. Energy demand and supply must always be discussed separately in terms of the allocation of emissions. Confusing demand and supply leads to mistakes and the double counting of emissions and/or energy units.

GICS Sector Definition: Utilities Sector

The Utilities sector comprises utility companies, such as electric, gas, and water utilities. It also includes independent power producers and energy traders and companies that engage in the generation and distribution of electricity from renewable sources.

Table 13: GICS class 55: Utilities

				No.	Sector	Matching EU Taxonomy Activities	Not Included	Relevant (< 2)	Increased Relevance (£ 5)	High Relevance (> 5 /sector)
55 Utilities								3	0	52
5510 Utilities	551010	Electric Utilities	55101010 Electric Utilities	6	Energy	6.7 – 6.16 | 6.27 | 6.31				12
	551020	Gas Utilities	55102010 Gas Utilities	6	Energy	6.17 | 6.22		2		
	551030	Multi-Utilities	55103010 Multi-Utilities	6	Energy	6.1 – 6.6 | 6.18 | 6.19| 6.21 | 6.23 – 6.26 | 6.28 – 6.30				15
				16	Water supply, sewerage, waste management, and remediation	16.1 | 16.3 – 16.6 | 16.9 | 16.11 | 16.12 | 16.15 | 16.16 | 16.17 | 16.20 | 16.23				13
	551040	Water Utilities	55104010 Water Utilities	16	Water supply, sewerage, waste management, and remediation	16.2 | 16.7 | 16.8 | 16.10 | 16.13 | 16.14 | 16.18 | 16.19 | 16.21 | 16.25 | 16.26				11
				15	Transport	15;10		1		
	551050	Independent Power and Renewable Electricity Producers	55105010 Independent Power Producers & Energy Traders							
			55105020 Renewable Electricity							

Table 14: GICS-specific Taxonomy Economic Activities

6	Energy	6.1	Co-generation of heat/cooling and power from bio-energy
6	Energy	6.2	Co-generation of heat/cooling and power from geothermal energy
6	Energy	6.3	Co-generation of heat/cooling and power from renewable non-fossil gaseous and liquid fuels
6	Energy	6.4	Co-generation of heat/cooling and power from solar energy
6	Energy	6.5	Construction and safe operation of new nuclear power plants, for the generation of electricity and/or heat, including for hydrogen production (…)
6	Energy	6.6	District heating/cooling distribution
6	Energy	6.7	Electricity generation from bio-energy
6	Energy	6.8	Electricity generation from gaseous fossil fuels
6	Energy	6.9	Electricity generation from geothermal energy
6	Energy	6.10	Electricity generation from hydro-power
6	Energy	6.11	Electricity generation from nuclear energy in existing installations
6	Energy	6.12	Electricity generation from ocean energy technologies
6	Energy	6.13	Electricity generation from renewable non-fossil gaseous and liquid fuels
6	Energy	6.14	Electricity generation from wind power
6	Energy	6.15	Electricity generation using concentrated solar power (CSP) technology
6	Energy	6.16	Electricity generation using solar photovoltaic technology
6	Energy	6.17	High-efficiency co-generation of heat/cooling and power from gaseous fossil fuels
6	Energy	6.18	Installation and operation of electric heat pumps
6	Energy	6.19	Manufacture of bio-gas and biofuels for use in transport and of bioliquids
6	Energy	6.20	Pre-commercial stages of advanced technologies to produce energy from nuclear processes with minimal waste from the fuel cycle
6	Energy	6.21	Production of heat/cooling from bio-energy
6	Energy	6.22	Production of heat/cooling from fossil gaseous fuels in an efficient district heating and cooling system
6	Energy	6.23	Production of heat/cooling from geothermal energy
6	Energy	6.24	Production of heat/cooling from renewable non-fossil gaseous and liquid fuels
6	Energy	6.25	Production of heat/cooling from solar thermal heating
6	Energy	6.26	Production of heat/cooling using waste heat
6	Energy	6.27	Storage of electricity
6	Energy	6.28	Storage of hydrogen
6	Energy	6.29	Storage of thermal energy
6	Energy	6.30	Transmission and distribution networks for renewable and low-carbon gases
6	Energy	6.31	Transmission and distribution of electricity
15	Transport	15.10	Infrastructure for water transport

16	Water supply, sewerage, waste management, and remediation	16.1	Anaerobic digestion of bio-waste
16	Water supply, sewerage, waste management, and remediation	16.2	Anaerobic digestion of sewage sludge
16	Water supply, sewerage, waste management, and remediation	16.3	Collection and transport of hazardous waste
16	Water supply, sewerage, waste management, and remediation	16.4	Collection and transport of non-hazardous and hazardous waste
16	Water supply, sewerage, waste management, and remediation	16.5	Collection and transport of non-hazardous waste in source-segregated fractions
16	Water supply, sewerage, waste management, and remediation	16.6	Composting of bio-waste
16	Water supply, sewerage, waste management, and remediation	16.7	Construction, extension, and operation of waste-water collection and treatment
16	Water supply, sewerage, waste management, and remediation	16.8	Construction, extension, and operation of water collection, treatment, and supply systems
16	Water supply, sewerage, waste management, and remediation	16.9	Depollution and dismantling of end-of-life products
16	Water supply, sewerage, waste management, and remediation	16.10	Desalination
16	Water supply, sewerage, waste management, and remediation	16.11	Landfill gas capture and utilisation
16	Water supply, sewerage, waste management, and remediation	16.12	Material recovery from non-hazardous waste
16	Water supply, sewerage, waste management, and remediation	16.13	Phosphorus recovery from waste water
16	Water supply, sewerage, waste management, and remediation	16.14	Production of alternative water resources for purposes other than human consumption
16	Water supply, sewerage, waste management, and remediation	16.15	Recovery of bio-waste by anaerobic digestion or composting
16	Water supply, sewerage, waste management, and remediation	16.16	Remediation of contaminated sites and areas
16	Water supply, sewerage, waste management, and remediation	16.17	Remediation of legally non-conforming landfills and abandoned or illegal waste dumps
16	Water supply, sewerage, waste management, and remediation	16.18	Renewal of waste-water collection and treatment
16	Water supply, sewerage, waste management, and remediation	16.19	Renewal of water collection, treatment, and supply systems
16	Water supply, sewerage, waste management, and remediation	16.20	Sorting and material recovery of non-hazardous waste
16	Water supply, sewerage, waste management, and remediation	16.21	Sustainable urban drainage systems (SUDS)
16	Water supply, sewerage, waste management, and remediation	16.22	Transport of CO_2
16	Water supply, sewerage, waste management, and remediation	16.23	Treatment of hazardous waste
16	Water supply, sewerage, waste management, and remediation	16.24	Underground permanent geological storage of CO_2
16	Water supply, sewerage, waste management, and remediation	16.25	Urban waste-water treatment
16	Water supply, sewerage, waste management, and remediation	16.26	Water supply

GICS 15: Materials

Large emissions-intensive industries are part of this sector. The TEA the steel, aluminium, and cement industries, but only parts of the energy- and emissions-intensive chemical industry. Inorganic chemical industries – such as chlorine production – is not within the listed TEA. However, chlorine production is the main electricity-consuming process in the chemical industry after oxygen and nitrogen production. Copper, gold, silver ,and other precious metals and minerals are also not covered by the TEA.

GICS Sector Definition: Materials Sector

The Materials sector includes companies that manufacture chemicals, construction materials, forest products, glass, paper, and related packaging products, and metals, minerals, and mining companies, including producers of steel.

Table 15: GICS class 15: Materials

				Sector No.	Sector	Matching EU Taxonomy Activities	Not Included	Relevant (< 2)	Increased Relevance (£ 5)	High Relevance (> 5/sector)
15 Materials								5	9	2
1510 Materials	151010	Chemicals	15101010 Commodity Chemicals	12	Manufacturing	12.6 | 12.8 | 12.16 | 12.17 |12.23			5	
			15101020 Diversified Chemicals	12	Manufacturing	12.19 |12.20		2		
			15101030 Fertilisers & Agricultural Chemicals	12	Manufacturing	| 12.3 |		1		
			15101040 Industrial Gases							
			15101050 Specialty Chemicals							
	151020	Construction Materials	15102010 Construction Materials	12	Manufacturing	12.7		1		
	151030	Containers & Packaging	15103010 Metal & Glass Containers							
			15103020 Paper Packaging							
	151040	Metals & Mining	15104010 Aluminium	12	Manufacturing	| 12.2 |				1
			15104020 Diversified Metals & Mining							
			15104025 Copper							
			15104030 Gold							
			15104040 Precious Metals & Minerals							
			15104045 Silver							
			15104050 Steel	12	Manufacturing	|12.13 |				1
	151050	Paper & Forest Products	15105010 Forest Products	7	Environmental protection and restoration activities	|7.1 |		1		
				9	Forestry	9.1 |9.2 | 9.3 | 9.4			4	
			15105020 Paper Products							

Table 16: GICS-specific Taxonomy Economic Activities

7	Environmental protection and restoration activities	7.1	Conservation, including restoration, of habitats [1], ecosystems [2] and species
9	Forestry	9.1	Afforestation
9	Forestry	9.2	Conservation forestry
9	Forestry	9.3	Forest management
9	Forestry	9.4	Rehabilitation and restoration of forests, including reforestation and natural forest regeneration after an extreme event
12	Manufacturing	12.1	Manufacture of active pharmaceutical ingredients or active substances
12	Manufacturing	12.2	Manufacture of aluminium
12	Manufacturing	12.3	Manufacture of anhydrous ammonia
12	Manufacturing	12.6	Manufacture of black carbon
12	Manufacturing	12.7	Manufacture of cement
12	Manufacturing	12.8	Manufacture of chlorine
12	Manufacturing	12.13	Manufacture of iron and steel
12	Manufacturing	12.16	Manufacture of nitric acid
12	Manufacturing	12.17	Manufacture of organic basic chemicals
12	Manufacturing	12.19	Manufacture of plastic packaging goods
12	Manufacturing	12.20	Manufacture of plastics in primary form
12	Manufacturing	12.23	Manufacture of soda ash

GICS 20: Industrials

The Industrials sector (20) covers the entire *Transport* sector, including the manufacturing of vehicles, planes ,and ships, machinery but also construction and building products, and parts of the service sector. The very diverse range of industries – with road transport the highest GHG emitter – is only sparsely covered by the economic activities defined under the EU Taxonomy. The entire *Machinery* sector and the *Commercial Services* sector are not included in the TEA.

GICS Sector Definition: Industrials Sector

The Industrials sector includes manufacturers and distributors of capital goods, such as in aerospace and defence products, building products, electrical equipment and machinery, and companies that offer construction and engineering services. It also includes providers of commercial and professional services, including printing, environmental, and facilities services, office services and supplies, security and alarm services, human resources and employment services, and research and consulting services. It also includes companies that provide transportation services.

Table 17: GICS class 20: Industrials

				Sector No.	Sector	Matching EU Taxonomy Activities	Not Included	Relevant (< 2)	Increased Relevance (£ 5)	High Relevance (> 5/sector)
20 Industrials								**13**	**28**	**7**
2010 Capital Goods	201010	Aerospace & Defence	20101010 Aerospace & Defence	12	Manufacturing	12.26		1		
	201020	Building Products	20102010 Building Products	12	Manufacturing	12:10		1		
	201030	Construction & Engineering	20103010 Construction & Engineering	3	Construction and real estate	3.2 | 3.3 | 3.4 | 3.5 | 3.6 | 3.9 | 3.10				7
				12	Manufacturing	| 12.18 |		1		
	201040	Electrical Equipment	20104010 Electrical Components & Equipment	3	Construction and real estate	3.7		1		
				12	Manufacturing	12.5 | 12.9 | 12.11 | 12.22			4	
			20104020 Heavy Electrical Equipment	6	Energy	|6.20 |		1		
	201050	Industrial Conglomerates	20105010 Industrial Conglomerates							
	201060	Machinery	20106010 Construction Machinery & Heavy Trucks							
			20106015 Agricultural & Farm Machinery							
			20106020 Industrial Machinery							
	201070	Trading Companies & Distributors	20107010 Trading Companies & Distributors							
2020 Commercial & Professional Services	202010	Commercial Services & Supplies	20201010 Commercial Printing							
			20201050 Environmental & Facilities Services	4	Disaster risk management	4.1 | 4.2 | 4.3			3	
			20201060 Office Services & Supplies							
			20201070 Diversified Support Services							
			20201080 Security & Alarm Services							
	202020	Professional Services	20202010 Human Resource & Employment Services							
			20202020 Research & Consulting Services	13	Professional, scientific, and technical activities	13.1 | 13.2 | 13.3 | 13.4 | 13.5			5	
			20202030 Data Processing and Outsourced Services							

4. Allocation Of GICS Classes to Taxonomy Economic Activities continued

				Sector No.	Sector	Matching EU Taxonomy Activities	Not Included	Relevant (< 2)	Increased Relevance (£ 5)	High Relevance (> 5/sector)
20 Industrials								13	28	7
2030 Transportation	203010	Air Freight & Logistics	20301010 Air Freight & Logistics	15	Transport	| 15.16 |		1		
	203020	Passenger Airlines	20302010 Passenger Airlines							
	203030	Marine Transportation	20303010 Marine Transportation	15	Transport	15.5 | 15.11 | 15.12 | 15.20 | 15.21			5	
	203040	Ground Transportation	20304010 Rail Transportation	12	Manufacturing	| 12.21 |		1		
				15	Transport	15.3		1		
			20304030 Cargo Ground Transportation	15	Transport	| 15.4 |		1		
			20304040 Passenger Ground Transport	12	Manufacturing	| 12.14 |		1		
				15	Transport	15.6 | 15.22 | 15.23			3	
	203050	Transportation Infrastructure	20305010 Airport Services	15	Transport	15.1 | 15.2 | 15.13 | 15.14			4	
			20305020 Highways & Rail Tracks	3	Construction and real estate	| 3.8 |		1		
				15	Transport	15.7 | 15.8 | 15.9 | 15.17			4	
			20305030 Marine Ports & Services	15	Transport	15.18 | 15.19		2		

Table 18: GICS-specific Taxonomy Economic Activities

3	Construction and real estate	3.2	Construction of new buildings
3	Construction and real estate	3.3	Demolition and wrecking of buildings and other structures
3	Construction and real estate	3.4	Installation, maintenance, and repair of charging stations for electric vehicles in buildings (and parking spaces attached to buildings)
3	Construction and real estate	3.5	Installation, maintenance, and repair of energy efficiency equipment
3	Construction and real estate	3.6	Installation, maintenance, and repair of instruments and devices for measuring, regulation and controlling energy performance of buildings
3	Construction and real estate	3.7	Installation, maintenance, and repair of renewable energy technologies
3	Construction and real estate	3.8	Maintenance of roads and motorways
3	Construction and real estate	3.9	Renovation of existing buildings
4	Disaster risk management	4.1	Emergency services
4	Disaster risk management	4.2	Flood risk prevention and protection infrastructure
4	Disaster risk management	4.3	Nature-based solutions for flood and drought risk prevention and protection
6	Energy	6.20	Pre-commercial stages of advanced technologies to produce energy from nuclear processes with minimal waste from the fuel cycle
12	Manufacturing	12.5	Manufacture of batteries (2X)
12	Manufacturing	12.9	Manufacture of electrical and electronic equipment (2X)
12	Manufacturing	12.10	Manufacture of energy efficiency equipment for buildings
12	Manufacturing	12.12	Manufacture of hydrogen (2X)
12	Manufacturing	12.18	Manufacture of other low-carbon technologies
12	Manufacturing	15:20	Sea and coastal freight water transport, vessels for port operations and auxiliary activities
12	Manufacturing	12.22	Manufacture of renewable energy technologies (2X)
12	Manufacturing	12.26	Manufacture of aircraft
13	Professional, scientific, and technical activities	13.1	Close-to-market research, development, and innovation
13	Professional, scientific, and technical activities	13.2	Consultancy for physical climate risk management and adaptation
13	Professional, scientific, and technical activities	13.3	Engineering activities and related technical consultancy dedicated to adaptation to climate change
13	Professional, scientific, and technical activities	13.4	Professional services related to energy performance of buildings
13	Professional, scientific, and technical activities	13.5	Research, development, and innovation for direct air capture of CO_2

15	Transport	15.1	Air transport ground handling operations
15	Transport	15.2	Airport infrastructure
15	Transport	15.3	Freight rail transport
15	Transport	15.4	Freight transport services by road
15	Transport	15.5	Infrastructure enabling low-carbon water transport
15	Transport	15.6	Infrastructure enabling low-carbon road transport and public transport
15	Transport	15.7	Infrastructure enabling road transport and public transport
15	Transport	15.8	Infrastructure for personal mobility, cycle logistics
15	Transport	15.9	Infrastructure for rail transport
15	Transport	15.11	Inland freight water transport
15	Transport	15.12	Inland passenger water transport
15	Transport	15.13	Leasing of aircraft
15	Transport	15.14	Low-carbon airport infrastructure
15	Transport	15.16	Passenger and freight air transport
15	Transport	15.17	Passenger inter-urban rail transport
15	Transport	15.18	Retrofitting of inland water passenger and freight transport
15	Transport	15.19	Retrofitting of sea and coastal freight and passenger water transport
15	Transport	15.20	Sea and coastal freight water transport, vessels for port operations and auxiliary activities
15	Transport	15.21	Sea and coastal passenger water transport
15	Transport	15.22	Transport by motorbikes, passenger cars, and light commercial vehicles
15	Transport	15.23	Urban and suburban transport, road passenger transport

GICS 25: Consumer Discretionary

The *Consumer Discretionary* (25) sector covers parts of the automobile industry and a large part of consumer goods and products, from furniture to electronics, and from fashion products to shopping malls and internet marketing. Entertainment, hotels, restaurants, and even cruise lines are also part of this sector. A very small part of this GICS sector is covered by TEA. The TEA focus on repair and re-use (= re-sell) and accommodation activities – which are most likely to support sustainable building standards for those venues and the GHG-free energy supply for the buildings used for those activities.

However, it is difficult to quantify actual emissions standards.

GICS Sector Definition: Consumer Discretionary Sector

The Consumer Discretionary Sector encompasses those businesses that tend to be the most sensitive to economic cycles. Its manufacturing segment includes automobiles and components, household durable goods, leisure products, and textiles and apparel. The services segment includes hotels, restaurants, and other leisure facilities. It also includes distributors and retailers of consumer discretionary products.

Table 19: GICS class 25: Consumer Discretionary

				Sector No.	Sector	Matching EU Taxonomy Activities	Not Included	Relevant (< 2)	Increased Relevance (£ 5)	High Relevance (> 5/sector)
25 Consumer Discretionary								3	6	0
2510 Automobiles & Components	251010	Auto Components	25101010 Auto Parts & Equipment							
			25101020 Tyres & Rubber							
	251020	Automobiles	25102010 Automobile Manufacturers	12	Manufacturing	| 12.4 |		1		
			25102020 Motorcycle Manufacturers							
2520 Consumer Durables & Apparel	252010	Household Durables	25201010 Consumer Electronics							
			25201020 Home Furnishings							
			25201030 Homebuilding							
			25201040 Household Appliances							
			25201050 Housewares & Specialties							
	252020	Leisure Products	25202010 Leisure Products							
	252030	Textiles, Apparel, & Luxury Goods	25203010 Apparel, Accessories, & Luxury Goods							
			25203020 Footwear							
			25203030 Textiles							

				Sector No.	Sector	Matching EU Taxonomy Activities	Not Included	Relevant (< 2)	Increased Relevance (£ 5)	High Relevance (> 5/sector)
25 Consumer Discretionary								3	6	0
2530 Consumer Services	253010	Hotels, Restaurants, & Leisure	25301010 Casinos & Gaming							
			25301020 Hotels, Resorts, & Cruise Lines	1	Accommodation activities	| 1.1 |		1		
			25301030 Leisure Facilities							
			25301040 Restaurants							
	253020	Diversified Consumer Services	25302010 Education Services	5	Education	| 5.1 |		1		
			25302020 Specialised Consumer Services	14	Services	14.2 | 14.3 | 14.4			3	
2550 Consumer Discretionary Distribution & Retail	255010	Distributors	25501010 Distributors							
	255020	Internet & Direct Marketing Retail	25502020 Internet & Direct Marketing Retail							
	255030	Broadline Retail	25503010 Department Stores							
			25503030 Broadline Retail							
	255040	Specialty Retail	25504010 Apparel Retail	14	Services	14.1 | 14.5 | 14.6			3	
			25504020 Computer & Electronics Retail							
			25504030 Home Improvement Retail							
			25504040 Specialty Stores							
			25504050 Automotive Retail							
			25504060 Home Furnishings Retail							

Table 20: GICS-specific Taxonomy Economic Activities

1	Accommodation activities	1.1	Hotels, holiday, camping grounds, and similar accommodation
5	Education	5.1	Education
12	Manufacturing	12.4	Manufacture of automotive and mobility components
14	Services	14.1	Marketplace for the trade of second-hand goods for re-use
14	Services	14.2	Preparation for re-use of end-of-life products and product components
14	Services	14.3	Product-as-a-service and other circular use- and result-oriented service models
14	Services	14.4	Repair, refurbishment, and remanufacturing
14	Services	14.5	Sale of second-hand goods
14	Services	14.6	Sale of spare parts

GICS 30: Consumer Staples

The GICS sector *Consumer Staples* (30) covers the 'grocery consumption' of consumers, mainly food products and beverages. The economic activities listed in the EU Taxonomy do not cover any activities regarding sustainable food production (reviewer please check). Therefore, the TEA 'Environmental protection and restoration activities', with the sub-category 'Restoration of 'wetlands', was allocated to the GICS sector *Food Products*. The GICS sector does not have a dedicated sector comparable to the NACE sector 'Environmental protection and restoration activities' – which is a short-coming of the GICS system.

GICS Sector Definition: Consumer Staples Sector

The Consumer Staples sector comprises companies whose businesses are less sensitive to economic cycles. It includes manufacturers and distributors of food, beverages, and tobacco and producers of non-durable household goods and personal products. It also includes distributors and retailers of consumer staples, including food and drug retailing companies.

Table 21: GICS class 30: Consumer Staples

				Sector No.	Sector	Matching EU Taxonomy Activities	Not Included	Relevant (< 2)	Increased Relevance (£ 5)	High Relevance (> 5/sector)
30 Consumer Staples								1	0	0
3010 Consumer Staples Distribution & Retail	301010	Consumer Staples Distribution & Retail	30101010 Drug Retail							
			30101020 Food Distributors							
			30101030 Food Retail							
			30101040 Consumer Staples Merchandise Retail							
3020 Food, Beverages, & Tobacco	302010	Beverages	30201010 Brewers							
			30201020 Distillers & Vintners							
			30201030 Soft Drinks							
	302020	Food Products	30202010 Agricultural Products	7	Environmental protection and restoration activities	| 7.2 |		1		
			30202030 Packaged Foods & Meats							
	302030	Tobacco	30203010 Tobacco							
3030 Household & Personal Products	303010	Household Products	30301010 Household Products							
	303020	Personal Care Products	30302010 Personal Care Products							

Table 22: GICS-specific Taxonomy Economic Activities

7	Environmental protection and restoration activities	7.2	Restoration of wetlands

GICS 35: Health Care

The GICS *Health Care* (35) sector is, to a large extent, not included in the TEA sectors. Only the manufacturing of pharmaceutical and medicinal products – which could also be part of the chemical industry, machinery; and/or agricultural sector – is represented in this group. Residential care activities are also covered. However, the impact of residential care on GHG emissions is unclear.

GICS Sector Definition: Health Care Sector

The Health Care sector includes health care providers & services, companies that manufacture and distribute health care equipment and supplies, and health care technology companies. It also includes companies involved in the research, development, production, and marketing of pharmaceuticals and biotechnology products.

Table 23: GICS class 35: Health Care

				Sector No.	Sector	Matching EU Taxonomy Activities	Not Included	Relevant (<2)	Increased Relevance (£ 5)	High Relevance (> 5/sector)
35 Health Care								3	0	0
3510 Health Care Equipment & Services	351010	Health Care Equipment & Supplies	35101010 Health Care Equipment							
			35101020 Health Care Supplies							
	351020	Health Care Providers & Services	35102010 Health Care Distributors							
			35102015 Health Care Services	10	Human health and social work activities	| 10.1 |		1		
			35102020 Health Care Facilities							
			35102030 Managed Health Care							
	351030	Health Care Technology	35103010 Health Care Technology							
3520 Pharmaceuticals, Biotechnology, & Life Sciences	352010	Biotechnology	35201010 Biotechnology							
	352020	Pharmaceuticals	35202010 Pharmaceuticals	12	Manufacturing	12.1 | 12.15		2		
	352030	Life Sciences Tools & Services	35203010 Life Sciences Tools & Services							

Table 24: GICS-specific Taxonomy Economic Activities

10	Human health and social work activities	10.1	Residential care activities
12	Manufacturing	12.1	Manufacture of active pharmaceutical ingredients or active substances
12	Manufacturing	12.15	Manufacture of medicinal products

GICS 40: Financials

Although sustainable finance and GHG targets for financial products are central to the net-zero pathways and the OECM, the economic activities identified by the EU Taxonomy are sparse in this sector. Only life insurance and re-insurance products are covered. The entire remaining finance industry and capital markets are not included in the Taxonomy.

GICS Sector Definition: Financials Sector

The Financials sector contains companies engaged in banking, financial services, consumer finance, capital markets, and insurance activities. It also includes financial exchanges and data and mortgage REITs.

Table 25: GICS class 40: Financials

				Sector No.	Sector	Matching EU Taxonomy Activities	Not Included	Relevant (<2)	Increased Relevance (£ 5)	High Relevance (> 5/sector)
40 Financials								2		
4010 Banks	401010	Banks	40101010 Diversified Banks							
			40101015 Regional Banks							
	401020	Thrifts & Mortgage Finance	40102010 Thrifts & Mortgage Finance							
4020 Financial Services	402010	Financial Services	40201020 Diversified Financial Services	8	Financial and insurance activities	| 8.1 |		1		
			40201030 Multi-Sector Holdings							
			40201040 Specialised Finance							
			40201050 Commercial and Residential Mortgage Finance							
			40201060 Transaction and Payment Processing Services							
	402020	Consumer Finance	40202010 Consumer Finance							
	402030	Capital Markets	40203010 Asset Management & Custody Banks							
			40203020 Investment Banking & Brokerage							
			40203030 Diversified Capital Markets							
			40203040 Financial Exchanges & Data							
	402040	Mortgage Real-Estate Investment Trusts (REITs)	40204010 Mortgage REITs							
4030 Insurance	403010	Insurance	40301010 Insurance Brokers							
			40301020 Life & Health Insurance							
			40301030 Multi-line Insurance							
			40301040 Property & Casualty Insurance							
			40301050 Re-insurance	8	Financial and insurance activities	| 8.2 |		1		

Table 26: GICS-specific Taxonomy Economic Activities

8	Financial and insurance activities	8.1	Non-life insurance: underwriting of climate-related perils
8	Financial and insurance activities	8.2	Re-insurance

GICS 45: Information Technology

The EU-Taxonomy-listed economic activities for the GICS class Information Technology (45) cover the software side but not all the hardware side of this industry. Included in software services are environmental services and environmental monitoring to collect data.

GICS Sector Definition: Information Technology sector

The Information Technology sector comprises companies that offer software and information technology services, and manufacturers and distributors of technology hardware and equipment, such as communications equipment, cellular phones, computers and peripherals, electronic equipment and related instruments, and semiconductors and related equipment and materials.

Table 27: GICS class 45: Information Technology

				Sector No.	Sector	Matching EU Taxonomy Activities	Not Included	Relevant (< 2)	Increased Relevance (£ 5)	High Relevance (> 5/sector)
45 Information Technology								5	5	0
4510 Software & Services	451020	IT Services	45102010 IT Consulting & Other Services	11	Information and communication	11.1 | 11.4 | 11.5 | 11.6 | 11.7			5	
			45102020 Data Processing & Out-sourced Services	11	Information and communication	11.2 | 11.3		2		
				15	Transport	| 15.15 |		1		
			45102030 Internet Services & Infrastructure							
	451030	Software	45103010 Application Software							
			45103020 Systems Software							
4520 Technology Hardware & Equipment	452010	Communications Equipment	45201020 Communications Equipment							
	452020	Technology Hardware, Storage, & Peripherals	45202030 Technology Hardware, Storage & Peripherals							
	452030	Electronic Equipment, Instruments, & Components	45203010 Electronic Equipment & Instruments							
			45203015 Electronic Components							
			45203020 Electronic Manufacturing Services	12	Manufacturing	12.24 | 12.25		2		
			45203030 Technology Distributors							
4530 Semi-conductors & Semi-conductor Equipment	453010	Semi-conductors & Semi-conductor Equipment	45301010 Semi-conductor Materials & Equipment							
			45301020 Semi-conductors							

Table 28: GICS-specific Taxonomy Economic Activities

11	Information and communication	11.1	Computer programming, consultancy, and related activities
11	Information and communication	11.2	Data processing, hosting, and related activities
11	Information and communication	11.3	Data-driven solutions for GHG emissions reductions
11	Information and communication	11.4	Programming and broadcasting activities
11	Information and communication	11.5	Provision of IT/OT data-driven solutions
11	Information and communication	11.6	Provision of IT/OT data-driven solutions for leakage reduction
11	Information and communication	11.7	Software enabling physical climate risk management and adaptation
12	Manufacturing	12.24	Manufacture, installation, and associated services for leakage control technologies enabling leakage reduction and prevention in water supply systems
12	Manufacturing	12.25	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
15	Transport	15.15	Operation of personal mobility devices, cycle logistics

GICS 50: Communication Services

Communication Services (50) is, to a large extent, not part of the listed Taxonomy Economic Activities. The three TEA allocated to this GICS sector are all related educational activities that promote climate adaptation or climate activities.

In the technical context of the OECM, these activities are impossible to cover. The use of equipment that requires energy and creates emissions is measurable. The content of a movie or art performance is not measurable in terms of emissions.

GICS Sector Definition: Communication Services sector

The Communication Services sector includes companies that facilitate communication and offer related content and information through various mediums. It includes telecom and media and entertainment companies, including producers of interactive gaming products and companies engaged in content and information creation or distribution through proprietary platforms.

Table 29: GICS class 50: Communication Services

				Sector No.	Sector	Matching EU Taxonomy Activities	Not Included	Relevant (< 2)	Increased Relevance (<=/ 5)	High Relevance (> 5/sector)
50 Communication Services								3		
5010 Telecommunication Services	501010	Diversified Telecommunication Services	50101010 Alternative Carriers							
			50101020 Integrated Telecommunication Services							
	501020	Wireless Telecommunication Services	50102010 Wireless Telecommunication Services							
5020 Media & Entertainment	502010	Media	50201010 Advertising							
			50201020 Broadcasting							
			50201030 Cable & Satellite							
			50201040 Publishing							
	502020	Entertainment	50202010 Movies & Entertainment	2	Arts, entertainment, and recreation	2.1 | 2.2		2		
			50202020 Interactive Home Entertainment							
	502030	Interactive Media & Services	50203010 Interactive Media & Services	2	Arts, entertainment, and recreation	| 2.3 |		1		

Table 30: GICS-specific Taxonomy Economic Activities

2	Arts, entertainment, and recreation	2.1	Creative arts and entertainment activities
2	Arts, entertainment, and recreation	2.2	Libraries, archives, museums, and cultural activities
2	Arts, entertainment, and recreation	2.3	Motion picture, video, and television programme production, sound recording, and music publishing activities

GICS 60: Real Estate

The *Real Estate* (60) sector covers buildings, which represent 16% of Europe's energy-related CO_2 emissions. However, only one TEA can be allocated to this sector, designated the 'Acquisition and ownership of buildings'.

GICS Sector Definition: Real Estate sector

The Real Estate sector contains companies engaged in real-estate development and operation. It also includes companies offering real-estate-related services and equity real estate investment trusts (REITs).

Table 31: GICS class 60: Real Estate

				Sector No.	Sector	Matching EU Taxonomy Activities	Not Included	Relevant (< 2)	Increased Relevance (£ 5)	High Relevance (> 5/sector)
60 Real Estate										
6010 Equity Real-Estate Investment Trusts (REITs)	601010	Equity Real-Estate Investment Trusts (REITs)	60101010 Diversified REITs	1	Construction and real estate	| 3.1 |		1		
	601025	Industrial REITs	60102510 Industrial REITs							
	601030	Hotel and Resort REITs	60103010 Hotel & Resort REITs							
	601040	Office REITs	60104010 Office REITs							
	601050	Health Care REITs	60105010 Health Care REITs							
			60106010 Multi-Family Residential REITs							
			60106020 Single-Family Residential REITs							
	601070	Retail REITs	60107010 Retail REITs							
	601080	Specialised REITs	60101080 Specialised REITs							
			60108010 Other Specialised REITs							
			60108020 Self-Storage REITs							
			60108030 Telecom Tower REITs							
			60108040 Timber REITs							
			60108050 Data Centre REITs							
	601020	Real-Estate Management & Development	60201010 Diversified Real-Estate Activities							
			60201020 Real-Estate Operating Companies							
			60201030 Real-Estate Development							
			60201040 Real-Estate Services							

Table 32: GICS-specific Taxonomy Economic Activities

3	Construction and real estate	3.1	Acquisition and ownership of buildings

5 Economy-wide coverage of taxonomy economic activities (GDP-GICS-TEA)

Based on the allocation of Taxonomy Economic Activities (TEA) to all the GICS sectors documented in section 3, the economy-wide coverage of the TEA is calculated. This calculation provides an estimate of the entire coverage of economic activities in relation to the overall economic activity. The emissions covered by the TEA are calculated based on this estimate.

Two examples are:

- **Taxonomy Economic Activities cover an entire GICS class:** The total GDP of all EU27 countries in 2020 was US$15.1 trillion and 55 *Utilities* contributed around US$800 billion. The economic activities defined under the EU Taxonomy that were allocated to the GICS 55 *Utilitie*s sector cover all the economic activities in this class. Therefore, 100% of the *Utilities* sector is covered – both with regard to the economic value (in US$) and to the emissions in tCO_2 per year.
- **Taxonomy Economic Activities that do not cover an entire GICS class:** Sector 30 *Consumer Staples* contributed around US$850 billion, 5.6% of the entire European GDP. The economic activities defined under the EU Taxonomy that were allocated to GICS sector 30 *Consumer Staples* cover only a small fraction. Of the economic activities in the entire GICS 30 class, only 302020 2010 *Agricultural Products* was allocated to the TEA (no. 7.2 – see section 3.3.6). The economic value allocated to this sub-sector was US$331 million 2% of the overall value of GICS class 30. Based on this, 2% of the annual emissions of GICS 30 are allocated to TEAs.

5.1 Calculation method to determine the economy-wide taxonomy economic activity coverage

Table 33 provides the summary results of our analysis of the economy-wide TEA coverage. The following list presents the content of the table (by column) and explains the calculation method.

Column A: Name of the GICS class

Column B: Coverage of TEA by GICS class – red, no coverage; green, high coverage

Column C: Number of TEA allocated to 8-digit GICS sector for each 2-digit GICS class

Column D: Shares of TEA allocated to 8-digit GICS sector for each 2-digit GICS class

Column E: Total value of all 8-digit GICS sectors covered by TEA within the 2-digit GICS class

Column F: Total share of the economic value covered by TEA within a 2-digit GICS class

Column G: Total energy-related CO_2 emission covered by TEA within a 2-digit GICS class

Column H: Total share of energy-related CO_2 emissions covered by TEA within a 2-digit GICS class

Column I: Economic value of the 2-digit GICS class

Column K: Energy-related CO_2 emission of the 2-digit GICS class

Column L: Assignment of the GICS class – supply (primary & secondary energy) or demand (end-use)

The calculation of the emissions in [G] is based on the emissions [K] and the economic coverage of the TEA [F].

Table 33: Economy-wide coverage of the Taxonomy Economic Activities regarding GDP and total energy-related CO_2 emissions – for 2020

A	B	C	D	E	F	G	H	I	K	L
GICS		Economic Activities (TEA) Number & coverage		GDP share of GICS sector covered by Taxonomy Economic Activities		Energy-related CO_2 covered by allocation of the TEA		GDP by GICS class	Energy-related CO_2 by GICS sector	
		[1]	[%]	[million $]	[%]	[$MtCO_2/a$]	[%] of total emissions	[million $]	[$MtCO_2/a$]	
10 Energy		3	2%	2,497	0.02%	0.39	0.02%	33,207	2,518	Primary
55 Utilities		55	36%	804,456	5.04%	70.18	5.04%	804,456	1,391	Secondary
Supply		58	38%	806,953	5.06%					Supply
15 Materials		16	11%	913,058	5.73%	19.64	5.73%	1,607,092	343	End-use
20 Industrials		48	32%	1,615,494	10.13%	68.23	10.13%	3,033,857	674	
25 Consumer Discretionary		9	6%	193,799	1.22%	1.88	1.22%	1,496,348	155	
30 Consumer Staples		1	1%	331,556	2.08%	2.70	2.08%	850,753	130	
35 Health Care		3	2%	215,801	1.35%	1.46	1.35%	1,034,875	108	
40 Financials		2	1%	185,833	1.17%	1.00	1.17%	1,765,410	86	
45 Information Technology		10	7%	168,923	1.06%	2.62	1.06%	731,999	247	
50 Communication Services		3	2%	198,070	1.24%	4.28	1.24%	990,352	345	
60 Real Estate		1	1%	199,984	1.25%	4.84	1.25%	3,599,714	386	
End-use		93	62%	4,022,518	26.62%	106.644	4.31%	15,110,400	2,473	
Total		151	100%	4,829,471	30.35%	176.827	7.2%		2,473	

Based on this methodology – and when the EU Taxonomy is fully implemented for the entire EU economy – the economic activities defined by the EU Taxonomy will involve 30% of the EU's GDP but only 7.2% of all energy-related CO2 emissions of the European Community (EU27).

6 Methodology: development of OECM taxonomy transformation pathways

The Taxonomy Economic Activities (TEA) that are allocated to GICS classes, as documented in the previous section, provide a 'static' picture of the investment and emissions situations for a specific year. The next step is to develop a methodology that allows the implementation of trajectory-based emission benchmarks for industry processes and pathways towards the full decarbonisation of a specific industry. Our research goal was to develop *Taxonomy Transformation Pathways* based on the One Earth Climate Model (OECM) pathways.

6.1 Methodology development: OECM data for the EU Taxonomy pathways

The OECM calculates the bottom-up energy intensities of different manufacturing technologies and processes, distributes the current utilisation shares to the overall industry sector, and calculates the resulting energy demand and supply based on increasing shares of renewable energy. The results are the industry-process-specific emissions for various industry sectors. To compare the values from the EU Taxonomy and the OECM with each other, the processes reported must be harmonised. In a second step, the calculated results from the OECM must reflect the currently reported values for the base year (2021). In a third step, the trajectory calculated with the OECM until 2050 is compared with the EU benchmarks and informs the percentage of the industry that must operate within those benchmarks to achieve the OECM emissions for the entire European steel industry, for example.

From static benchmarks to transformative pathways

To explain the idea of *Transformation Pathways* for the EU Taxonomy, the following simple example is used.

A benchmark for the best available technical process to produce 1 tonne of material emits 0.5 tCO_2. In comparison, the highest-emitting technology to produce the same material generates 2.0 tCO_2 per tonne. The highest-emitting production technology is currently the process most commonly used in the industry, with a market share of (for example) 95%. In this case, only 5% of production meets the benchmark of 0.5 tCO_2, whereas the other 95% of the production processes does not meet the Taxonomy benchmark.

The best available technology benchmarks for the major industry and service sectors in the EU Taxonomy are similar, to a large extent, to those used for the development of the OECM pathways. An exception is the 1.5°C-aligned technologies for the hard-to-abate sectors (steel, aviation, long-distance maritime transport, and the chemical sector), where disruptive technologies, such as hydrogen-based steel making and synthetic fuels and chemicals, are required for sustainable pathways. These disruptive technologies are currently not covered in the EU Best Available Technology Reference documents (BREFs). However, the OECM takes the existing production technologies into account and provides – in addition – the average emissions per tonne of material (or service) for 5-year intervals from 2025 to 2050.

The OECM pathways provide Paris Agreement-aligned mitigation pathways for various sectors and countries, which allow an industry sector to develop a sector-specific transformative pathway by taking increased shares of the best available technologies. The OECM does not take into account all new technologies currently under development. Table 34 presents a simple example with two different technologies and an increased market share of the best available technology. The 'average emissions' represents the OECM sectoral pathway. To implement the OECM pathway, the best available technology must increase – in this example – from a 5% market share in 2025 to a 20% market share in 2030 and a 100% share in 2050.

Table 34: Example – Towards Taxonomy Transformation Pathways

		2025	2030	2050
Best available technology	[tCO_2/tonne material]	0.500	0.500	0.500
Market share of best available technology	[%]	5%	20%	100%
Highest-emitting technology	[tCO_2/tonne material]	2.000	2.000	2.000
Market share of highest-emitting technology	[%}	95%	80%	0%
Average emissions = OECM sectoral pathway	[tCO_2/tonne material]	1.925	1.700	0.500

The 'average emissions' for each tonne of steel, cement, or aluminium produced per square metre of commercial building or per passenger kilometre for vehicles are provided by the following OECM pathways and form the basis for a Taxonomy Transformation Pathway. Each industry can achieve the appropriate emissions trajectory by increasing the market share of the best available technology and an orderly phase-out of current production processes.

What must be done to harmonise the Taxonomy values with the OECM?

The EU emissions benchmarks for different processes and the bottom-up OECM calculation of industry-specific emissions – for today and the future – are based on energy intensities for specific (manufacturing) technologies and the supply trajectories for generation technologies. Both parameters – the EU benchmarks, which are 'technology agnostic', and the OECM results must match. The OECM will add additional valuable information on how the entire industry will perform (regarding emissions) and what percentage of the manufacturing plants must use new technologies to meet the EU benchmark for the entire industry.

The following section describes the application of this methodology to the main industry sectors. The *Steel* sector, as the first described sector, serves as a case study for the newly developed methodology.

6.2 Steel industry: benchmarks and OECM results

As documented in section 1.3, the EU Taxonomy distinguishes between *climate mitigation* and *climate adaptation* emissions values. The *mitigation* emissions values are always lower than those in the *adaptation* category. Therefore, these are essentially the upper and lower limits of emissions, respectively.

For the *Steel* sector, *climate mitigation* is demonstrated by lower greenhouse gas (GHG) emissions benchmarks for sector activities (see Table 35), which can be achieved by phasing-out fossil-fuel-based production facilities (blast oxygen furnace-blast furnace [BOF–BF] technology). At the same time, the benchmarks encourage investment in and a shift to a green (hydrogen-based direct reduced iron, DRI-H_2) infrastructure. It should be noted that the EU Taxonomy supports natural-gas-powered DRI facilities in addition to green infrastructure, which constitutes climate mitigation compared with 100% DRI-H_2 (hydrogen-based steel production), where emissions are lower than in the coal-based BOF–BF route.

The OECM also uses benchmark values – for both energy demand and emissions – for the various technologies used in iron- and steel-making processes. Therefore, the EU benchmarks and the OECM benchmarks must correspond with each other. Furthermore, the OECM calculates a combination of utilised technologies – which add up to an overall emissions trajectory for the entire (iron and steel) industry sector. Overall, steel has a high recycling rate (up to 90%). Quality losses are minimal throughout secondary production and do not compromise the material's strength or reinforcing capacity, allowing the re-use and re-purposing of the material (Arcelor Mittal, 2023[26]; Australian Steel Institute, 2024[27]). Although the steel industry has obvious potential to contribute to the circular economy, the EU Taxonomy does not list its activities as a 'substantial contribution' (Arcelor Mittal, 2023). Other elements of the circular economy include carbon capture and the use of waste gases and the waste heat produced during steel manufacturing processes. Waste gases and heat are generally used in electricity generation or contribute to other industrial processes, thus improving a plant's energy efficiency.

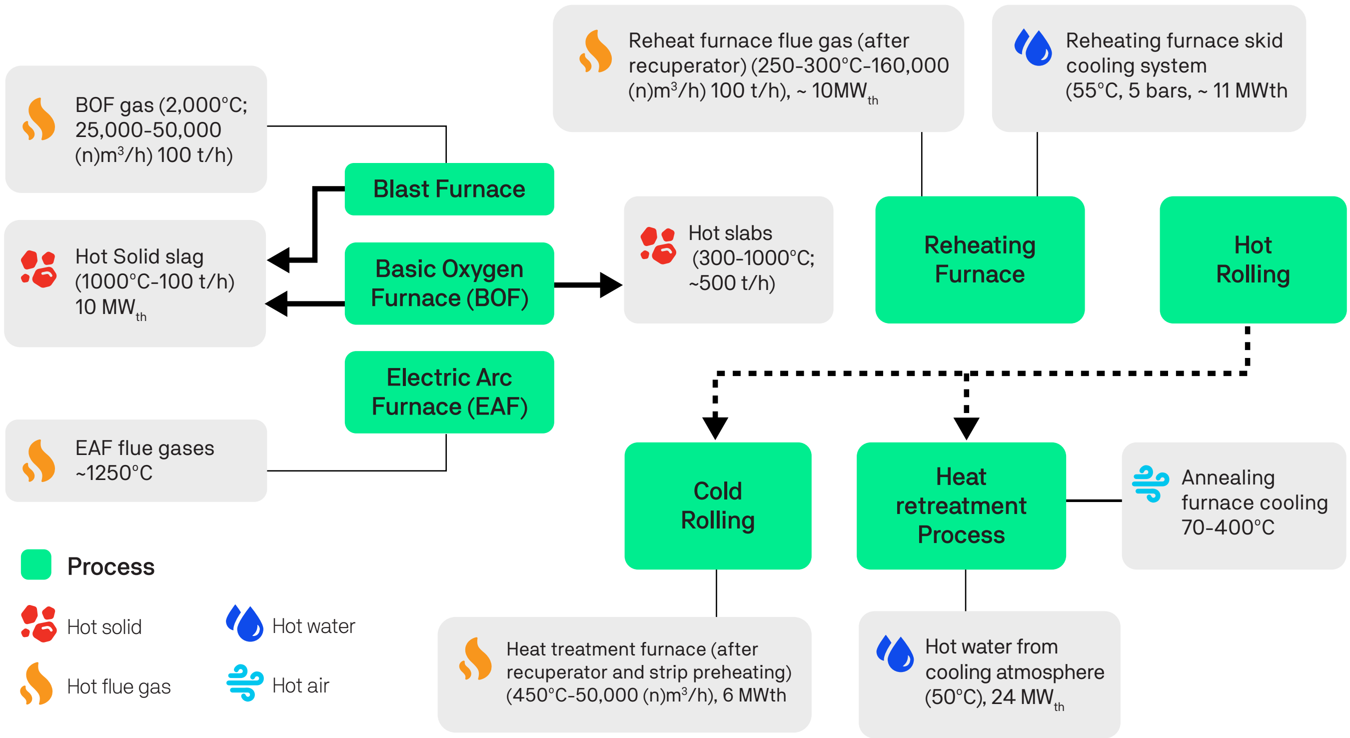
26 Arcelor Mittal (2023); https://corporate.arcelormittal.com/climate-action/steel-s-sustainability-credentials

27 Australian Steel Institute 2024; https://www.steel.org.au/what-we-do/focus-areas/sustainability/

Iron & Steel industry: Benchmarks for processes or technologies?

Waste heat or waste gas is produced during primary (blast furnace) and secondary (electric arc furnace, EAF) steel production. Their recovery is possible for use as different heat resources, which are categorised according to their high or low temperatures (ranging from < 200°C to 200–500°C, and > 500°C). The organic Rankine cycle (ORC) is an established technology used to convert industrial excess heat to electricity at temperatures < 400°C (Ja'fari et al., 2023)[28].

Figure 8: Production of waste and flue gases and their re-application to subsequent processes (Ja'fari et al., 2023)



During secondary (scrap-based) steel production, waste gases are produced through the melting of scrap or directly reduced iron in an EAF using carbon electrodes (EAF flue gases). '*As the hot waste gases leave the EAF, combustion air is introduced to the pipe to convert the existing CO into CO_2 (post-combustion CO control)*' (Bailera et al., 2021)[29]. During the BO–BF process, coke oven flue gases in addition to high-temperature liquids, including high-temperature iron slag, steel slag, and high-temperature water, can become heat recovery sources (Ja'fari et al., 2023). The applications of waste gases or waste heat include in reheating the furnace (Figure 8), and hot residual gases are used to maintain high temperatures and reduce fluctuations in the system. The application of the ORC technology can increase the energy efficiency of steel production plants by up to 25% (Ja'fari et al., 2023).

28 Ja'fari et al. (2023). Waste heat recovery in iron and steel industry using organic Rankine cycles. *Chemical Engineering Journal (Lausanne, Switzerland.* 1996:477:146925. https://doi.org/10.1016/j.cej.2023.146925

29 Bailera, M., Lisbona, P., Peña, B., & Romeo, L. M. (2021). A review on CO_2 mitigation in the iron and steel industry through Power to X processes. *Journal of CO_2 Utilization*, *46*, 101456. https://doi.org/10.1016/j.jcou.2021.101456

6.3 Data requirements for reporting and transparency

A key aspect of harmonising the OECM calculations with the EU Taxonomy benchmarks is to compare the data requirements and the data available. In this research, we use EU Navigator (EU Taxonomy assessment tool), which includes technology-related production data and economic data:

1. Production- and plant-related data.
2. Economic data
   - Assets
   - Financial information, including:
     - turnover
     - capital expenditure (CapEx)
     - operational expenditure (OpEx)–investment.
3. Emissions-related data (by material, production route).

Currently covered, under the EU Taxonomy, are direct production processes for iron and steel production. Two different emission categories are included in the EU Taxonomy: A. *climate mitigation* and B. *climate adaptation*.

A. Climate mitigation – Substantial contribution

Iron and steel manufacture, during which GHG emissions, reduced by the amount of emissions assigned to the production of waste gases in accordance with point 10.1.5(a) of Annex VII to Regulation (EU) 2019/331, do not exceed the following values in the different steps of the manufacturing process:

1. hot metal = 1.331 tCO_2e/tonne product
2. sintered ore = 0.163 tCO_2e/tonne product
3. coke (excluding lignite coke) = 0.144 tCO_2e/tonne product
4. iron casting = 0.299 tCO_2e/t product
5. EAF high-alloy steel = 0.266 tCO_2e/tonne product
6. EAF carbon steel = 0.209 tCO_2e/tonne product (tCO_2e = tonne of CO_2 equivalents).

For steel in EAFs producing EAF carbon steel or EAF high-alloy steel, as defined in Commission Delegated Regulation (EU) 2019/331, the steel scrap input relative to product output is not lower than:

- 70% to produce high-alloy steel
- 90% to produce carbon steel.

When the CO_2 that would otherwise be emitted from the manufacturing process is captured for the purpose of underground storage, the CO_2 is transported and stored underground. The OECM does not include carbon capture and storage (CCS) because the introduction of this technology is still very far from market prices, and it seems questionable whether competitive technology costs for CCS can ever be achieved.

B. Climate adaption – the *Do no significant harm* criterion

The activity manufactures one of the following:

1. Iron and steel, during which GHG emissions, reduced by the amount of emissions assigned to the production of waste gases in accordance with point 10.1.5(a) of Annex VII to Regulation (EU) 2019/331, do not exceed the following values applied to the different steps in the manufacturing process:
   a. hot metal = 1.443 tCO_2e/tonne product
   b. sintered ore = 0.242 tCO_2e/tonne product
   c. coke (excluding lignite coke) = 0.237 tCO_2e/tonne product
   d. iron casting = 0.390 tCO_2e/tonne product
   e. EAF high-alloy steel = 0.360 tCO_2e/tonne product
   f. EAF carbon steel = 0.276 tCO_2e/tonne product
2. Steel in EAFs producing EAF carbon steel or EAF high-alloy steel, as defined in Commission Delegated Regulation (EU) 2019/331, for which the steel scrap input relative to product output is:
   a. at least 70% to produce high-alloy steel
   b. at least 90% for production of carbon steel

Other relevant processes, which are currently not covered, include the type of plant or technology, the quantity of plants, ownership information, production locations, plant lifetimes, production routes, and feedstock and energy sources used.

OECM: energy Used and emissions intensities

Emissions-related data from best practice plants is helpful in verifying the EU Taxonomy benchmarks.

Table 35: EU Taxonomy benchmarks for iron- and steel-making activities relative to best practice plants

By Route	By Product/ Sub-installation	Condition	Units	EU Taxonomy Benchmark for GHG Emissions	EU-ETS Benchmark GHG Emissions OECD (2020)	Literature
Primary production (BF)	Hot metal	n/a	tCO_2e/tonne product	1.331	1.328	DRI-NG produces 1.5 tCO_2/product[#]
Primary production (BF)	Sintered ore	n/a	tCO_2e/tonne product	0.163	0.171	0.200 (by plant)*
Primary production	Coke	excluding lignite coke	tCO_2e/tonne product	0.144	0.286	0.794 (by plant)*
Primary production	Iron casting	n/a	tCO_2e tonne product	0.299	0.325	n/a
Electric Arc Furnace (EAF)	High-alloy steel	scrap input ^{3}70%	tCO_2e/tonne product	0.266	0.352	n/a
Electric Arc Furnace (EAF)	Carbon steel	scrap input ^{3} 90%	tCO_2e/tonne product	0.209	0.283	n/a

*Gupta (2014) Sinter Making. https://www.sciencedirect.com/topics/engineering/sintered-ore

**Pardo, N. and Moya, J.A. Prospective scenarios on energy efficiency and CO_2 emissions in the European iron and steel industry. Energy 2013;54:113–128. https://doi.org/10.1016/j.energy.2013.03.015

*** https://publications.jrc.ec.europa.eu/repository/bitstream/JRC129297/JRC129297_01.pdf

OECD (2020) https://www.oecd-ilibrary.org/sites/5e092588-en/index.html?itemId=/content/component/5e092588-en

[#] Worldsteel (2022) Hydrogen (H_2)-based ironmaking. Fact Sheet, https://worldsteel.org/wp-content/uploads/Fact-sheet-Hydrogen-H2-based-ironmaking.pdf

Table 36: Energy intensity per process plant for EU used in the OECM scenario(s)

Plant	Energy Intensity per Process Plant	Coke	Coal	Electricity	Natural gas
Coke	GJ/process plant	-30.1	42.08	0.12	-
Sinter	GJ/process plant	1.37	-	0.09	0.09
Blast Furnace (BF)	GJ/process plant	10.33	4.15	0.16	-
BOF	GJ/process plant	-	-	0.12	0.23
DRI-EAF (gas)	GJ/process plant	-	0.48	2.07	9.7
DRI-EAF (coal)	GJ/process plant	-	24.4	2.27	0.3
EAF (secondary)	GJ/process plant	-	0.48	1.73	0.3
Source: Koolen & Vidovic (2022)					

Table 37: Estimates of specific energy consumption and specific CO_2 emissions per tonne of product in BF–BOF and EAF pathways for iron and steel production in Europe

	Direct Energy (GJ/t)	Direct CO_2 Emissions (tCO_2/tonne)
Coke plant	6.539	0.794
Sinter plant	1.549	0.2
Pellet plant	0.901	0.057
Blast furnace	12.309	1.219
BOS plant	0.853	0.181
Electric arc furnace	2.505	0.24
Bloom, slab, and billet mill	1.783	0.088
Hot strip mill	1.7	0.082
Plate mill	1.905	0.098
Section mill	1.828	0.084
Pickling line	0.222	0.004
Cold mill	0.743	0.008
Annealing	1.086	0.049
Hot dip metal coating	1.491	0.059
Electrolytic metal coating	2.619	0.046
Organic coating	0.758	0.003
Power plant	12.173	1.98
Source: Pardo, N. & Moya, J. A. (2013) Prospective scenarios on energy efficiency and CO_2 emissions in the European iron and steel industry. Energy (Oxford), 2013;54:113-128. https://doi.org/10.1016/j.energy.2013.03.015		

6.4 Steel sector – alignment of EU taxonomy and OECM data

Section 5.2 and section 5.3 provide the background information related to emissions reduction measures for the *Steel* sector. In this section, we compare the EU Taxonomy criteria with OECM data to confirm that the EU Taxonomy criteria are consistent with a 1.5°C increase in global temperature.

Primary steel production

The EU Taxonomy divides the primary steel-making process into four separate processes (hot metal, sintered ore, coke, and iron casting). In contrast, the OECM differentiates between energy-related GHG emissions from electricity generation and emissions from the generation of the heat (process emissions) that is required for steel-making.

Table 36 outlines the criteria and compares the EU Taxonomy criteria against OECM data to confirm that the EU Taxonomy criteria are 1.5°C-compatible. Row 2 compares the EU Taxonomy emissions for hot metal, as outlined in the *climate adaption* (1.331 tCO_2/tonne steel) and the *climate mitigation* criteria (1.328 tCO_2/tonne steel), with OECM projections for specific CO_2 emissions per tonne of steel, combining energy- and process-related data, for which values decline between 2020 and 2050.

The comparison shows that the EU Taxonomy data are aligned with the OECM data in early stages of the timeline (1.34 tCO_2/tonne steel in 2020), but are no longer aligned as the timeline progresses to 2030 (1.04 tCO_2/tonne steel). As a result, the EU data do not meet the emissions reduction requirements for 2050.

With an annual decarbonisation rate of 7% per year, which is recommended by the EU, the emissions benchmark for steel must decrease to 0.44 tCO_2/tonne steel for primary steel and 0.08 tCO_2/tonne steel for secondary steel by 2035 (see Table 38).

Secondary steel production

The EU Taxonomy and OECM data for secondary steel production are consistent early in the time line (for the year 2020), but not beyond 2030. The *climate mitigation* benchmark for carbon steel manufactured via the secondary production route (0.209 tCO_2/tonne steel), as defined by the EU Taxonomy (Table 38 row 8), is compared with the OECM emissions intensity data for secondary steel production. It is consistent with the value for the year 2020 (0.2 tCO_2/tonne steel), but is not consistent into the future, including the projections for the years 2030 (0.04 tCO_2/tonne steel) and 2050 (0.0 tCO_2/tonne steel). The EU Taxonomy criteria for *climate adaption* do not meet the 1.5°C requirements that are outlined by the OECM.

Table 38: Alignment of EU Taxonomy criteria and OECM data for the *Steel* sector by route and process, 2020–2050

					EU Taxonomy		OECM		
		EU Taxonomy Steel Production	**OECM Steel Production**	**Units**	**Climate mitigation**	**Climate adaption**	**2020**	**2030**	**2050**
Benchmark Criteria	**Raw Materials**	-	Iron ore mining – energy intensity	$MtCO_2$/year	--	--	0.1		
	Primary Steel Production	Hot metal	Specific CO_2 emissions per tonne of steel (energy + process)	tCO_2/tonne steel	1.331	1.328	1.34	1.04	0.08
		Sintered ore		tCO_2/tonne steel	0.163	0.171	-	-	-
		Coke		tCO_2/tonne steel	0.144	0.286	-	-	-
		Iron casting		tCO_2/tonne steel	0.299	0.325	-	-	-
			Basic oxygen furnace (BOF) – emission factor	tCO_2/tonne steel			1.46	1.46	1.46
	Secondary Steel Production	High-alloy steel		tCO_2/tonne steel	0.266	0.352	-	-	-
		Carbon steel		tCO_2/tonne steel	0.209	0.283	-	-	-
		--	Emissions intensity – secondary steel – total	tCO_2/tonne steel			0.2	0.04	0.0

Steel Industry: Taxonomy Transformation pathways

The EU Taxonomy benchmarks for the steel industry are among the most detailed and documented compared with those of other industry sectors. For example, the EU Taxonomy benchmarks for chemicals do not include significant high-emissions parts of the *Chemicals* sectors.

Emissions intensities versus energy intensities

Energy intensities for specific industrial processes are technical benchmarks and represent the amount of energy required for a certain technical process executed with the most efficient technology currently available. The energy intensity for a technical process can never be zero.

There are two different kinds of **emissions intensities:**

1. **Emissions intensities for energy-related processes** depend on the energy intensity of a process (see above) and how the energy required is made available. A very efficient technology still requires some energy. If the energy is provided by fossil fuels, even the most efficient process will still have emissions. Only if the required energy has been generated with carbon-free generation technologies and/or fuel will the emissions intensity be zero when the energy intensity is not.
2. **Process-related emissions intensities** are independent of the energy intensity and how the required energy has been generated. Instead, the process itself causes the emissions. An example is cement production: CO_2 is a by-product of a chemical conversion process used in the production of clinker, a component of cement, in which limestone ($CaCO_3$) is converted to lime (CaO). Those emissions can be avoided by a change in the manufacturing process, or perhaps by capturing those emissions. However, capturing emissions does not avoid the emissions themselves, but only contains them. This leads to additional requirements for storage space, technologies to capture the emissions, and others to avoid their release into the environment. The problem of the actual emissions is not solved so there is not a long-term solution.

Table 39 shows the Taxonomy Transformation Pathway for steel based on the OECM 1.5°C mitigation pathway for the EU27 steel industry. The *mitigation* benchmarks reflect the emissions of the currently dominant BOF process of just under 2 tonnes of CO_2 equivalents per tonne of primary steel production (1.94 tCO_2e/tonne steel) and 0.27 tCO_2e/tonne steel for secondary steel production. Although this is a realistic benchmark for the possible specific steel industry emissions in 2025, it is insufficient for a future benchmark that must lead to carbon neutrality by 2050.

Table 39 shows that the OECM emission limits for steel are within the EU-specified decarbonisation rate of 7% per year and will be achieved between 2035 and 2040.

Table 39: Taxonomy Transformation Pathway for steel, based on the OECM 1.5°C mitigation pathway for the EU27 steel industry

Total Materials / Steel			2020	Taxonomy Benchmark: Climate Mitigation for 2025	2025	2030	2035	Decarbonisation rate, 7%/a 2035 (Base: 2024 Emissions)	2040	2045	2050
Market Development	Regional: Mining Iron Ore – production volume in megatonnes per year	[Mt/a]	33		34	36	38		41	44	48
	Annual Production Volume – iron & steel Industry	[Mt/a]	216.4		223.0	235.5	251.3		268.0	288.7	311.0
	Primary Steel Production – share on total production	[%]	60%		50%	45%	40%		37%	35%	52%
	Secondary/Scrap Steel – share on total production	[%]	40%		50%	55%	60%		63%	65%	48%
Energy Intensity	Average Energy Intensity in steel production	[GJ/ tonne steel]	4.7		9.8	9.5	11.0		10.2	10.6	10.5
	Energy Intensity – PRIMARY steel (FINAL ENERGY)	[GJ/ tonne steel]	13.6	13.6	13.6	13.6	12.7		11.1	10.7	10.3
	Energy Intensity – SECONDARY steel (FINAL ENERGY)	[GJ/ tonne steel]	4.3		6.1	6.1	9.8		9.7	10.5	10.7
	Primary Steel – process-related CO_2 emissions	[tCO_2/ tonne steel]	0.00		0.06	0.06	0.04	0.03	0.01	0.01	0.01
	Secondary Steel – process-related CO_2 emissions	[tCO_2/ tonne steel]	0.01		0.01	0.01	0.00	0.00	0.00	0.00	0.00
Carbon Intensity	Primary Steel – Electricity CO_2 emissions	[tCO_2/ tonne steel]	0.14		0.05	0.02	0.01	0.03	0.00	0.00	0.00
	Secondary Steel – Electricity CO_2 emissions	[tCO_2/ tonne steel]	0.31		0.13	0.05	0.04	0.06	0.01	0.00	0.00
	Primary Steel – Process Heat CO_2 emissions	[tCO_2/ tonne steel]	0.92		0.75	0.75	0.52	0.38	0.27	0.15	0.00
	Secondary Steel – Process Heat CO_2 emissions	[tCO_2/ tonne steel]	0.02		0.02	0.02	0.01	0.01	0.00	0.00	0.00
	Primary Steel – energy-related CO_2 emissions	[tCO_2/ tonne steel]	1.06		0.80	0.77	0.53	0.41	0.28	0.15	0.00
	Secondary Steel – energy-related CO_2 emissions	[tCO_2/ tonne steel]	0.33		0.14	0.06	0.04	0.07	0.01	0.00	0.00
	Primary Steel – total CO_2 equivalents (including process emissions)	[tCO_2/ tonne steel]	1.06	1.94	0.86	0.82	0.57	0.44	0.28	0.15	0.01
	Secondary Steel – total CO_2 equivalents (including process emissions)	[tCO_{2e}/ tonne steel]	0.34	0.27	0.15	0.07	0.05	0.08	0.02	0.00	0.00

6.5 Aluminium Industry: EU taxonomy Benchmarks and Compatibility with OECM results

The EU Taxonomy has developed benchmarks for the aluminium manufacturing process. Benchmarks are defined for primary aluminium production, which is 95% more energy-intensive and 92% more carbon-intensive than scrap-based secondary production (BIR, 2024).[30] The EU Taxonomy does not provide benchmark criteria for secondary aluminium production or bauxite mining. In 2023, EU listed bauxite as a critical raw material for the EU, and the manufacture and availability of aluminium are critical in driving the energy transition (EU, 2023).[31]

The EU Taxonomy has developed two sets of GHG emissions benchmark criteria: (a) to ensure substantial contributions to climate mitigation; and (b) to do no significant harm, in the form of climate adaption benchmarks. The GHG emissions thresholds for aluminium manufacturing are defined for direct GHG emissions, indirect GHG emissions, and electricity consumption, and will come into effect in 2025.

Aluminium Industry: Benchmarks for the sector

The benchmark criteria for GHG emissions thresholds for aluminium manufacture, as stated by the EU Taxonomy (2024), are:

Contribution to *climate mitigation*

Manufacture of aluminium with a primary alumina (bauxite) process or secondary aluminium recycling[32].

Substantial contribution criteria

The activity manufactures one of the following:

1. primary aluminium where the economic activity complies with two of the following criteria until 2025 and with the following criteria after 2025:
    a. GHG emissions do not exceed 1.484 tCO_2e per tonne of aluminium manufactured
    b. the average carbon intensity for indirect GHG emissions does not exceed 100 gCO_2e/kWh
    c. the electricity consumption for the manufacturing process does not exceed 15.5 MWh/tonnes Al
2. secondary aluminium.

Contribution to climate adaptation

Manufacture of aluminium through a primary alumina (bauxite) process or secondary aluminium recycling 33.

30 https://www.bir.org/the-industry

31 EC (2023). European Commission: Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs. Grohol, M. and Veeh, C., Study on the critical raw materials for the EU 2023–Final report. Publications Office of the EU. https://data.europa.eu/doi/10.2873/725585

32 The economic activities in this category could be associated with NACE codes C24.42 and C24.53, in accordance with the statistical classification of economic activities established by Regulation (EC) No. 1893/2006.

33 The economic activities in this category could be associated with NACE codes C24.42 and C24.53, in accordance with the statistical classification of economic activities established by Regulation (EC) No. 1893/2006.

Do no significant harm

The activity manufactures one of the following:

1. primary aluminium, where the economic activity complies with two of the following criteria until 2025 and with all of the following criteria after 2025:
   a. GHG emissions do not exceed 1.604 tCO_2e per tonne of aluminium manufactured
   b. indirect GHG emissions do not exceed 270 gCO_2e/kWh
   c. the electricity consumption for the manufacturing process does not exceed 15.5 MWh/tonne Al
2. secondary aluminium.

Table 40: Overview of EU Taxonomy criteria for climate mitigation and adaption showing GHG emissions benchmarks for the *Aluminium* sector

		Units	Climate mitigation	Climate adaption	Variation
Primary Aluminium Production	Bauxite mining	tCO_2 per tonne bauxite	--	--	--
	Direct GHG emissions	tCO_2 per tonne aluminium	1.484	1.604	1.2 (+7%)
	Indirect GHG emissions	gCO_2e/kwh	100	270	170 (+63%)
	Electricity consumption	MWh per tonne aluminium	15.5	15.5	0

The benchmark criteria for climate mitigation are greater than the climate adaption benchmarks. In the case of indirect emissions, the variation between the climate mitigation value and the climate adaption value is more than 60%, which is a significant variance.

Aluminium industry – Alignment of EU Taxonomy and OECM data

In this section, we aim to align the primary aluminium production value – compatible with the Paris Agreement to limit global warming to 1.5°C, as set out in the OECM – and the EU Taxonomy benchmark criteria.

The OECM proposes GHG emission trajectories for the *Aluminium* sector for the EU27 countries. The model calculates bottom-up energy intensities for different aluminium manufacturing routes (primary and secondary production) and different manufacturing processes (clinker and cement). GHG emissions are determined from the base year 2021 and projected to 2050. It is important to note that the OECM distinguishes between energy-related GHG emissions from electricity generation and those from the generation of heat (process emissions). The EU Taxonomy does not make this distinction.

The OECM decarbonises the energy-related GHG emissions by implementing a 100% renewable-energy-based generation portfolio. Process-related emissions arise from the processed material itself or from processes that are necessary to produce the aluminium. The largest process-related GHG emissions arise from the generation of perfluorocarbon (PFC)[34].

Table 40 shows the average energy- and process-related emissions from primary aluminium production globally, published by the International Aluminium Institute. The OECM provides separate benchmarks for energy-related and process-related GHG emissions because their phase-out requires technically different measures.

34 PFC Emissions from Primary Aluminium Production: Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC): The primary aluminium production process has been identified as the largest anthropogenic source of emissions of two perfluorocarbons (PFCs): tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6). Primary aluminium is produced using the Hall-Héroult electrolytic process, where the smelting pot itself acts as the electrolysis cell during the reduction process. When the alumina ore content of the electrolytic bath falls below the critical level required for electrolysis, rapid voltage increases occur, termed "anode effects". Anode effects cause carbon from the anode and fluorine from the dissociated molten cryolite bath to combine, producing CF_4 and C_2F_6. The frequency and duration of anode effects depend primarily on the pot technology and operating procedures. Therefore, emissions of CF_4 and C_2F_6 vary significantly from one aluminium smelter to the next, depending on these parameters.

Table 41: Greenhouse gas emissions intensities for primary aluminium production – global averages in 2022[35]

	Tonnes of CO_2 equivalents per tonne of primary aluminium in 2022 according to the International Aluminium Institute						
	Electricity – Indirect	Thermal Energy – Direct/Indirect	Perfluorocarbon (PFC) – Direct	Process (CO_2) – Direct	Ancillary Materials – Indirect (*)	Transport – Indirect	Total – Cradle to Gate
	Energy-related CO_2 emissions		Process emissions				
Mining		0.04					0.04
Refining	0.3	1.7			0.4	0.2	2.6
Anode Production	0.03	0.1		0.1	0.6		0.9
Electrolysis	8.9		0.8	1.5	0.1	0.2	11.4
Casting	0.04	0.1					0.1
Primary Aluminium	9.3	1.8	0.8	1.6	1.2	0.4	15.1

(*) Ancillary materials (AMs) – also known as ancillary products, ancillary reagents, and process reagents – are raw materials that are not intended to be present in a final product but are critically important in its manufacture.

As outlined in section 5.1, the comparison of EU Taxonomy values with OECM data provides an assessment of whether EU Taxonomy values are consistent with the 1.5°C target of the Paris Agreement, as set out by the OECM. Comparison of the OECM results and the EU Taxonomy criteria showed that the factor for energy intensity matches, but this is a standardised value for currently used technologies (Table 41). Comparison of the projections for direct and indirect GHG emissions is more complex because the EU Taxonomy does not distinguish between electricity and process emissions (see rows 2–5 of Table 41). The OECM calculates emission trajectories until 2050, and comparing these with the EU benchmarks identifies the percentage of the industry that must operate within those benchmarks to achieve the OECM emissions for the entire European aluminium industry.

Table 42: Greenhouse gas emissions from the manufacture of primary aluminium: comparing EU Taxonomy and OECM (2025)

				EU Taxonomy		OECM		
	EU Taxonomy Aluminium Production	**OECM Aluminium Production**	**Units**	**Climate mitigation (from 2025)**	**Climate adaption (from 2025)**	**2020**	**2030**	**2050**
Benchmark criteria	--	Bauxite mining–energy intensity	PJ/Mt	--	--	0.721	0.689	0.63
	--	Bauxite mining–emission factor for primary energy (coal/oil/gas)	$ktCO_2$/PJ	--	--	coal: 93, oil: 75, gas: 53		
	Primary Al Production – Direct Emissions	Primary Al production–specific process CO_2 emissions per tonne of Al (energy + process)	tCO_2/tonne Al	1.484	1.604	2.50	2.26	1.84
	Primary Al Production – Indirect Emissions, Carbon Intensity	Primary Al production–specific CO_2 emissions: electricity (based on scenario)	gCO_2e/kWh	100	270	167	20	0
	Primary Al Production – Electricity Production	Primary Al production–energy intensity: electricity (anode, electrolysis, ingot)	MWh/tonne Al	15.5	15.5	15.5	15.5	15.5
	--	Primary Al production–energy intensity: thermal (anode, electrolysis, ingot)	MWh/tonne Al	--	--	18.4	17.5	17.8
	--	Secondary Al production–energy intensity: electricity (anode, electrolysis + ingot)	MWh/tonne Al	--	--	2.8	2.7	2.4
	--	Secondary Al production–energy intensity: thermal (anode, electrolysis + ingot)	MWh/tonne Al	--	--	0.9	0.9	0.8

35 International Aluminium Institute, online database – data for 2022.

Aluminium industry: Transformation pathways

Table 43 shows a comparison of the 2025 EU benchmarks for the aluminium industry, the calculated benchmarks for 2035 with a 7% decarbonisation rate, and the OECM 1.5°C mitigation pathway. The EU benchmark for process emissions from primary aluminium production, 1.48 tCO_2/tonne Al, is significantly lower than the current average emissions of around 2.5 tCO_2/tonne Al. The calculated benchmark for 2035 is also lower than the OECM value for the same year, as is that for 2050. The specific energy-related emissions for electricity generation in 2025 are significantly below the current emissions, whereas the calculated emission benchmark for 2035 is almost three times higher than that under the OECM pathway.

Table 43: Taxonomy Transformation pathway for aluminium based on the OECM 1.5°C mitigation pathway for the EU27 aluminium industry

Aluminium			2020	Taxonomy Benchmark: Climate Mitigation for 2025	2025	2030	2035	Decarbonisation Rate, 7%/a 2035 (Base: 2024 Emissions)	2040	2045	2050
Carbon Intensity	Sector CO_2 Intensity	[tCO_2/PJ]	61,888	No data	47,087	31,849	16,922	24,298	10,737	3,525	0
	Electricity: Carbon Intensity	[gCO_2/kWh]	279	100	163	80	29	84	14	4	0
Market Development	Mining Bauxite – production volume in megatonnes per year	[Mt/a]	2	No data	2	2	3		3	3	3
	Annual Production Volume – aluminium Industry	[Mt/a]	2	No data	2	2	2		2	2	2
	Primary Aluminium Production – share of total production	[%]	29%	No data	29%	29%	29%		29%	29%	29%
	Secondary/Scrap Aluminium – share of total production	[%]	71%	No data	71%	71%	71%		71%	71%	71%
Energy Intensity	Bauxite Mining – energy intensity	[PJ/Mt]	0.7	No data	0.7	0.7	0.7		0.7	0.6	0.6
	Primary Aluminium – energy intensity: electricity (anode, electrolysis + ingot)	[PJ/Mt]	55.8	55.0	54.4	53.1	51.7		50.4	49.2	47.9
	Secondary Aluminium–energy intensity: electricity (anode, electrolysis + ingot)	[PJ/Mt]	2.8	No data	2.7	2.7	2.6		2.5	2.5	2.4
Carbon Intensity	Specific ENERGY – RELATED CO_2 emissions per tonne of aluminium	[tCO_2/tonne Al]	3.4		2.5	1.3	0.8	1.3	0.4	0.2	0.0
	Specific PROCESS – RELATED CO_2 emissions per tonne of aluminium	[tCO_2/tonne Al]	2.5	1.48	2.4	2.3	2.1	1.23	2.0	1.9	1.8
	Specific CO_2 emissions per tonne of aluminium (energy + process)	[tCO_2/tonne Al]	5.9		4.9	3.6	3.0	2.54	2.4	2.1	1.8

6.6 Cement Industry: Compatibility of Taxonomy Benchmarks and OECM results

Cement is the second-most-consumed substance in the world after water and is a central ingredient in almost everything we build – from civil infrastructure projects and power generation plants to domestic houses. Typically made from raw materials such as limestone, sand, clay, shale, and chalk, cement acts as a binder between aggregates in the formation of concrete. Cement manufacturing is a resource- and emissions-intensive process, associated with around 7% of total global CO_2 emissions.

The economic value of the European cement industry was estimated to be US$19.02 billion in 2023 (Statista, 2024[36]). In 2012, the US cement industry's shipments (to support construction projects) were estimated to be worth US$7.5 billion (Portland Cement Association, 2019), equivalent to 1.6% of global revenue. In the EU, the cement manufacturing industry's turnover was estimated to be €15.2 billion in 2015, and €4.8 billion in value added (European Commission, 2018).

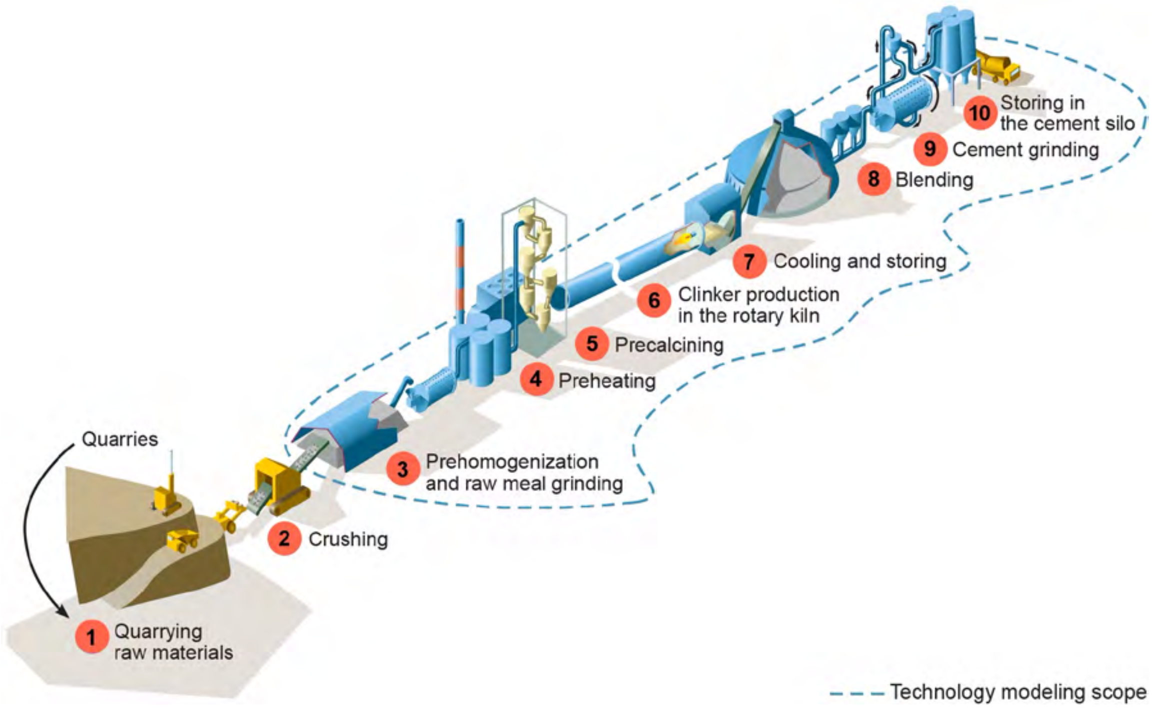
Beyond the mining of raw materials, there are five main steps in the cement production process (overview, see Figure 9).

1. Raw material preparation – this stage involves the crushing or grinding, classification, mixing, and storage of the raw materials and additives. This is an electricity-intensive production step, requiring 25–35 kilowatt hours (kWh) per tonne of raw material (steps 2 & 3).
2. Fuel preparation – this phase involves optimising the size and moisture content of the fuel for the pyro-processing system of the kiln (steps 4 & 5).
3. Clinker production – the production of clinker involves the transformation of raw materials (predominantly limestone) into clinker (lime), which is the basic component of cement (Figure 11, step 6). This is achieved by heating the raw materials to temperatures > 1450°C in large rotary kilns. Clinker production is the most energy-intensive stage of the cement manufacturing process, accounting for more than 90% of the total energy used by the cement industry. Moreover, a large amount of process CO_2 is released directly from the material in the conversion of limestone to clinker.
4. Clinker cooling – after the clinker is discharged from the kiln, it is cooled rapidly (step 7).
5. Finish grinding – after cooling, the clinker is crushed and mixed with other materials (gypsum, fly ash, ground granulated blast furnace slag, and fine limestone) to produce the final product, cement (steps 8–10).

The literature distinguishes between the energy consumed in the production of the intermediary product *clinker* (in the form of small rock-like nodules), and cement production, which is based on clinker. In this section, we introduce the EU Taxonomy benchmark criteria for clinker and cement production for *climate mitigation* and *climate adaption* and assesses the alignment between the projections for the *Cement* sector processes, calculated in the OECM, and the 1.5°C target of the Paris Climate Agreement.

36 Statista (2024) Market size of the European cement industry from 2022 to 2023, with a forecast for 2033 (in million U.S. dollars), online database accessed September 2024, https://www.statista.com/statistics/1488014/market-size-of-cement-industry-europe/

Figure 9: Steps in cement production, from mining to product. Source: IEA (2020c)



Cement industry: Benchmarks for the sector

The benchmark criteria for *climate mitigation* and *climate adaption* measures to decarbonise the *Cement* sector are defined by the EU Taxonomy as follows.

Climate mitigation

The activity manufactures one of the following:

a. grey cement clinker, for which the specific GHG emissions are < 0.722 tCO_2e per tonne of product
b. cement from grey clinker or an alternative hydraulic binder, for which the specific GHG emissions from the production of clinker and cement or alternative binder are < 0.469 tCO_2e per tonne of cement or alternative binder manufactured.

Where CO_2 that would otherwise be emitted from the manufacturing process is captured for the purpose of underground storage, the CO_2 is transported and stored underground, in accordance with the technical screening criteria set out in the Appendix (see section 6).

Climate adaption

The activity manufactures one of the following:

a. grey cement clinker, for which the specific GHG emissions are < 0.816 tCO_2e per tonne of product
b. cement from grey clinker or alternative hydraulic binder, for which the specific GHG emissions from the production of clinker and cement or alternative binder are < 0.53 tCO_2e per tonne of cement or alternative binder manufactured

Where CO_2 that would otherwise be emitted from the manufacturing process is captured for the purpose of underground storage, the CO_2 is transported and stored underground, in accordance with the technical screening criteria set out in the Appendix (see section 6).

Cement Industry – Alignment of EU Taxonomy and OECM data

In this section, we discuss the alignment between the clinker and cement production thresholds outlined by the EU Taxonomy and the values determined by the OECM, which are compatible with the 1.5°C target increase in global temperature.

Table 44: GHG emission values for clinker and cement production as outlined in the EU Taxonomy and OECM

EU Taxonomy Cement Production	OECM Cement Production	Units	EU Taxonomy Climate mitigation	EU Taxonomy Climate adaption	OECM 2017	OECM 2020	OECM 2025	OECM 2030	OECM 2050
---	Limestone mining – GHG emissions	tCO_2 per tonne limestone	–	–	–	–		–	–
Clinker Production (grey)	Specific ENERGY-RELATED CO_2 emissions per tonne of clinker	tCO_2 per tonne clinker	0.722	0.816	0.773	0.658	0.421	0.08	0
Cement Production (grey)	Specific ENERGY-RELATED CO_2 emissions per tonne of cement	tCO_2 per tonne cement	0.469	0.53	0.826	0.699	0.444	0.091	0.016

Clinker production:

The threshold for clinker production set out in the EU Taxonomy climate mitigation criteria (0.772 tCO_2 per tonne of clinker) is not consistent with the OECM requirement covering the time period 2020–2050 (0.67 tCO_2 per tonne of clinker) but matches the 2017 data (0.773 tCO_2 per tonne of clinker). Therefore, the **climate adaption data for clinker production do not match OECM requirements after 2025**.

Cement production:

The thresholds for cement production set out in the EU Taxonomy *climate adaption* criteria (0.469 tCO_2 per tonne of clinker) are consistent with the OECM requirements in the time period 2020–2025 (0.444 tCO_2 per tonne of cement) but do not match future decarbonisation requirements in 2025–2050 (< 0.444 tCO_2 per tonne of cement). **Therefore, the climate adaption data for cement manufacturing do not match the OECM requirements after 2025**.

Cement industry: Taxonomy Transformation pathways

Table 45 compares the OECM and the EU benchmarks for 2025 and the calculated benchmarks for 2035 for the cement industry. The parameter are consistent to a large extent. However, the complete decarbonisation of all energy- and process-related CO_2 emissions by 2050 is not possible with a decarbonisation rate of 7% per year, which is supported by the EU.

Table 45: Taxonomy Transformation Pathway for cement based on the OECM 1.5°C mitigation pathway for the EU27 cement industry

Total Materials / Cement			2020	Taxonomy Benchmark: Climate Mitigation for 2025	2025	2030	2035	Decarboni-sation Rate, 7%/a 2035 (Base: 2024 Emissions)	2040	2045	2050
Carbon Intensity	Sector CO_2 Intensity	[tCO_2/PJ]	61,888	No data	47,087	31,849	16,922	24,298	10,737	3,525	0
	Electricity: Carbon Intensity	[gCO_2/kWh]	279	100	163	80	29	84	14	4	0
Market Development	Cement Production Volume in megatonnes per year	[Mt/a]	182		186	191	196		201	206	211
	Clinker Production Volume in megatonnes per year	[Mt/a]	148		130	122	119		116	113	111
Energy Intensity	Thermal Energy Intensity per tonne of clinker	[GJ/tonne]	3.6		3.30	3.20	3.20		3.20	3.15	3.10
	Cement Production-electricity intensity	[kWh/ tonne]	116		103	98	93		88	81	79
	Thermal Energy intensity per tonne of cement	[GJ/tonne]	4.19		4.00	3.50	3.00		2.07	2.04	2.01
	Product Energy Intensity (thermal + electricity)	[GJ/tonne cement]	4.61		4.37	3.85	3.33		2.38	2.33	2.29
Carbon Intensity	Specific ENERGY-RELATED CO_2 Emissions per tonne of clinker	[tCO_2/tonne clinker]	0.658	0.722	0.421	0.421	0.08	0.13	0.03	0.01	0.00
	Specific ENERGY-RELATED CO_2 Emissions per tonne of cement	[tCO_2/tonne cement]	0.699	0.469	0.444	0.444	0.09	0.14	0.03	0.01	0.00
	Specific CO_2 Emissions per tonne of cement (including process emissions)	[tCO_2/tonne cement]	0.63		0.61	0.46	0.39	0.32	0.31	0.27	0.24

Red – check values when all countries are added up in new EU file

6.7 Chemical Industry: Compatibility of taxonomy benchmarks and OECM results

In this section, we introduce the EU Taxonomy benchmark criteria for chemicals production for *climate mitigation* and *climate adaption* and assess their alignment with projections for the *Cement* sector processes calculated in the OECM, which are compatible with the 1.5°C target of the Paris Climate Agreement.

Chemical industry: Benchmarks for the sector

The chemical industry is a massive industry that produces tens of thousands of products and materials. Only a few processes are covered in the EU Taxonomy. Figure 10 and Figure 11 present the processes covered.

The chemicals discussed in the following sections are:

- Hydrogen
- Ethylene (as part of base hydrocarbons)
- Propylene (as part of base hydrocarbons)
- Ammonia
- Chlorine.

Currently, there is no coverage of the full chemical industry, but from a sustainability perspective, priority areas for the EU Taxonomy can be identified. The production of the chemicals ethylene, propylene, ammonia, benzene, toluene, xylene, and methanol involves the largest overall energy use and non-energy emissions. Furthermore, chlorine production is one of the largest electricity users among the sectors and is added to the list for that reason.

The alignment of the EU Taxonomy for the chemical industry with the 1.5°C OECM pathways will be discussed in the following sections. However, it should be noted that an overall description for methanol, a major chemical, is missing, as are descriptions for many other chemicals manufactured in the sector.

Figure 10: Chemical industry coverage by the EU Taxonomy – part 1. Arrows pointing downwards refers to further downstream products

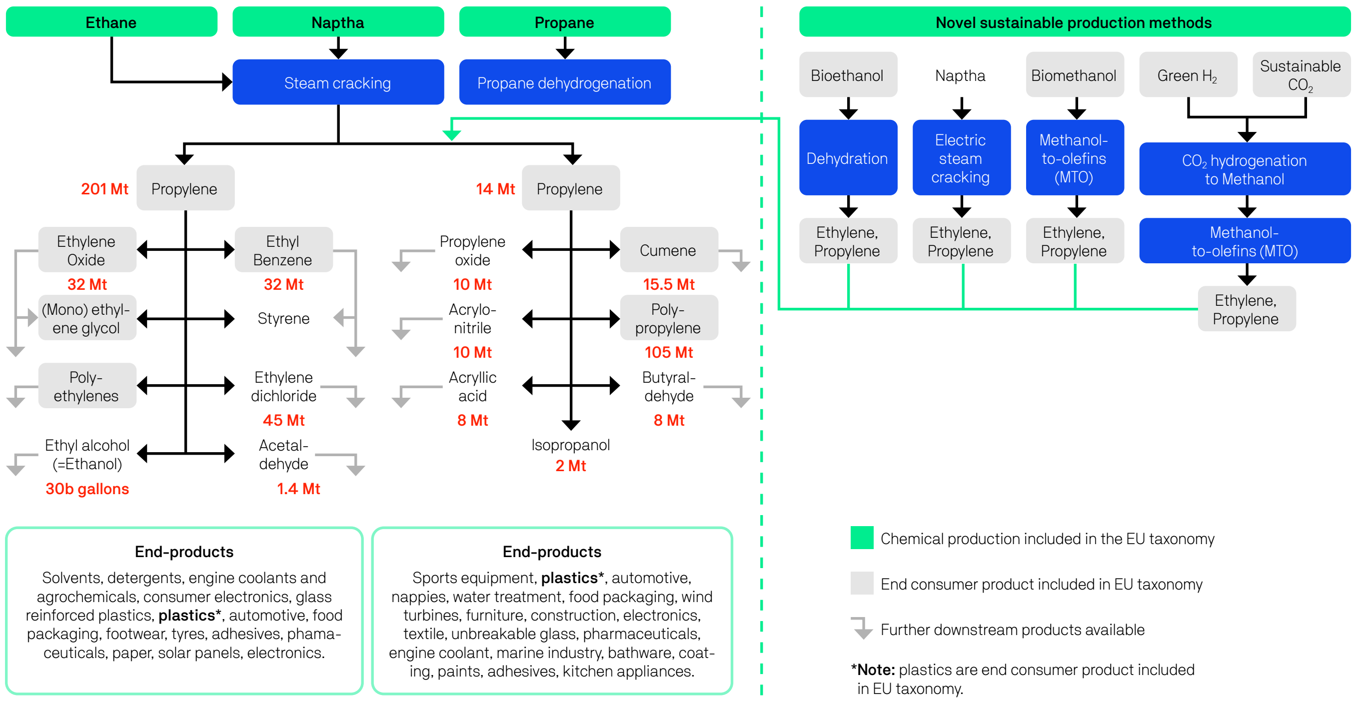
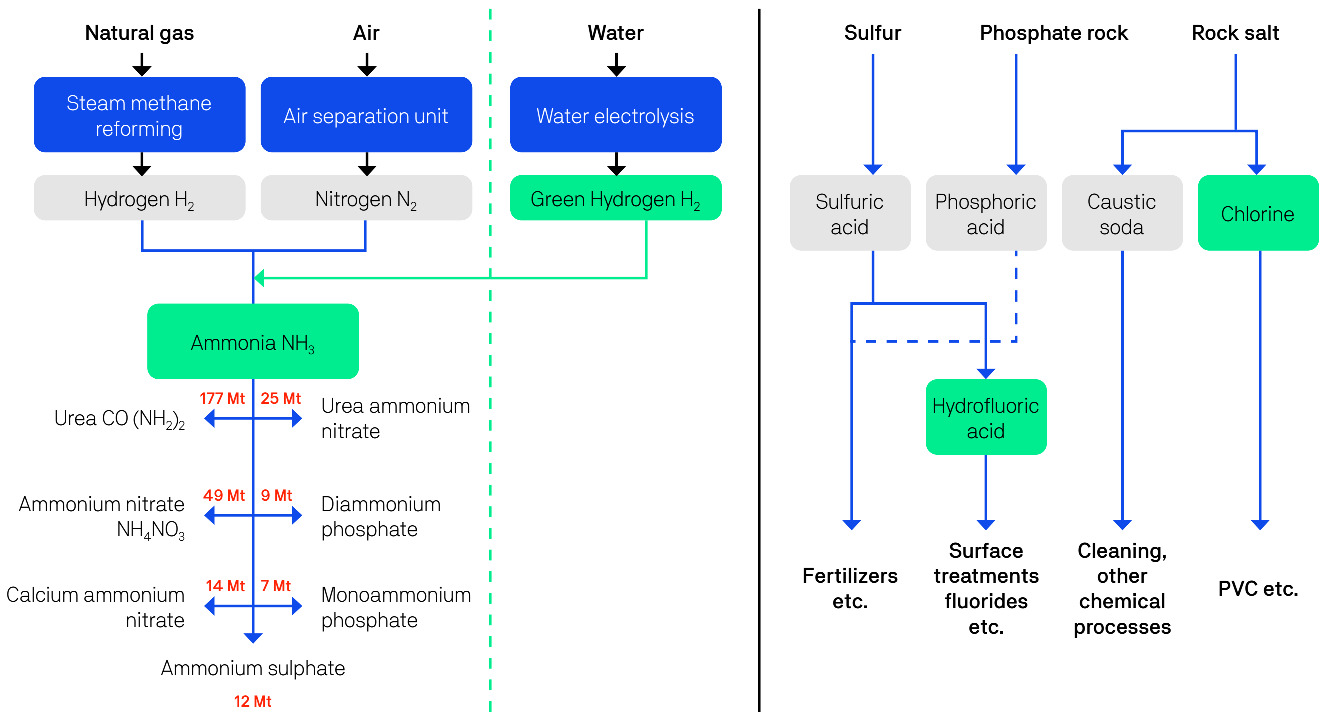


Figure 11: Chemical industry coverage by the EU Taxonomy – part 2



Hydrogen – Chemical industry: Benchmarks for the sector

The benchmark criteria stated by the EU Taxonomy (2024):

Contribution to *climate mitigation*: Description

Manufacture of hydrogen and hydrogen-based synthetic fuels[37].

Contribution to *climate mitigation*: Criteria

The activity complies with the life-cycle GHG emissions savings requirements of:

- 73.4% for hydrogen – resulting in life-cycle GHG emissions of < 3 tCO_2e/tonnes H_2
- 70% for hydrogen-based synthetic fuels relative to a fossil-fuel comparator of 94 gCO_2e/MJ38
- where CO_2 that would otherwise be emitted from the manufacturing process is captured for the purpose of underground storage, the CO_2 is transported and stored underground[39]

Contribution to *climate adaptation* – Criteria for *climate mitigation*

The activity complies with the life-cycle GHG emissions savings requirement of 70% relative to a fossil-fuel comparator of 94 gCO_2e/MJ40.

Hydrogen – Chemical Industry: Alignment of EU Taxonomy and OECM data

The alignment of the 1.5°C-aligned OECM pathway and the EU Taxonomy criteria relies on the criteria that define sustainable hydrogen and a sustainable renewable fuel of non-biological origin (RFNBO). However, a missing link is that the 1.5°C-aligned OECM pathway sets targets for the use of green hydrogen in the production of renewable ammonia and methanol up to 2050.

Table 46: Sustainability criteria for hydrogen

		Alignment
Criterion 1: Hydrogen life-cycle assessment (LCA) emissions	Hydrogen feedstock with GHG emissions < 3 tCO_2e/tonne H_2.	Aligned. Both the 1.5°C-aligned OECM pathway and the EU Taxonomy consider ammonia produced from renewable hydrogen sustainable.
Criterion 2: Hydrogen-based fuels	LCA emissions that are 73.4% lower than the fossil-fuel alternative	Aligned.

37 The economic activities in this category could be associated with NACE code C20.11, in accordance with the statistical classification of economic activities established by Regulation (EC) No. 1893/2006.

38 The life-cycle GHG emissions must be consistent with the approach set out in Article 25(2) of and Appendix V to Directive (EU) 2018/2001. Life-cycle GHG emissions savings are calculated with the methodology referred to in Article 28(5) of Directive (EU) 2018/2001 or, alternatively, ISO 14067:2018 or ISO 14064-1:2018. The quantified life-cycle GHG emissions savings are verified in line with Article 30 of Directive (EU) 2018/2001 where applicable, or by an independent third party.

39 The CO_2 capture and transport process must be in accordance with the technical screening criteria set out by the European Commission.

40 Further details are set out in Article 25(2) of Directive (EU) 2018/2001 of the European Parliament and of the Council and Appendix V to that Directive. Life-cycle GHG emissions savings are calculated with the methodology referred to in Article 28(5) of Directive (EU) 2018/2001 or, alternatively, with ISO 14067:2018 or ISO 14064-1:2018. The quantified life-cycle GHG emissions savings are verified in line with Article 30 of Directive (EU) 2018/2001 where applicable, or by an independent third party.

Base hydrocarbons – Chemical industry: Benchmarks for the sector

Contribution to *climate mitigation*: Description

Manufacture of:[41]

1. High-value chemicals (HVC):
   a. acetylene
   b. ethylene
   c propylene
   d. butadiene.
2. Aromatics:
   a. mixed alkylbenzenes, mixed alkylnaphthalenes other than HS 2707 or 2902
   b. cyclohexane
   c. benzene
   d. toluene
   e. o-xylene
   f. p-xylene
   g. m-xylene and mixed xylene isomers
   h. ethylbenzene
   i. cumene
   j. biphenyl, terphenyls, vinyltoluenes, other cyclic hydrocarbons, excluding cyclanes, cyclenes, cycloterpenes, benzene, toluene, xylenes, styrene, ethylbenzene, cumene, naphthalene, and anthracene
   k. benzol (benzene), toluol (toluene), and xylol (xylenes).
3. Naphthalene and other aromatic hydrocarbon mixtures (excluding benzole, toluole, and xylole):
   a. vinyl chloride
   b. styrene
   c. ethylene oxide
   d. monoethylene glycol
   e. adipic acid.

41 The economic activities in this category could be associated with NACE code C20.14, in accordance with the statistical classification of economic activities established by Regulation (EC) No 1893/2006. An economic activity in this category is a transitional activity as referred to in Article 10(2) of Regulation (EU) 2020/852, when it complies with the technical screening criteria set out in this section.

Contribution to *climate mitigation*: criteria for substantial contribution

GHG emissions from the production processes of basic organic chemicals are lower than:

a. for HVC: 0.693 tCO_2e/tonne HVC
b. for aromatics: 0.0072 tCO_2e/tonne complex weighted throughput
c. for vinyl chloride: 0.171 tCO_2e/tonne vinyl chloride
d. for styrene: 0.419 tCO_2e/tonne styrene
e. for ethylene oxide/ethylene glycols: 0.314 tCO_2e/tonne ethylene oxide/glycol
f. for adipic acid: 0.32 tCO_2e/tonne adipic acid.

The life-cycle GHG emissions of the chemical, manufactured wholly or partially from renewable feedstock, are lower than the life-cycle GHG emissions of the equivalent chemical manufactured from fossil-fuel feedstock[42].

Agricultural and forest biomass used for the manufacture of basic organic chemicals must comply with the sustainability criteria of the European Renewable Energy Directive (EU) 2018/2001, which excludes bio-energy produced from primary forest or land wooded in native species, and from land with high biodiversity. **In this document, this is hereinafter referred to as 'sustainable biomass'**[43].

Contribution to *climate adaptation*: Do no significant harm – *climate mitigation*

GHG emissions from the production processes for organic chemicals must be lower than:

a. for HVC: 0.851 tCO_2e/tonne HVC
b. for aromatics: 0.0300 tCO_2e/tonne complex weighted throughput
c. for vinyl chloride: 0.268 tCO_2e/tonne vinyl chloride
d. for styrene: 0.564 tCO_2e/tonne styrene
e. for ethylene oxide/ethylene glycols: 0.489 tCO_2e/tonne ethylene oxide/glycol
f. for adipic acid: 0.76 tCO_2e/tonne adipic acid.

The life-cycle GHG emissions of the manufactured chemical, manufactured wholly or partially from renewable feedstock, are lower than the life-cycle GHG emissions of the equivalent chemical manufactured from fossil-fuel feedstock. Agricultural and forest biomass must meet the criteria for *'sustainable biomass'*.

42 Life-cycle GHG emissions are calculated with Recommendation 2013/179/EU or alternatively, with ISO 14067:2018 or ISO 14064-1:2018. Quantified life-cycle GHG emissions are verified by an independent third party.

43 For more details, see Directive (EU) 2018/2001, Article 29.

High-value chemicals – Chemical Industry: Alignment of EU Taxonomy and OECM data

Ethylene

The emissions from ethylene production mainly come from the combustion of fuels for heat for steam cracking. Steam cracking produces between 0.85 and 1.8 tonnes of CO_2 per tonne of ethylene produced.[44] The following table contains the emissions per tonne of ethylene produced for a sustainable pathway containing electrified steam crackers powered with renewable energy. Another sustainable alternative is the production of bio-ethylene from bio-ethanol.

Table 47: Alignment of sustainability criteria for ethylene

		Alignment
Criterion 1: GHG emissions	0.693 tCO_2e/tonne HVC	This is in alignment with the 1.5°C OECM pathway. Fossil-fuel-based ethylene production reaches between 0.85 and 1.8 tonnes of CO_2 per tonne ethylene produced.
Criterion 2: Renewable feedstock	Wholly or partially produced from renewable feedstock; life-cycle GHG emissions are lower than those from fossil-fuel variant.	Although this criterion is a step in the right direction, it lacks an actual target percentage of renewable feedstock (any change at this point would fulfil the criterion).

Table 48: Taxonomy Transformation Pathway for ethylene production based on the OECM 1.5°C mitigation pathway for the EU27 steel industry

Chemical sector			2020	EU Taxonomy	2025	2030	2035	Decarbonisation Rate, 7%/a 2035 Base: EU Benchmark	2040	2045	2050
Market Development	Mt ethylene produced	Mt ethylene/a	19.6	n.a.	19.4	19.4	19.4		19.4	19.4	19.4
	% electrified steam crackers	%	0%		2.5%	10%	18%		25%	50%	75%
GHG Intensity	Energy emissions	$MtCO_2$/a	24.7	n.a.	19.4	19.4	19.4		19.4	19.4	19.4
	tCO_2/tonne ethylene	tCO_{2e}/tonne ethylene	1.67	0.693	1.50	0.82	0.53	0.36	0.25	0.09	0.00

Propylene

The emissions from propylene production mainly come from the combustion of fuels for heat for steam cracking, for which the fossil-fuel-based process is 2.4 tonnes of CO_2 per tonne of propylene produced, on average.[45]

Table 49: Alignment of sustainability criteria for ethylene

		Alignment
Criterion 1: GHG emissions	0.693 tCO_2e/tonne propylene	This is in alignment with the 1.5°C OECM pathway. Fossil-fuel-based propylene production reaches between around 2.4 tonnes of CO_2 per tonne of propylene produced.
Criterion 2: Renewable feedstock	Wholly or partially produced from renewable feedstock; life-cycle GHG emissions are lower than those from fossil-fuel variant.	Although this criterion is a step in the right direction, it lacks an actual target percentage of renewable feedstock (any change at this point would fulfil the criterion).

44 S&P Global (2022) Net zero carbon ethylene production via recovery of CO_2 from cracking furnace flue gas. Accessed online on 13th September 2024 from: https://www.spglobal.com/commodityinsights/en/ci/products/net-zero-carbon-ethylene-production.html

45 Zhao (2017) Life cycle assessment of primary energy demand and greenhouse gas (GHG) emissions of four propylene production pathways in China. Online: http://dx.doi.org/10.1016/j.jclepro.2015.12.099

Table 50: Taxonomy Transformation Pathway for propylene production based on the OECM 1.5°C mitigation pathway for the EU27 chemical industry

Chemical sector			2020	EU Taxonomy	2025	2030	2035	Decarboni-sation Rate, 7%/a 2035 Base: EU Benchmark	2040	2045	2050
Market Development	Mt propylene produced	Mt propylene/a		n.a.							
	% Electrified steam crackers	%	0%		2.5%	10%	18%		25%	50%	75%
GHG Intensity	Energy emissions	$MtCO_2$/a	23.1	n.a.	20.4	11.0	7.1		3.4	1.3	0.0
	tCO_2/tonne propylene	tCO_2e tonne propylene	1.7	0.693	1.5	0.8	0.5	0.36	0.3	0.1	0.0

Ammonia – Chemical industry: Benchmarks for the sector

The benchmark criteria stated by the EU Taxonomy (2024):

Contribution to *climate mitigation*: Description

Manufacture of anhydrous ammonia[46].

Contribution to *climate mitigation*: Substantial contribution criteria

The activity complies with one of the following criteria:

a. ammonia is produced from hydrogen that complies with the technical screening criteria (see section 6.7.3)

b. ammonia is recovered from wastewater.

Contribution to *climate adaptation*: Do no significant harm – Climate mitigation

The activity complies with one of the following criteria:

a. the manufacturing of anhydrous ammonia has GHG emissions < 1.948 tCO_2e per tonne of anhydrous ammonia

b. ammonia is recovered from wastewater.

46 The economic activities in this category could be associated with NACE code C20.15 in accordance with the statistical classification of economic activities established by Regulation (EC) No 1893/2006.

Ammonia – Chemical Industry: Alignment of EU Taxonomy and OECM data

The alignment of the sustainability criteria of the EU Taxonomy for ammonia with those of the 1.5°C-aligned OECM pathway depends on two specific characteristics: the definition of sustainability for ammonia and the fraction of renewable ammonia.

Sustainability criteria for ammonia

Table 51: Sustainability criteria for ammonia

		Alignment
Criterion 1: Made from hydrogen as classified in the EU Taxonomy	Hydrogen feedstock with GHG emissions < 3 tCO_2e/tonne H_2	Aligned. The 1.5°C-aligned OECM pathway and the EU Taxonomy both consider ammonia produced from renewable hydrogen sustainable.
Criterion 2: Ammonia made from wastewater	n.a.	n.a.
Criterion 3: Greenhouse gas (GHG) emissions per tonne ammonia	Lower than 1.948 tCO_2e/tonne anhydrous ammonia	Not aligned. This value represents fossil-fuel-based ammonia production. As described in the 2007 BREF Ammonia guideline, the steam reformation of natural gas results in 1.15–1.4 $kgCO_2$/kg ammonia and the partial oxidation of the residual oils results in 2–2.6 $kgCO_2$/kg NH_3. The real sustainable ammonia produced from green hydrogen, renewable heat, or renewable electricity will have much lower CO_2e emissions.

Fraction of renewable ammonia in EU Taxonomy

Table 52: Taxonomy transformation pathway for ammonia production based on the OECM 1.5°C mitigation pathway for the EU27 chemical industry

Chemical sector			2020	EU Taxonomy	2025	2030	2035	Decarboni-sation rate 7%/a 2035 Base: EU benchmark	2040	2045	2050
Market Development	Mt ammonia produced	$MtNH_3$/a	20.5	n.a.	20.5	20.5	20.5		20.5	20.5	20.5
	% of renewable ammonia (from green hydrogen)		0%	n.a.	2.5%	10%	18%		25%	50%	75%
GHG Intensity	Process emissions	$MtCO_2$/a	37.0	n.a.	36.0	33.3	30.5		27.7	18.5	9.2
	Energy emissions	$MtCO_2$/a	12.7		10.0	5.2	3.2		1.6	0.7	0
	tCO_2/tonne NH_3	tCO_2e/tonne NH_3	2.4	1.948	2.2	1.9	1.6	1.01	1.4	0.9	0.4

Chlorine – Chemical industry: Benchmarks for the sector

Contribution to *climate mitigation*: Description

The manufacture of chlorine is defined as a 'transitional activity'. These are activities for which there are no technologically or economically feasible low-carbon alternative, but that support the transition to a climate-neutral economy in a manner that is consistent with the 1.5°C pathway[47].

Contribution to *climate mitigation*: Substantial contribution criteria

a. Electricity consumption for electrolysis and the treatment of chlorine is £ 2.45 MWh per tonne of chlorine

b. The average life-cycle GHG emissions from the electricity used for chlorine production are £ 100 g CO_2e/kWh[48]

Contribution to *climate adaptation*: Do no significant harm – Climate mitigation

The electricity consumption for electrolysis and the of treatment chlorine is £2.45 MWh per tonne of chlorine.

The average direct GHG emissions from the electricity used for chlorine production is £270 gCO_2e/kWh.

Chlorine – Chemical Industry: Alignment of EU Taxonomy and OECM data

Sustainability criteria for chlorine production

The sustainability criteria for the carbon intensity of the electricity for chlorine production is consistent with the 1.5°C-aligned OECM pathway until 2030. After 2030, it must follow the intensity presented in the table below.

Table 53: Sustainability criteria for chlorine production

		Alignment
Criterion 1:	Electricity consumption is £ 2.45 MWh per tonne of chlorine	Not aligned. The EU Taxonomy has a stricter target for efficiency. (The OECM 1.5°C pathway puts more emphasis on lowering the carbon footprint of the electricity used for chlorine production).
Criterion 2:	Life-cycle GHG emissions from the electricity used for chlorine production	This is in alignment for 2025 (see Table 51)

Table 54: Taxonomy transformation pathway for chlorine production based on the OECM 1.5°C mitigation pathway for the EU27chemical industry

Chemical Sectors			2020	Taxonomy Benchmark: Climate Mitigation for 2025	2025	2030	2035	Decarboni-sation Rate, 7%/a Base EU Bench-mark	2040	2045	2050
Market Development	Mt chlorine produced	Mt chlorine/a	9.2	n.a.	9.6	9.6	9.6		9.6	9.6	9.6
	Energy/tonne chlorine produced	MWh/tonne chlorine.	2.78	n.a.	2.78	2.78	2.78		2.78	2.78	2.78
GHG Intensity	Electricity energy intensities	gCO_2/a	264	100.0	162	80	29	51.6	14	4	0
	Energy emissions	MtCO_2/a	7.6	n.a.	5.1	2.6	1.1		0.5	0.2	0.0
	tCO_2/tonne chlorine	tCO_2e/tonne chlorine	0.80	n.a.	0.50	0.30	0.10		0.10	0.00	0.00

47 The economic activities in this category could be associated with NACE code C20.13, in accordance with the statistical classification of economic activities established by Regulation (EC) No. 1893/2006. An economic activity in this category is a transitional activity, as referred to in Article 10(2) of Regulation (EU) 2020/852, when it complies with the technical screening criteria set out in this section.

48 Life-cycle GHG emissions are calculated with Recommendation 2013/179/EU or, alternatively, with ISO 14067:2018 or ISO 14064-1:2018. Quantified life-cycle GHG emissions are verified by an independent third party.

6.8 Real estate/Buildings – Compatibility of Taxonomy Benchmarks and OECM Results

The *Buildings* sector is responsible for 39% of process-related greenhouse gas (GHG) emissions globally and accounts for almost 32% of the final global energy demand, making the *Buildings* sector pivotal in reducing the global energy demand and climate change (Ürge-Vorsatz et al., 2015a)[49]. The *Buildings* sector is often suggested to have the largest low-cost climate change mitigation potential, achievable by reducing its energy demand[50].

In the European Community, the *Buildings* sector is responsible for 18% of energy-related CO_2 emissions. Greenhouse gas emissions from EU buildings decreased by 31% between 2005 and 2021. This progress was driven by higher energy efficiency standards for new buildings, energy efficiency improvements in existing buildings, decarbonisation of the *Electricity* and *Heating* sectors, and warmer temperatures. Over the longer term, the trend toward declining emissions is expected to continue, but a substantial acceleration in energy renovations is required to reach the EU 2030 targets (EEA, 2023)[51].

The calculation of the energy demand for the *Buildings* sector is based on the methodology of the *High-Efficiency Building (HEB) Model* (Chatterjee & Uerge-Vorsatz, 2020)[52] developed under the scientific leadership of Prof. Dr. Diana Ürge-Vorsatz of the Central European University Budapest, Hungary[53]. Based on the results of the HEB model analysis, a high-efficiency scenario was chosen for commercial buildings and a moderate-efficiency scenario for residential buildings. These scenarios were chosen after stakeholder consultation with representatives of the respective industries, members of the Carbon Risk Real Estate Monitor (CRREM), the Net-Zero Asset Owner Alliance, and academia. To integrate the *Buildings* sector with the 1.5°C pathway as part of the OECM, consistent with all other industry and service sectors and the *Transport* sector, the selection of one specific pathway for the *Buildings* sector as a whole was necessary. The energy demand for the *Construction* sector was also required to calculate the emissions for the GICS category.

49 Ürge-Vorsatz et al. (2015a) Ürge-Vorsatz, D., Cabeza, L. F., Serrano, S., et al. (2015a). Heating and cooling energy trends and drivers in buildings. Renewable and Sustainable Energy Reviews 41:85–98. https://doi.org/10.1016/J.RSER.2014.08.039

50 Chatterjee, S., Kiss, B., Ürge-Vorsatz, D., Teske, S. (2022). Decarbonisation Pathways for Buildings. In: Teske, S. (eds) Achieving the Paris Climate Agreement Goals. Springer, Cham. https://doi.org/10.1007/978-3-030-99177-7_7

51 EEA (2023) Greenhouse gas emissions from energy use in buildings in Europe; 24 Oct 2023, online database, assessed September 2024, https://www.eea.europa.eu/en/analysis/indicators/greenhouse-gas-emissions-from-energy

52 Chatterjee, S, Ürge-Vorstaz, D. (2020) D3.1: Observed trends and modelling paradigms. Topic: LC-SC3-CC-2-2018 of the horizon 2020 work program: Modelling in support to the transition to a low-carbon energy system in Europe. Building a low-carbon, climate resilient future: Secure, clean and efficient energy. SENTINEL. https://sentinel.energy/wp-content/uploads/2021/02/D-3.1-837089-EC.pdf

53 Teske, S., Orbe, J.G., Assaf, J., Chatterjee, S., Kiss, B., Ürge-Vorsatz, D. (2022). Methodology. In: Teske, S. (eds) Achieving the Paris Climate Agreement Goals. Springer, Cham. https://doi.org/10.1007/978-3-030-99177-7_3

Real estate/Buildings – Benchmarks for the sector

The benchmark criteria for the *climate mitigation* and c*limate adaption* measures to decarbonise the *Buildings* sector have been defined by the EU Taxonomy as follows.

Contribution to *climate mitigation*: Substantial contribution criteria

Constructions of **new buildings** for which:

a. The primary energy demand, defining the energy performance of a building resulting from its construction, is at least 10% lower than the threshold set for the nearly-zero-energy building requirements in national measures implementing Directive 2010/31/EU of the European Parliament and the Council. Energy performance is certified with an as-built Energy Performance Certificate (EPC).
b. For buildings larger than 5000 m^2, upon completion, the building resulting from the construction is tested for air-tightness and thermal integrity, and any deviation from the levels of performance set at the design stage or defects in the building envelope are disclosed to investors and clients. Alternatively, robust and traceable quality control processes in place during the construction process are acceptable as an alternative to thermal integrity testing.
c. For buildings larger than 5000 m^2, the life-cycle global warming potential of the building resulting from its construction is calculated for each stage in its life cycle and is disclosed to investors and clients upon demand.

Contribution to *climate adaptation*: Do no significant harm – Climate mitigation

The EU Taxonomy does not include building-specific criteria but *Generic Criteria for Climate Change Adaptation*[54], none of which addresses the actual energy consumption of the building.

Real Estate/Buildings – Alignment of EU Taxonomy and OECM data

Energy Performance of Buildings Directive

The energy demands of buildings is **NOT** part of the EU Taxonomy but falls under the revised **Energy Performance of Buildings Directive (EU/2024/1275**, which came into force in all EU countries on 28 May 2024. This directive aims to increase the rate of renovation in the EU, particularly of the worst-performing buildings in each country. The energy performance standards are not regulated at the level of the EU but are the responsibility of the member states.

The directive contributes to the objectives of reducing GHG emissions by at least **60% in the** *Buildings* **sector by 2030** compared with 2015, and **achieving a decarbonised, zero-emissions building stock by 2050**. It works hand-in-hand with other European Green Deal policies, such as the emissions trading system for the fuels used in buildings, the revised Energy Efficiency Directive, the revised Renewable Energy Directive, and the Alternative Fuels Infrastructure Regulation[55].

Based on the Energy Performance of Buildings Directive, the Taxonomy benchmarks are calculated for 2025 and 2035 and compared with the OECM pathway for energy supply (Table 55). According to the directive, the building stock should have achieved 18.1% decarbonisation of between 2015 and 2020, whereas the real reduction was only 7.8%. By 2025, the carbon reduction rate should be back to the original value of 35%[56] based on the emissions of 2025, which is the assumption for the calculated theoretical Taxonomy benchmark. Table 55 shows the calculated values for 2035 and the OECM pathway for comparison.

54 According to Appendix A of 'Do No Significant Harm (DNSH)', https://ec.europa.eu/sustainable-finance-taxonomy/activities/activity/350/view

55 European Commission, Energy, Climate Change, Environment, online database, accessed September 2024, https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/energy-performance-buildings-directive_en

56 Buildings Performance Institute Europe (BPIE) (2023). EU Buildings Climate Tracker: A call for faster and bolder action. Available at: https://www.bpie.eu/publication/eu-buildings-climate-tracker-a-call-for-faster-and-bolder-action/

Table 55: Taxonomy Transformation Pathway for buildings based on the OECM 1.5°C mitigation pathway for the EU27 Buildings sector

Residential & Commercial Buildings and Construction			2020	Taxonomy Benchmark: Climate Mitigation for 2025 (*)	2025	2030	2035	Decarbonisation rate 7%/a 2035 Calculated (*)	2040	2045	2050
Stock	Building Stock: Residential	[billion m²]	18.0		18.0	18.2	19.8		21.3	21.4	21.4
	Building Stock: Commercial	[billion m²]	6.1		6.2	6.7	7.3		7.9	8.6	9.4
Energy Intensity	Residential Buildings: Energy Intensity	[kWh/m²]	101		98	93	83		73	58	42
	Commercial Buildings: Energy Intensity	[kWh/m²]	95		92	85	73		60	46	32
	Construction: Residential and Commercial Building – Energy Intensity	[MJ/$GDP]	0.70		0.57	0.56	0.56		0.56	0.55	0.54
Carbon Intensity	Residential Buildings: Total Emissions Intensity (Heating & Electricity)	[$kgCO_2$/kWh]	0.39	0.28	0.24	0.12	0.05	0.03	0.03	0.01	0.00
	Residential Buildings: Emission Intensity – Heat per square metre	[$kgCO_2/m^2$]	11.0	8.03	7.5	3.7	1.8	1.01	0.9	0.2	0.0
	Residential Buildings: Emissions Intensity – Heat	[$kgCO_2$/kWh]	0.110	0.08	0.077	0.039	0.021	0.01	0.013	0.003	0.000
	Residential Buildings: Emissions Intensity – Electricity	[$kgCO_2$/kWh]	0.279	0.20	0.163	0.080	0.029	0.02	0.014	0.004	0.000
	Commercial Buildings: Total Emissions Intensity (Heating & Electricity)	[$kgCO_2$/kWh]	24.60	17.91	17.16	8.62	4.17	2.39	2.17	0.48	0.00
	Commercial Buildings: Emissions Intensity – Heat per square metre	[$kgCO_2/m^2$]	24.3	17.72	17.0	8.5	4.1	2.35	2.1	0.5	0.0
	Commercial Buildings: Emissions Intensity – Heat	[$kgCO_2$/kWh]	0.256	0.19	0.185	0.100	0.057	0.03	0.035	0.010	0.000
	Commercial Buildings: Emissions Intensity – Electricity	[$kgCO_2$/kWh]	0.279	0.20	0.163	0.080	0.029	0.02	0.014	0.004	0.000

* Values are calculated based on average building emissions from 2015 and 2020, according to statistical information of the IEA and data from the EU Buildings Climate Tracker 2023–2035, which take the target of the revised Energy Performance of Buildings Directive (EU/2024/1275) into account.

6.9 Transport – Compatibility of Taxonomy Benchmarks and OECM Results

The *Transport* sector consumed 25% of the final European Communities energy demand in 2021. Therefore, its decarbonisation potential is among the most important of all industries. Given its size and diversity, not only in terms of the different transport modes and technologies but also regional differences among the 27 European member states, it is also one of the most challenging sectors. In 2021, transport consumed 79% of the total European oil demand – the road transport sector, using 75% of the total oil demand, was by far the largest sector, whereas aviation and shipping consumed about 2% each.

Therefore, the transition from oil to electric drives for road and rail transport and to synthetic fuels and biofuels for aviation and shipping is key to achieving the goals of the Paris Climate Agreement. The rapid uptake of electric mobility, combined with a renewable power supply, is the single most important measure to be taken if we are to remain within the carbon budget of the 1.5°C pathway.

The OECM methodology for the *Transport* sector was developed in 2019 (Teske et al., 2019)[57] and 2021. The TUMI Transport Outlook 1.5°C (Teske et al., 2021)[58] was developed within a multi-stakeholder dialogue, including two workshops organised by Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ) and the University of Technology Sydney/Institute for Sustainable Futures (UTS/ISF) in June and September 2021.

The EU Taxonomy identifies 23 economic activities related to transport, the majority of which are related to infrastructure improvements for aviation, shipping, rail, and road transport (see Section 4.3, Table 17). In this research, we have focused on the energy demand and emissions caused by passenger and freight transport by planes, ships, and road vehicles only.

Aviation – Benchmarks for the sector

The benchmark criteria for *climate mitigation* and *climate adaption* measures to decarbonise the *Transport* sector have been defined by the EU Taxonomy as follows.

Contribution to *climate mitigation*: Description

Passenger and freight air transport: The purchase, financing, and operation of aircraft, including the transport of passengers and goods. The economic activity does not include the leasing of aircrafts.[59]

Contribution to *climate mitigation*: Substantial contribution criteria

The activity is performed under one of the following emissions standards (further details on EU webpage):

a. aircraft with zero direct (tail-pipe) CO_2 emissions
b. from 1 January 2030, aircraft (must be) operated with a minimum share of sustainable aviation fuels (SAF), corresponding to 15% in 2030 and increasing by 2% annually thereafter
c. aircraft operate with a minimum share of SAF corresponding to 5% SAF in 2022, with the percentage of SAF increasing by 2% annually thereafter

The SAF use requirements, referred to in points (b) and (c), are calculated with reference to the total aviation fuel used by the compliant aircraft and the SAF used at the fleet level, respectively. Operators calculate compliance as the ratio of the quantity (expressed in tonnes) of SAF purchased at the fleet level divided by the total aviation fuel used by the compliant aircraft multiplied by 100. SAF are defined by a regulation that ensures a level playing field for sustainable air transport.

57 Teske, S., Pregger, T., Simon, S., et al. (2019). Achieving the Paris climate agreement goals global and regional 100% renewable energy scenarios with non-energy GHG pathways for +1.5°C and +2 °C. Springer International Publishing.

58 Teske, S., Niklas, S., & Langdon, R. (2021). TUMI transport outlook 1.5 °C – A global scenario to decarbonise transport; https://www.transformative-mobility.org/wp-content/uploads/2023/03/TUMI-Transport-Outlook-Sol1tB.pdf

59 The economic activities in this category could be associated with several NACE codes, in particular H51.1 and H51.21, in accordance with the statistical classification of economic activities established by Regulation (EC) No. 1893/2006.

Contribution to *climate mitigation*: Substantial contribution criteria

The EU Taxonomy does not include aviation-specific criteria, but *Generic Criteria for Climate Change Adaptation*[60], none of which addresses the actual energy consumption for aircrafts.

Aviation – Alignment of EU Taxonomy and OECM data

The energy intensity for aviation freight transport is assumed to have been around 30 MJ/tkm in 2019 (Pagenkopf et al., 2019)[61], decreasing by 1% per year until 2025. By 2050, the energy intensity for freight planes is estimated to be 25 MJ/tkm, 17% below today's value. The energy intensity for aviation passenger transport will decrease from 5.8 to 4.2 MJ/pkm between 2020 and 2050. Technical improvements in the aerodynamics, materials, weight, and turbine efficiency of both freight and passenger planes are assumed. The volume of freight (in tonne–kilometres, tkm) and the passenger–kilometres (pkm) are assumed to decrease by 30% globally between 2019 and 2050, an average reduction of around 1% per year.

The emissions factor for kerosene is calculated to be 73.3 g of CO_2 per MJ (gCO_2/MJ) (Jurich, 2016)[62]. The specific CO_2 emissions for aviation freight will decrease from 2.3 to 2.0 $kgCO_2$/tkm in 2025. The specific emissions will more than halve by 2035, to 0.8 $kgCO_2$/tkm, and will be completely decarbonised by 2050.

In passenger aviation transport, specific CO_2 emissions will decrease from 425 gCO_2/pkm in 2019 to 350 gCO_2/pkm in 2025, will halve by 2035, and will be CO_2-free by 2050 – analogous to freight transport. Both reduction trajectories will be achieved by the gradual replacement of fossil kerosene with organic kerosene, and after 2040, with synthetic kerosene that is generated with renewable electricity. Because aviation is a truly global sub-sector, the assumptions for the European aviation sector are the same for all global regions

Table 56: Taxonomy Transformation Pathway for aviation based on the OECM 1.5°C mitigation pathway for the EU27 aviation sector

Transport – Aviation			2020	Taxonomy Benchmark: Climate Mitigation for 2025	2025	2030	2035	Decarboni-sation Rate, 7%/a 2035 (Base: 2024 Emissions)	2040	2045	2050
Quantity of Service	Aviation										
	Quantity: Passenger (domestic & international)	[million pkm/a]	40,635		41,206	39,187	35,422		30,418	26,121	22,431
	Quantity: Freight (domestic & international)	[Mtonkm/a]	815		829	799	722		620	532	457
Energy Intensity	Aviation – Passenger Transport										
	Energy Intensity	[MJ/pkm]	5.81		4.83	4.51	4.39		4.28	4.23	4.18
	Aviation – Freight Transport:										
	Energy Intensity	[MJ/tonkm]	32.20		29.12	27.16	26.46		25.76	25.48	25.20
Carbon Intensity	Aviation – Passenger Transport										
	Emissions Intensity	[gCO_2/pkm]	425.87		347.24	280.91	199.62	179.18	125.38	62.01	0.00
	Aviation – Freight Transport:										
	Emissions Intensity	[gCO_2/tkm]	2360.23		2091.81	1692.20	1202.50	1079.41	755.28	373.54	0.00

The alignment between the EU Taxonomy and the 1.5°C OECM pathway with respect to SAFs is presented in the following table. Up to 2030, there is alignment between the two trajectories, but beyond 2030, the EU Taxonomy must implement higher targets for the percentage of sustainable aviation fuels to meet the targets of the OECM pathway.

Table 57: Taxonomy transformation pathway for aviation – Sustainable aviation fuels

60 According to Appendix A of "Do No Significant Harm (DNSH)", https://ec.europa.eu/sustainable-finance-taxonomy/activities/activity/350/view

61 Pagenkopf, J., van den Adel, B., Deniz, Ö., & Schmid, S. (2019). Transport transition concepts. In S. Teske (ed.), Achieving the Paris climate agreement goals: Global and regional 100% renewable energy scenarios with non-energy GHG pathways for +1.5°C and +2°C (pp. 131–159). Springer International Publishing.

62 Jurich, K. (2016). CO_2 emission factors for fossil fuels.

Total Transport Sector	2020	2025	2030	2030	2035	2040	2040	2045	2050	2050
Aviation										
% of sustainable aviation fuel	1%	2%	15%	15%	38%	25%	60%	80%	35%	100%

Shipping – Passenger: Benchmarks for the sector

Contribution to *climate mitigation*: Description

Sea and coastal passenger water transport

The purchase, financing, chartering (with or without crew), and operation of vessels designed and equipped for passenger transport, on sea or coastal waters, whether scheduled or not. The economic activities in this category include the operation of ferries, water taxies and excursions, and cruise or sightseeing boats[63].

Contribution to *climate mitigation*: Substantial contribution criteria

1. Are able to run on zero-direct (tail-pipe)-emissions fuels or on fuels from renewable sources
2. Where it is not technologically or economically feasible to comply with point (a), from 1 January 2026, vessels that can run on zero-direct (tail-pipe)-emissions fuels or on fuels from renewable sources will have attained an Energy Efficiency Design Index (EEDI) value equivalent to reducing the EEDI reference line by at least 20%below the EEDI requirements applicable on 1 April 2022, and:
   a. are able to plug-in at berth;
   b. for gas-fuelled ships, demonstrate the use of state-of-the-art measures and technologies to mitigate methane slippage emissions.
3. Where it is not technologically or economically feasible to comply with point (a), from 1 January 2026, in addition to an attained Energy Efficiency Existing Index (EEXI) value equivalent to reducing the EEDI reference line by at least 10% below the EEXI requirements applicable on 1 January 2023, the yearly average GHG intensity of the energy used on-board by a ship during a reporting period must not exceed the following limits:
   a. 76.4 gCO_2e/MJ from 1 January 2026 until 31 December 2029;
   b. 61.1 gCO_2e/MJ from 1 January 2030 until 31 December 2034;
   c. 45.8 gCO_2e/MJ from 1 January 2035 until 31 December 2039;
   d. 30.6 gCO_2e/MJ from 1 January 2040 until 31 December 2044;
   e. 15.3 gCO_2e/MJ from 1 January 2045.

63 The activity could be associated with several NACE codes, in particular H50.10, N77.21, and N77.34, in accordance with the statistical classification of economic activities established by Regulation (EC) No. 1893/2006.

Contribution to *climate adaptation*: Do no significant harm – Climate mitigation

The EU Taxonomy does not include shipping-specific criteria but *Generic Criteria for Climate Change Adaptation*[64], none of which addresses the actual energy consumption of the ships.

Shipping – Freight: Benchmarks for the sector

Contribution to *climate mitigation*: Description

Sea and coastal freight water transport, vessels for port operations and auxiliary activities.

The purchase, financing, chartering (with or without crew), and operation of vessels designed and equipped for the transport of freight or for the combined transport of freight and passengers on sea or coastal waters, whether scheduled or not. The purchase, financing, renting, and operation of vessels required for port operations and auxiliary activities, such as tugboats, mooring vessels, pilot vessels, salvage vessels, and ice-breakers[65].

Contribution to *climate mitigation*: Substantial contribution criteria

The activity complies with one or more of the following criteria:

1. The vessel has zero direct (tail-pipe) CO_2 emissions
2. Until 31 December 2025, hybrid and dual-fuel vessels derive at least 25% of their energy from zero-direct (tail-pipe)-CO_2-emissions fuels or plug-in power for their normal operation at sea and in ports
3. Where it is not technologically or economically feasible to comply with the criterion in point (a), until 31 December 2025, and only where it can be proved that the vessel is used exclusively for operating coastal and short sea services designed to allow the modal shift of freight currently transported by land to sea, the vessel has direct (tail-pipe) CO_2 emissions, calculated with the International Maritime Organisation (IMO) Energy Efficiency Design Index (EEDI)[(278)], 50% lower than the average reference CO_2 emissions value defined for heavy-duty vehicles (vehicle sub-group 5-LH) in accordance with Article 11 of Regulation 2019/1242
4. Where it is not technologically or economically feasible to comply with the criterion in point (a), until 31 December 2025, the vessel has attained an EEDI value 10% below the EEDI requirements applicable on 1 April 2022 if the vessel can run on zero-direct (tail-pipe)-CO_2-emissions fuels or on fuels from renewable sources
5. Where it is not technologically or economically feasible to comply with point (a), from 1 January 2026, a vessel that can run on zero-direct (tail-pipe)-CO_2-emission fuels or on fuels from renewable sources has attained an EEDI value equivalent to reducing the EEDI reference line by at least 20%below the EEDI requirements applicable on 1 April 2022, and:
    a. is able to plug-in at berth;
    b. for gas-fuelled ships, can demonstrate the use of state-of-the-art measures and technologies to mitigate methane slippage emissions.

64 According to Appendix A of 'Do No Significant Harm (DNSH)', https://ec.europa.eu/sustainable-finance-taxonomy/activities/activity/350/view

65 The economic activities in this category could be associated with several NACE codes, in particular H50.2, H52.22, and N77.34, in accordance with the statistical classification of economic activities established by Regulation (EC) No. 1893/2006.

6. Where it is not technologically and economically feasible to comply with the criterion in point (a), from 1 January 2026, in addition to an attained EEXI value equivalent to reducing the EEDI reference line by at least 10% below the EEXI requirements applicable on 1 January 2023, the yearly average GHG intensity of the energy used on-board by a ship during a reporting period does not exceed the following limits:
   a. 76.4 gCO_2e/MJ from 1 January 2026 until 31 December 2029;
   b. 61.1 gCO_2e/MJ from 1 January 2030 until 31 December 2034;
   c. 45.8 gCO_2e/MJ from 1 January 2035 until 31 December 2039;
   d. 30.6 gCO_2e/MJ from 1 January 2040 until 31 December 2044;
   e. 15.3 gCO_2e/MJ from 1 January 2045.

The vessels is not dedicated to the transport of fossil fuels

Contribution to *climate adaptation*: Do no significant harm – Climate mitigation

The EU Taxonomy does not include shipping-specific criteria but *Generic Criteria for Climate Change Adaptation*[66], none of which addresses the actual energy consumption of vessels.

Shipping – Alignment of EU Taxonomy and OECM data

Of the global energy demand for shipping, 90% is for freight transport, and only around 10% is for passenger transport (mainly cruise ships and ferries). In 2024, the worldwide cruise ship passenger capacity was 673,000 passengers on 360 ships, and 28.8 million passengers were transported in 2023 (Cruise Market Watch, 2024)[67]. In comparison, around 53,000 merchant ships were registered globally in January 2019: approximately 17,000 cargo ships, 11,500 bulk cargo carriers, 7500 oil tankers, 5700 chemical tankers, and 5150 container ships. The remaining ships included roll-on, roll-off passenger and freight transport ships and liquefied natural gas tankers (Statista, 2024)[68].

The energy intensity for freight transport by ship was assumed to be 0.19 MJ/tkm in 2019 and will decrease only slightly to 0.18 MJ/tkm in 2030 and 0.17 MJ/tkm in 2050. An equivalent trajectory is assumed for passenger shipping, from 0.056 to 0.054 MJ/pkm in 2030 and to 0.052 MJ/pkm in 2050. Shipping is already by far the most efficient transport mode. However, further technical improvements, especially in ship engines, are required. The volume of freight (in tkm) is assumed to increase with growing economic activities by around 1% per year until 2050, whereas passenger transport volumes will remain at today's levels over the entire modelling period.

The emission factor for heavy fuel oil is calculated to be 81.3 gCO_2/MJ. The specific CO_2 emissions for shipping freight will decrease from 15 gCO_2/tkm to 10 $kgCO_2$/tkm by 2030. By 2040, freight shipping will be completely decarbonised. The specific CO_2 emissions for passenger shipping transport will decrease from 5 gCO_2/pkm in 2019 to 3 gCO_2/pkm in 2030, and analogous to freight shipping, passenger transport by ship will be carbon neutral by 2040. Both reduction trajectories will be achieved by the gradual replacement of fossil fuels with biofuels and after 2040, with renewables-generated synthetic fuels (Pagenkopf et al., 2019)[69].

66 According to Appendix A of 'Do No Significant Harm (DNSH)', https://ec.europa.eu/sustainable-finance-taxonomy/activities/activity/350/view

67 Cruise Market Watch (2020) Capacity | Cruise market watch, accessed September 2024, https://cruisemarketwatch.com/capacity/

68 Statista (2024). Global merchant fleet – Number of ships by type. Accessed September 2024, https://www.statista.com/statistics/264024/number-of-merchant-ships-worldwide-by-type/

69 Pagenkopf, J., van den Adel, B., Deniz, Ö., & Schmid, S. (2019). Transport transition concepts. In S. Teske (ed.), Achieving the Paris climate agreement goals: Global and regional 100% renewable energy scenarios with non-energy GHG pathways for +1.5°C and +2°C (pp. 131–159). Springer International Publishing.

Table 58: Taxonomy Transformation Pathway for shipping based on the OECM 1.5°C mitigation pathway for the EU27 shipping sector

Transport Shipping			2020	Taxonomy Benchmark: Climate Mitigation for 2025	2025	2030	2035	Decarboni-sation rate, 7%/a 2035 (Base 2024 Emissions)	2040	2045	2050
Quantity of Service	**Shipping**										
	Quantity: Passengers	[million pkm/a]	4,316		4,403	4,628	4,768		5,012	5,267	5,536
	Quantity: Freight	[Mtkm/a]	814,907		865,575	909,728	932,700		956,252	980,398	1,005,155
Energy Intensity	**Shipping – Passenger Transport:**										
	Energy Intensity	[MJ/pkm]	0.06		0.05	0.05	0.05		0.05	0.05	0.05
	Shipping – Freight Transport:										
	Energy Intensity	[MJ/tkm]	0.19		0.19	0.18	0.18		0.18	0.17	0.17
Carbon Intensity	**Shipping – Passenger Transport:**										
	Emissions Intensity	[gCO_2/pkm]	0.85		0.87	0.71	0.63	0.45	0.14	0.03	0.00
	Shipping – Freight Transport:										
	Emission Intensity	[gCO_2/tkm]	15.33		14.76	11.49	9.83		2.15	0.42	0.00

Road Transport – Passengers: Benchmarks for the sector

Contribution to *climate mitigation*: Description

Transport by motorbikes, passenger cars, and light commercial vehicles

The purchase, financing, renting, leasing, and operation of vehicles designated as category M1(258), N1(259), or both, falling under the scope of Regulation (EC) No. 715/2007 of the European Parliament and of the Council, or category L (two- and three-wheel vehicles and quadricycles)[70].

Contribution to *climate mitigation*: Substantial contribution criteria

The activity complies with the following criteria:

1. vehicles of categories M1 and N1, both falling under the scope of Regulation (EC) No. 715/2007
2. until 31 December 2025, specific emissions of CO_2, as defined in Article 3(1), point (h) of Regulation (EU) 2019/631, will be lower than <u>50 gCO_2/km</u> (low- and zero-emissions light-duty vehicles)
3. from 1 January 2026, specific emissions of CO_2, as defined in Article 3(1), point (h) of Regulation (EU) 2019/631, will be zero
4. for vehicles in category L, tail-pipe CO_2 emissions will be equal to <u>0 gCO_2e/km</u> when calculated in accordance with the emissions test laid down in Regulation (EU) 168/2013

70 The economic activities in this category could be associated with several NACE codes, in particular H49.32, H49.39, and N77.11, in accordance with the statistical classification of economic activities established by Regulation (EC) No. 1893/2006. Where an economic activity in this category does not fulfil the substantial contribution criteria specified in point (a) (ii) and (b) of this section, the activity is a transitional activity, as referred to in Article 10(2) of Regulation (EU) 2020/852, provided it complies with the remaining technical screening criteria set out in this section.

Contribution to *climate adaptation*: Do no significant harm – Climate mitigation

The EU Taxonomy does not include road-transport-specific criteria but *Generic Criteria for Climate Change Adaptation*[71], none of which addresses the actual energy consumption of the vehicle

Road Transport – Freight: Benchmarks for the sector

Contribution to *climate mitigation*: Description

Freight transport services by road

The purchase, financing, leasing, rental, and operation of vehicles designated as category N1, N2(269), or N3(270), falling under the scope of EURO VI(271), step E or its successor, for freight transport services by road[72].

Contribution to *climate mitigation*: Substantial contribution criteria

1. The activity complies with one of the following criteria:
   a. vehicles of category N1 have zero direct (tail-pipe) CO_2 emissions
   b. vehicles of categories N2 and N3 with a technically permissible maximum laden mass not exceeding 7.5 tonnes are 'zero-emissions heavy-duty vehicles', as defined in Article 3, point (11) of Regulation (EU) 2019/1242.
   c. vehicles of categories N2 and N3 with a technically permissible maximum laden mass exceeding 7.5 tonnes are one of the following:
      i. 'zero-emission heavy-duty vehicles', as defined in Article 3, point (11) of Regulation (EU) 2019/1242
      ii. where it is not technologically or economically feasible to comply with the criterion in point (i), 'low-emission heavy-duty vehicles' as defined in Article 3, point (12) of that Regulation.
2. Vehicles are not dedicated to the transport of fossil fuels.

Contribution to *climate adaptation*: Do no significant harm – Climate mitigation

The EU Taxonomy does not include transport-specific criteria, but *Generic Criteria for Climate Change Adaptation*[73], none of which addresses the actual energy consumption of the vehicle.

71 According to Appendix A of 'Do No Significant Harm (DNSH)', https://ec.europa.eu/sustainable-finance-taxonomy/activities/activity/350/view

72 The economic activities in this category could be associated with several NACE codes, in particular H49.4.1, H53.10, H53.20, and N77.12, in accordance with the statistical classification of economic activities established by Regulation (EC) No. 1893/2006. Where an economic activity in this category does not fulfil the substantial contribution criterion specified in point (1)(a), (1)(b), or (1)(c)(i) of this section, the activity is a transitional activity, as referred to in Article 10(2) of Regulation (EU) 2020/852, provided it complies with the remaining technical screening criteria set out in this section.

73 According to Appendix A of 'Do No Significant Harm (DNSH)', https://ec.europa.eu/sustainable-finance-taxonomy/activities/activity/350/view

Road Transport – Alignment of EU Taxonomy and OECM data

Although the most-efficient transport mode for long distances over land is railways, vehicular road transport for passenger and freight dominates by an order of magnitude. Road transport is the single largest consumer of oil, not only in the European Community but also globally. Whereas electric-powered planes or ships are still in the early stages of development, there are no technical barriers to the phasing-out of internal combustion engines or the transition to efficient electric vehicles (EVs) for passenger and freight transport[74]. The vehicle technology required is widely available and market shares are rising sharply. In 2012, only 110,000 battery electric vehicles (BEVs) had been sold worldwide. Since then, sales have almost doubled every year, reaching 1.18 million BEVs in 2016, 3.27 million in 2018, 4.79 million in 2019, and close to 14 million in 2023, 95% of which were in China, Europe, and the United States (IEA, 2024[75]).

Passenger transport by road makes up by far the commonest and most important form of travel. There are numerous technical options to 'move people with vehicles' – bicycles, motorcycles, tricycles, city cars, four-wheel drive SUVs – and each vehicle has a very different energy intensity per kilometre. There is a wide variety of public transport vehicles, ranging from rickshaws to taxis and from minibuses to long-distance trains. The occupation rates for those vehicles are key to calculating the energy intensity per passenger kilometre. For example, a diesel-powered city bus that transports 75 passengers requires, on average, about 27.5 litres per 100 kilometres. If the bus is operating at full capacity during peak hour, the energy demand per passenger is as low as 400 ml per kilometre – lower than almost all other fossil-fuel-based road transport vehicles. However, if the occupancy drops to 10% (e.g., for a night bus), the energy intensity increases to 3.7 litres per kilometre, equal to that of a small energy-efficient car. Occupation rates vary significantly and depend upon the time of day, day of the week, and season.

The energy intensity data for freight transport are not as diverse as those for passenger transport, because the transport vehicle types are more standardised and the fuel demands are well known. However, the utilisation rate of the load capacity varies significantly, and consistent data are not available for the regional and global levels calculated. Therefore, the assumed utilisation rate has a huge influence on the calculated energy intensity per tonne–kilometre (Pagenkopf et. al., 2019)[76]. The energy intensities for the main passenger and freight vehicle types, which form the basis for the OECM calculations, are published by Springer in the Open Access book 'Achieving the Paris Climate agreement Goals (Part 2), Decarbonisation Pathways for Transport, chapter 8, Tables 8.4[77] and 8.5[78].

74 Teske, S.; Bratzel, S., Tellermann, R., Stephan, B., Vargas, M. Net Zero: The Remaining Global Market Volume for Internal Combustion Engines in Light-Duty Vehicles under a 1.5°C Carbon Budget Trajectory. Energies 2022;15:8037. https://doi.org/10.3390/en15218037

75 Global EV Outlook 2024. Moving towards increased affordability. International Energy Agency, April 2024, https://iea.blob.core.windows.net/assets/a9e3544b-0b12-4e15-b407-65f5c8ce1b5f/GlobalEVOutlook2024.pdf

76 Pagenkopf, J., van den Adel, B., Deniz, Ö., & Schmid, S. (2019). Transport transition concepts. In S. Teske (ed.), Achieving the Paris climate agreement goals: Global and regional 100% renewable energy scenarios with non-energy GHG pathways for +1.5°C and +2°C (pp. 131–159). Springer International Publishing

77 Table 8.4 Energy intensities for public transport – road and rail transport, https://link.springer.com/chapter/10.1007/978-3-030-99177-7_8/tables/4

78 Table 8.5 Energy intensities for freight transport – road and rail transport, https://link.springer.com/chapter/10.1007/978-3-030-99177-7_8/tables/5

Table 59: Taxonomy Transformation Pathway for road transport based on the OECM 1.5°C mitigation pathway for the EU27 passenger and freight road transport sector

Transport – Road Transport			2020	Taxonomy Benchmark: Climate Mitigation for 2025	2025	2030	2035	Decar-bonisa-tion Rate, 7% per year 2035	2040	2045	2050
Quantity of Service	**Road**										
	Quantity: Passenger	[million pkm/a]	3,024,726		3,228,377	2,772,318	2,442,677		2,207,987	1,995,845	1,804,086
	Quantity: Freight	[Mtkm/a]	2,153,341		3,166,006	3,010,840	2,863,279		2,722,950	2,338,290	2,007,969
Energy Intensity	**Road Passenger Transport**										
	Road Passenger: Energy Intensity	[MJ/pkm]	2.43		1.77	1.59	0.82		0.67	0.55	0.50
	Road Freight Transport										
	Road Freight: Energy Intensity	[MJ/tkm]	1.34		1.17	1.11	0.81		0.74	0.66	0.66
Carbon Intensity	**Road Passenger Transport**										
	Road Passenger: Emissions Intensity	[gCO_2/pkm]	157.99		114.42	99.97	25.81	59.04	12.53	2.25	0.00
	Road Freight Transport										
	Road Freight: Emissions Intensity	[gCO_2/tkm]	86.80		73.42	67.73	26.86	37.89	16.45	2.22	0.00

6.10 Energy supply – compatibility of taxonomy benchmarks and OECM results

In 2022, the 27 EU member states had a total primary energy demand of around 57 EJ/a, 22% of which was from renewable energy sources, 12% each from coal and nuclear, 22% from natural gas, and 27% from oil. The EU is highly dependent on energy imports. In 2022, the main imported energy product category was oil and petroleum products (including crude oil, which was the main component), accounting for 63% of energy imports into the EU, followed by natural gas (26%) and solid fossil fuels (7%). The member states with the highest import dependencies were Cyprus (94%) and Malta (87%); for natural gas were Italy and Hungary (both 39%); and for solid fossil fuels, were Poland (18%), Slovakia, and Czechia (both 14%).

In 2022, more than half of the oil and petroleum imports into the EU originated from five countries: Russia (21%), the United States (11%), Norway (10%), Saudi Arabia, and the United Kingdom (both 7%). A similar analysis showed that 64% of the EU's imports of natural gas came from Russia (23%), Norway (17%), the United States (14%), and Algeria (11%), whereas the largest solid fossil fuel (mostly coal) imports originated from Russia (23%), followed by the United States (18%), Australia (16%), South Africa (14%), and Colombia (13%). Due to the EU sanctions imposed as a consequence of the Russian war of aggression against Ukraine since 2022, this situation is subject to change[79].

One Earth Climate Model: GIS-based spatial analysis of solar and onshore wind energy potential using [R]E Space

Renewable-energy-based energy supply technologies are at the core of the One Earth Climate Model (OECM) concept. A comprehensive GIS-based spatial solar and wind energy assessment is an integral part of the OECM methodology. To identify and map areas with potential utility for the generation of renewable energy, the Renewable Energy Potential under Space Constraint Conditions ([R]E Space) approach was developed in 2019 as an important component of the OECM and has been upgraded since (Miyake et. al 2024)[80]. The [R]E Space methodology incorporates the Boolean raster overlay approach, focusing on multiple land-resource constraint factors that can affect decisions about the locations of renewable energy projects. Individual criteria were set for each land-resource constraint factor so that multiple spatial data inputs on different themes could be combined into a single output raster, thereby generating maps of solar or onshore wind energy potential. Mapping was performed with the ESRI ArcMap 10.6.1 software and publicly available, global spatial data. Both maps were developed using the same method but with different constraint factors and criteria. Areas with potential for solar or onshore wind power generation were calculated and visualised by country with GIS.

Table 60: Solar and onshore wind potential in the EU27, estimated with the [R}E SPACE–OECM methodology

Suitable area		Electricity Generation Potential		OECM Projection – EU27 Electricity Demand in 2050	Calculated Potential versus Electricity Demand in 2050	
[km²]		[TWh/a]		[TWh/a]	[1]	
Solar	Onshore Wind	Solar	Onshore Wind		Solar	Onshore Wind
1,376,011	1,326,087	37,840	19,891	5,247	7	4

Table 60 shows the results of the solar and wind potential assessments with the [R]E SPACE methodology for the European Community. The EU could generate its projected electricity demand for 2050 seven times over with solar photovoltaic and four times over with onshore wind. Furthermore, the EU has additional offshore wind potential, which was not part of the analysis, as well as bio-energy and geothermal energy. Renewable energy is available in abundance in Europe and will provide 100% of its energy under the OECM pathway by 2050.

79 EUROSTAT, online database, accessed September 2024, https://ec.europa.eu/eurostat/web/interactive-publications/energy-2024

80 Miyake, S., Teske, S., Rispler, J., Feenstra, M. Solar and wind energy potential under land-resource constrained conditions in the Group of Twenty (G20). Renewable and Sustainable Energy Reviews, 2024;202:114622, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2024.114622

Renewable Energy for Industry Supply

Heat generation currently relies, to a large extent, on combustion processes. In 2022, approximately 90% of Europe's final energy supply for industrial process heat came from fossil fuels, whereas less than 3% was provided by electric heating systems, and 6% was supplied by renewable heating predominantly derived from biomass. Less than 0.5% was derived from solar or geothermal heating systems. To decarbonise Europe's heat supply is more challenging than to decarbonise the electricity sector, because geographic limitations make it difficult to provide high-temperature heat from direct solar or geothermal energy due to their dependence on locally available resources. However, the use of renewable electricity for heating is key to a successful 1.5°C pathway. Industry involves a large variety of processes that demand heat. These requirements range, for example, from 40°C to around 300°C in the food industry to metal production with furnaces well above 800°C and cement production with dry kilns at around 1500°C.

Decarbonising process heat for energy-intensive industries, such as the steel, aluminium, cement, and chemical industries, is a major prerequisite to remaining within a 1.5°C increase in the global temperature. Three main groups of technologies can provide renewable process heat at different temperatures:

1. Direct heat systems: geothermal and concentrated solar systems
2. Electric heat systems: heat pumps, electromagnetic, di-electric, infrared, induction, resistance, and arc furnace heating
3. Fuel-based heat systems: that use bio-energy, hydrogen, or the other synthetic fuels

The energy sources for these heat-generation technologies are either biomass, geothermal energy, solar energy, or electricity, used either directly or as fuels produced with electricity, such as hydrogen and other synthetic fuels. Whereas the most efficient transformation to renewable energy is the direct application of renewable heat, many industrial processes require higher temperatures or fuels, which cannot be provided directly by renewables. Therefore, as the next best option in terms of efficiency, the direct electrification of processes is preferable. However, some processes will still rely on fuel input in the future. In this case, power-based synthetic fuels will be required, with increasing efficiency losses along the chain from hydrogen to synthetic gas to synthetic liquid fuels. To comply with the 1.5°C carbon budget, all the electricity used for heat or fuel production must be produced from renewable energy[81].

OECM 1.5°C Pathway for the EU27 Energy Supply

The OECM 1.5°C pathway for EU27 focuses on the phase-out of coal for electricity generation by 2030, natural gas by 2040, and a total fossil-fuel phase-out across all sectors (electricity, heat and fuels for transport) by 2050. Figure 12 shows Europe's primary energy supply under the OECM 1.5°C pathway until 2050. Carbon capture and storage (CCS) is not part of the mitigation technologies for the energy sector. Figure 13 shows the role of bio- and synthetic fuels (including hydrogen) across all sectors. The shares of synthetic and hydrogen fuels – mainly for the industry sector – in Europe's final total energy supply will increase to around 4% by 2050.

81 Teske, S., Pregger, T., Simon, S., Harpprecht, C. (2022). Renewable Energy for Industry Supply. In: Teske, S. (ed.) Achieving the Paris Climate Agreement Goals. Springer, Cham. https://doi.org/10.1007/978-3-030-99177-7_9

Figure 12: EU27 primary energy supply under the OECM 1.5°C pathway until 2050

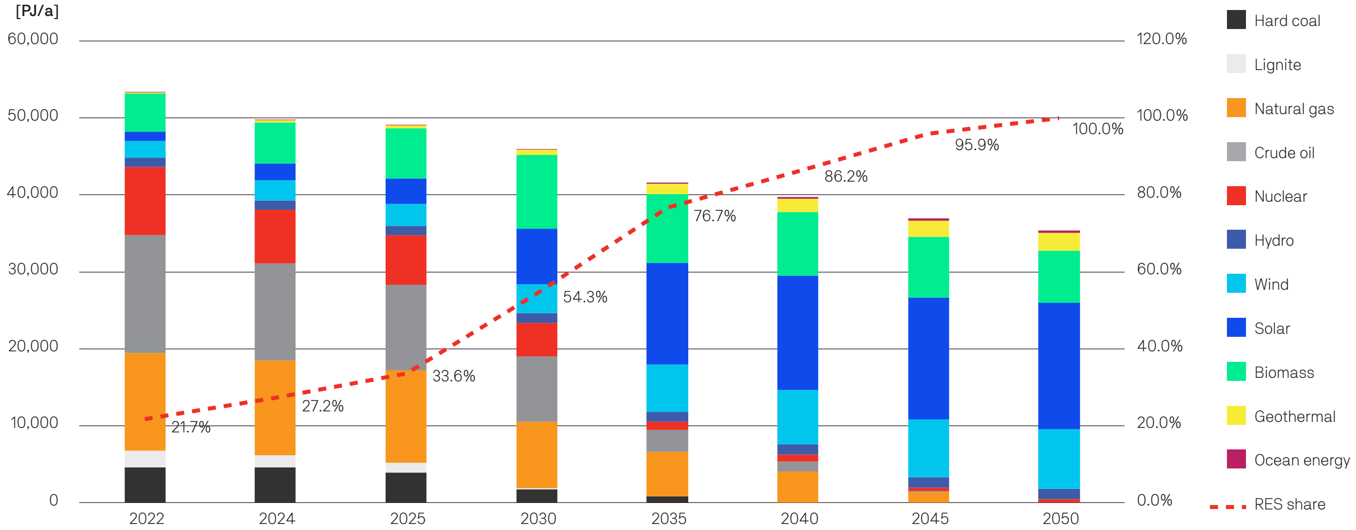
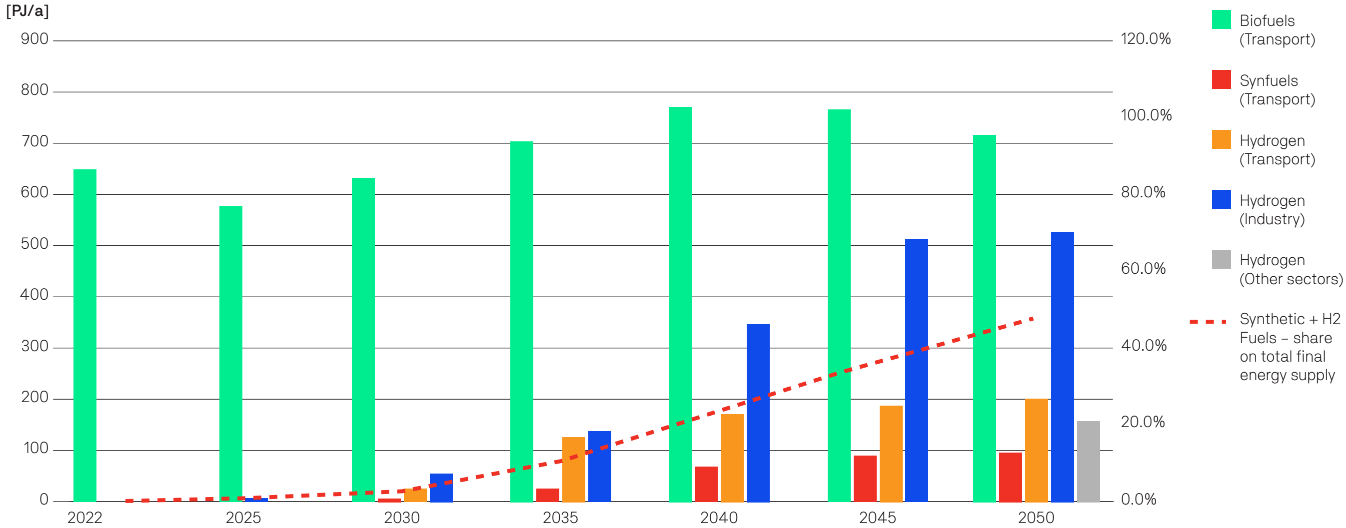


Figure 13: EU27–OECM 1.5°C pathway: the roles of biofuels, synthetic fuels, and hydrogen across all sectors until 2025



Energy – Benchmarks for the sector

The benchmark criteria for *climate mitigation* and *climate adaption* measures to decarbonise the supply side of the energy sector are not yet part of the EU Taxonomy, except the '*manufacture' of hydrogen* and the *transport of CO_2*. Currently, both economic activities play very minor roles and represent < 1% of the European energy sector.

By the end of 2022, the EU27's total cumulative hydrogen production capacity was approximately 11.30 Mt, 99.9% of which was not green hydrogen but produced from fossil fuels – mainly natural gas[82].

According to the Global CCS Institute, 35 CO_2 transport and storage networks are in development In Europe. '*Other industries where CCS features prominently include hydrogen, ammonia and fertiliser facilities (20), power generation and heat (19 facilities), cement (17), and biomass to power/heat (15). Four facilities are operational, with six in construction (…)83*. The CCS CO_2 capture capacity of European facilities is not available. However, the total **global** annual capacity of all operational CCS facilities combined is estimated to be around 50 $MtCO_2$ per year (Global CCS Institute, 2024[81]), equal to 6 ½ days of European energy-related CO_2 emissions in 2022.

The benchmark criteria for *climate mitigation* and *climate adaption* measures for both identified economic activities have been defined by the EU Taxonomy as follows.

'Manufacture' of hydrogen

Contribution to *climate mitigation*: Description

Manufacture of hydrogen and hydrogen-based synthetic fuels.

Contribution to *climate mitigation*: Substantial contribution criteria

See Chemical sector, section 6.7.1.

Transport of CO_2

Contribution to *climate mitigation*: Description

Transport of captured CO_2 via all modes. Construction and operation of CO_2 pipelines and retrofitting of gas networks where the main purpose is the integration of captured CO_2[84].

Contribution to *climate mitigation*: Substantial contribution criteria

1. The CO_2 transported from the installation where it is captured to the injection point does not lead to CO_2 leakages above 0.5% of the mass of CO_2 transported.
2. The CO_2 is delivered to a permanent CO_2 storage site that meets the criteria (defined by the EU) for the underground geological storage of CO_2; or to other transport modalities, which lead to permanent CO_2 storage.
3. Appropriate leak detection systems are applied and a monitoring plan is in place, with the report verified by an independent third party.
4. (…) Assets are installed that increase the flexibility and improve the management of an existing network.

82 The European hydrogen market landscape, November 2023 (Report 01), European Hydrogen Observatory, https://observatory.clean-hydrogen.europa.eu/sites/default/files/2023-11/Report%2001%20-%20November%202023%20-%20The%20European%20hydrogen%20market%20landscape.pdf

83 Global Status of CCS 2023 Scaling up Through 2030, Global CCS Institute.

84 The economic activities in this category could be associated with several NACE codes, in particular F42.21 and H49.50, in accordance with the statistical classification of economic activities established by Regulation (EC) No. 1893/2006.

Energy Sector – Alignment of EU Taxonomy and OECM data

Table 61 compares the OECM energy supply trajectory with that of the new Renewable Energy Directive. The new renewable energy target for 2030 has been increased from 32% to at least 42.5%. To maintain the same benchmark years as reported for all other sectors, the calculated renewable energy shares for the Taxonomy benchmarks are interpolated.

Table 61: Taxonomy Transformation Pathway for the energy industry (GICS 10) based on the OECM 1.5°C mitigation pathway for the EU27 Energy sector.

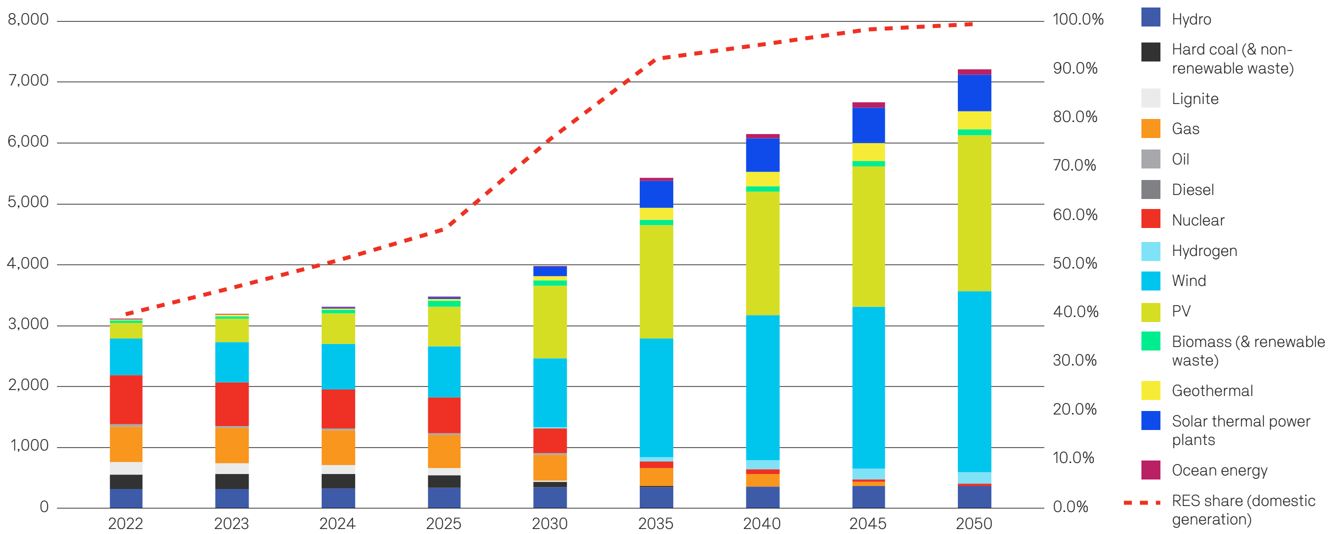
Energy Sector (GICS 10)			2020	Taxonomy Benchmark: Climate Mitigation for 2025	2025	2030	2035	Decarbonisation Rate, 7%/a 2035	2040	2045	2050
Primary Energy Supply											
Energy Supply	Coal (Hard + Brown)	[PJ/a]	7,392	n.a.	5,183	1,888	828	n.a.	15	15	0
	Oil	[PJ/a]	14,484	n.a.	11,109	8,512	2,804	n.a.	1,276	173	0
	Gas	[PJ/a]	12,520	n.a.	12,013	8,620	5,804	n.a.	4,074	1,324	0
	Renewable Energy Share	[%]	20%	25%	34%	54%	77%	45%	86%	96%	100%
Carbon Intensity	Sector CO_2 Intensity	[tCO_2/PJ]	61,888		47,087	31,849	16,922	24,298	10,737	3,525	0

6.12 Electricity supply – Compatibility of Taxonomy Benchmarks and OECM Results

Although Europe's final electricity demand remained relatively stable over the past decade at around 2800 TWh/a, the structure of power generation changed significantly. The share of renewable electricity increased from around 22% in 2013 to 44% in 2023[85].

Solar photovoltaic, onshore wind, and increasingly offshore wind dominate renewable energy growth, whereas coal and gas continue to decline. In 2023, 81 GW of new renewable power generation was added, compared with Europe's total power-generation capacity of just under 1000 GW. The rapid expansion of solar photovoltaic and onshore and offshore wind generation is expected to continue for the entire scenario projections until 2050. Figure 14 shows the projected development of electricity generation, with the renewable electricity share increasing from 44% currently to 100% by 2050.

Figure 14: EU27 electricity generation under the OECM 1.5°C pathway



Electricity supply: Benchmarks for the sector

Electricity generation from various renewable energy sources.

Contribution to *climate mitigation*: Description

All renewable electricity-generation technologies (solar photovoltaic, concentrated solar power [CSP], geothermal, bioenergy, and hydro-power) are listed as separate economic activities but have identical descriptions:

Construction and operation of electricity generation installations that produce electricity.

In the case of fuel-based co-generation, restrictions to sustainable (bio)fuels are added and blending with non-renewable fuels is not permitted.

85 European Electricity Review 2024, Europe's electricity transition takes crucial strides forward. Ember, Sarah Brown, S. & Jones, D. 2024, https://ember-climate.org/insights/research/european-electricity-review-2024/#supporting-material

Contribution to *climate mitigation*: Substantial contribution criteria

- **Geothermal:** The life-cycle GHG emissions from the combined generation of heating/cooling and power (209) from geothermal energy are < 100 gCO_2e per 1 kWh of energy output from their combined generation.
- **Bio-energy/renewable non-fossil gaseous and liquid fuels:**
  - Agricultural biomass used in the activity complies with the 'sustainable bio-energy criteria'
  - The GHG emissions savings from the use of biomass in co-generation installations are at least 80% relative to the GHG emissions saving methodology
  - Where co-generation installations rely on the anaerobic digestion of organic material, the production of the digestate meets the sustainable bio-energy criteria.

Hydropower:

- The electricity-generation facility is a run-of-river plant and does not have an artificial reservoir
  - The power density of the electricity-generation facility is > 5 W/m^2
  - The life-cycle GHG emissions from the generation of electricity from hydropower are < 100 gCO_2e/kWh
- **Solar and wind power:** Installations have no additional criteria, as long as they are only generating electricity with solar or wind energy.

Contribution to *climate adaptation*: Do no significant harm – Climate mitigation

The EU Taxonomy does not include energy-specific criteria but *Generic Criteria for Climate Change Adaptation*[86], none of which addresses the actual power-generation technology itself.

Energy Sector – Alignment of EU Taxonomy and OECM data

Table 59 compares the OECM electricity supply trajectory with the newly available Taxonomy benchmarks for 2025 and the new advanced target of the Renewable Energy Directive from October 2023[87]. The Taxonomy benchmark for the carbon intensity of electricity for 2025, with a maximum of 100 gCO_2/kWh, is not only significantly lower than the average emissions intensity of 279 gCO_2/kWh in 2020, but also than the intensity of the OECM benchmark for 2025 of 163 gCO_2/kWh. However, the specific emissions per kWh under the OECM pathway decrease to 14 gCO_2 per kWh by 2035, faster than EU Taxonomy recommendation of 7% per year, which would lead to 52 gCO_2 per kWh In 2035

The new renewable **electricity** target for 2030 under the *REPowerEU* Plan has been increased from 40% to at least 45%. To maintain the same benchmark years as reported for all other sectors, the calculated renewable energy shares for the taxonomy benchmarks are interpolated.

86 According to Appendix A of 'Do No Significant Harm (DNSH)', https://ec.europa.eu/sustainable-finance-taxonomy/activities/activity/350/view

87 Directive (EU) 2023/2413, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32023L2413&qid=1699364355105

7 Appendix 1: The One Earth Climate Model (OECM) Methodology

7.1 Overview

The 1.5°C pathways for all EU27 member states are based on the advanced version of the One Earth Climate Model (OECM 2.0). The OECM is an integrated energy assessment model that was originally developed in an interdisciplinary research project between the University of Technology Sydney, the German Aerospace Centre (DLR), and the University of Melbourne between 2017 and 2019. The task was to develop a detailed 1.5°C-targeting energy-related GHG emissions trajectory for 10 world regions. OECM 1.0 was developed based on established DLR and UTS energy models, and consisted of three independent modules:

1. Energy system model (EM): a mathematical accounting system for the energy sector[88].
2. Transport scenario model (Transport Energy Model, TRAEM), with high technical resolution[89].
3. Power system analysis model [R]E 24/7, which simulates the electricity system on an hourly basis and at geographic resolution to assess the requirements for infrastructure, such as grid connections between different regions and electricity storage types, depending on the demand profiles and power-generation characteristics of the system[90].

Based on the OECM[91], the Institute for Sustainable Futures, University of Technology Sydney (UTS/ISF), in close co-operation with the UN-convened Net Zero Asset Owners Alliance, updated the OECM 1.0 model. The advanced One Earth Climate Model (OECM 2.0) merges the energy system model (EM), the transport model (TRAEM), and the power system model ([R]E 24/7) into one MATLAB-based energy system module. The OECM 2.0 has now been applied to 19 countries and the EU27 region, which formed the G20 in 2023, to produce energy scenarios and fair carbon budgets for each country, as well as detailed carbon budgets for key industries in each country.

The GICS was used in OECM 2.0 to allow the design of energy and emissions pathways for clearly defined industry sectors (sectoral pathways). Finding pathways to reduce emissions for industry sectors requires very high technical resolution for the calculation and projection of future energy demands and supply for electricity, (process) heat, and fuels, which are necessary for (for example) the steel and chemical industries. An energy model with high technical resolution must be able to calculate the energy demand based on either the sector-specific GDP projections or market forecasts of material flows, such as the demand for steel, aluminium, or cement in tonnes per year.

The methodology chapter outlines five fundamental elements of the modelling process (as described below):

1. databases and model calibration;
2. sector and sub-sector definitions;
3. cost calculations;
4. a demand module; and
5. a supply module.

88 Simon S, Naegler T, Gils HC. Transformation towards a renewable energy system in Brazil and Mexico – technological and structural options for Latin America. Energies 2018;11;907.

89 Pagenkopf J, van den Adel B, Deniz Ö, Schmid S. Transport transition concepts. Achieving the Paris Climate Agreement Goals: Global and Regional 100% Renewable Energy Scenarios with Non-Energy GHG Pathways for +15°C and +2 °C. 2019:131–59.

90 Teske S. Bridging the Gap between Energy and Grid Models, Developing an integrated infrastructural planning model for 100% renewable energy systems in order to optimise the interaction of flexible power generation, smart grids and storage technologies. Chapter 2, 2015.

91 Teske S, Pregger T, Naegler T, Simon S, Pagenkopf J, van den Adel B, et al. Energy scenario results. Achieving the Paris Climate Agreement Goals: Global and Regional 100% Renewable Energy Scenarios with Non-Energy GHG Pathways for +1.5°C and +2 °C. 2019:175–401.

7.2 Databases and model calibration

The OECM uses several databases for energy statistics, energy intensities, technology market shares, and other market or socio-economic parameters. The calculation of the energy balance for the base year is based on the International Energy Agency (IEA) Advanced World Energy Balances[92] and additional sector and nation-specific databases.

The energy statistics for a calculated country and/or region are uploaded via an interface module. The data for each year from 2005 onwards until the last year for which data are available are used to calibrate the model. This process is based on the Energy System Model (EM), which was developed by the German Aerospace Centre DLR. The market shares are calculated based on the IEA statistics and a technical database for energy intensities for various appliances and applications across all sectors. These data are inputs, and the calibration process is performed with a standardised Excel tool. The calibration method is briefly outlined below using the *Transport* sector as an example. To calibrate the model, the transport demand of the past decade is recalculated based on the available energy statistics. The IEA's Advanced World Energy Balances provides the total final energy demand by transport mode – aviation, shipping, rail, or road – by country, region, or globally. However, it provides no further specification of the energy use within each of the transport modes. Therefore, a further division into passenger and freight transport is made, and energy use is calculated using percentage shares. These proportions are determined with literature research, together with the average energy intensity for each of the transport modes for passenger and freight vehicles.

Table 62: Calibration for calculating the transport demand

Calculation Concept	Process	Until 2019	Unit	Comment
Transport Demand				
Aviation, Shipping, Rail, and Road – Past to Present				
Annual Demand	Data	Database	[PJ/yr]	Data: IEA Advanced World Energy Balances
Passenger share	Input	Literature	[%]	Shares of total energy demand from the literature
Freight share	Input	Literature	[%]	Shares of total energy demand from the literature
Average Energy Intensity – passenger transport	Data	Literature	[MJ/pkm]	Literature review – based on current supply mix
Average Energy Intensity – freight transport	Data	Literature	[MJ/tkm]	Literature review – based on current supply mix
Passenger kilometres	Calculation	= Annual Demand/ Energy Intensity	[pkm]	Checked against OECD statistics
Tonne kilometres	Calculation		[tkm]	Checked against OECD statistics
Annual Growth/Decrease – passenger kilometres	Calculation	= Annual Demand previous year/Annual Demand calculated year	[%/yr]	Calculated to understand the trend between 2005 and 2020
Annual Growth/Decrease – tonne kilometres	Calculation		[%/yr]	
Population – indicator of passenger transport development	Data	Database	[million]	Data: UN
GDP per capita – indicator of passenger & freight transport development	Data	Database	[$GDP/ capita]	Data: World Bank
GDP – indicator of freight transport development	Data	Database	[$GDP]	Data: World Bank

92 IEA. IEA World Energy Statistics and Balances. IEA. 2021. https://doi.org/https://doi.org/10.1787/enestats-data-en

The annual transport demand in passenger kilometres per year [pkm/yr] and tonne kilometres per year [tkm/yr] is calculated as the annual energy demand divided by the average energy intensity by mode. In this work for Australia, these results were compared with statistics from the Bureau ofInfrastructure and Transport Research Economic (BITRE)[93], which provide both parameters, pkm/yr and tkm/yr. Calibrating the model based on historical data ensures that the basis of the scenario projections for the coming years and decades is correctly mapped and that the changes are calculated most realistically.

For the forward projection of the transport demand, the calculation method is reversed: the transport demand for each transport mode is calculated based on the annual change, as a percentage. The calculated total annual passenger kilometres and tonne kilometres are the inputs for the energy demand calculation.

Table 63: Methodology of OECM 2.0 – Projection of transport demand based on the changing demand in kilometres

Process	2020–2050	Unit	Comment
Aviation, Navigation, Rail, Road – Projection			
Calculation	= (passenger km previous year) × (increase/decrease in %/yr)	[pkm]	Starting point: base year 2019
Calculation	= (tonne km previous year) × (increase/decrease in %/yr)	[tkm]	Starting point: base year 2019
Input	INPUT in %/yr	[%/yr]	Assumption
Input	INPUT in %/yr	[%/yr]	Assumption
Calculation	INPUT in %/yr	[million]	Assumption based on UN projection
Calculation	= $GDP/population	[$GDP/ capita]	
Calculation	INPUT in %/yr	[$GDP]	Assumption based on World Bank projection
Result	Time series 2020–2050: Passenger km per year & region	[pkm/yr]	Input for energy demand calculation
Result	Time series 2020–2050: Freight km per year & region	[tkm/yr]	Input for energy demand calculation

This methodology for calibration and projection is used across all sectors.

7.3 Sector boundaries: sectors and sub-sectors

The OECM was developed to calculate energy pathways for geographic regions, as documented by Teske et al. 2019[94]. The OECM was further developed to meet the requirements of the financial industry and to design energy and emissions pathways for clearly defined industry sectors (sectoral pathways). The finance industry uses different classification systems to describe sub-areas of certain branches of industry. Those scenario sector boundaries are based on the GICS classification. The GICS is an important economic classification system[95], but the GICS sub-industries do not match the IEA statistical breakdown of the energy demands of certain industries. Table 64 shows examples of the finance sector calculated with the OECM model, the GICS codes, and the statistical information used. Although the OECM model allows all the GICS coded sub-Industries to be calculated, the availability of statistics is the factor limiting the resolution of the sectoral pathways. For example, the statistical data for the textile and leather industry are stored in the IEA database, but the database does not separate the two industries further (see also Teske, Niklas, Talwar, Atherton 2022[96]).

93 The Bureau of Infrastructure and Transport Research Economics (BITRE) provides economic analysis, research, and statistics on infrastructure and transport issues to inform Australian Government policy development and wider community understanding. BITRE is part of the Data, Analytics and Policy Division of the Department of Infrastructure, Transport, Regional Development, Communications and the Arts. (https://www.bitre.gov.au/)

94 Teske S, Pregger T, Naegler T, Simon S, Pagenkopf J, van den Adel B, et al. Energy scenario results. Achieving the Paris Climate Agreement Goals: Global and Regional 100% Renewable Energy Scenarios with Non-Energy GHG Pathways for +1.5°C and +2 °C. 2019;175–401.

95 MSCI. website that provides an overview about the Global Industry Classification Standard (GICS). 2021. https://www.msci.com/our-solutions/indexes/gics

96 Teske, S., Niklas, S., Talwar, S. et al. 1.5°C pathways for the Global Industry Classification (GICS) sectors chemicals, aluminium, and steel. *SN Appl. Sci.* 2022;4:125. https://doi.org/10.1007/s42452-022-05004-0

Table 64: Examples of industry sub-sectors based on the Global Industry Classification Standard (GICS)

Financial Sector	GICS	IEA Statistic Categories	Sector Definition
Transportation			
	203010 Air Freight & Logistics	World Aviation Bunkers	Covers fuels delivered to aircraft of all countries that are engaged in international aviation (*International aviation bunkers*) for the world total aviation bunker demand
	20301010 Air Freight & Logistics	Domestic Aviation	Aviation fuels to aircraft for domestic aviation – commercial, private, agricultural use
	203020 Airlines		
	20302010 Airlines		
	203030 Marine	World Marine Bunkers	Fuels delivered to ships of all flags not engaged in international navigation (International marine bunkers) for the global marine bunker demand
	20303010 Marine	Domestic Navigation	Fuels delivered to vessels of all flags not engaged in international navigation
	203040 Road & Rail	Road	Fuels used in road vehicles and for agricultural and industrial highway use. Excludes military consumption and the motor gasoline used in stationary engines and the diesel oil used in tractors that are not for highway use
	20304010 Railroads		
	20304020 Trucking	Rail	Rail traffic, including industrial railways, and rail transport laid in public roads as part of urban or suburban transport systems (trams, metros, etc.)
	203050 Transportation Infrastructure	Pipeline Transport	Energy used in the support and operation of pipelines transporting gases, liquids, slurries, and other commodities, including the energy used for pump stations and the maintenance of pipelines.
	20305010 Airport Services		
	20305020 Highways & Rail tracks	Transport Equipment (part of Manufacturing)	Manufacture of transportation equipment such as ship building and boat manufacture, the manufacture of railroad rolling stock and locomotives, air and spacecraft and the manufacture of parts thereof.
	20305030 Marine Ports & Services		
Agriculture	3010 Food & Staples Retailing	Farming	Food and tobacco production, excluding the energy demand for agriculture, as defined under the IEA energy statistic 'other sectors'. Additional statistics from industry partners are required because the IEA statistics only provide the accumulated energy demand for agriculture and forestry.
	3020 Food, Beverages, & Tobacco	Food Production and Supply	
Forestry	1510 Materials	Agricultural & Forestry	Energy demand for all wood and wood products, including pulp & paper and printing. Also includes all energy demands for agricultural services not included in food and tobacco production.
	151050 Paper & Forest Products	Paper & Forest Products	
	15105010 Forest Products		
	15105020 Paper Products		
Chemicals	1510 Materials	Chemical Industry	Energy demand for all chemical, petrochemical, glass, and ceramic products.
	151010 Chemicals	Chemical Products	
		Petrochemical Products	
		Glass & Ceramics	
Aluminium	151040 Metals & Mining	Aluminium	Energy demand for the production of primary and secondary aluminium, as well as bauxite mining.
	15104010 Aluminium		
Textiles & Leather	2520 Consumer Durables & Apparel	Textile & Leather Industry	This sector covers the energy demand for the textile and leather industry.
	252030 Textiles, Apparel, & Luxury Goods		

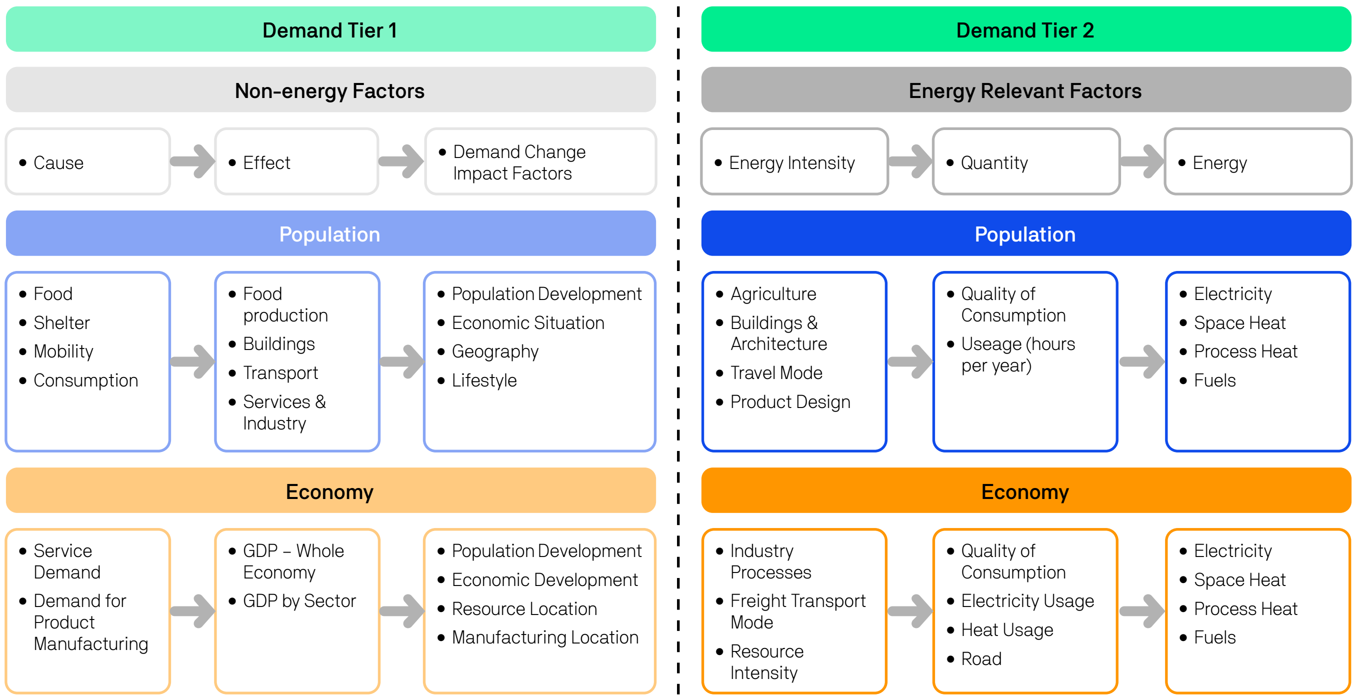
7.4 Demand module

The demand module uses a bottom-up approach to calculate the energy demand for a process (e.g., steel production) or a consumer (e.g., a household) in a region (e.g., a city or country) or transport services over a period of time. One of the most important elements of this approach is the strict separation of the original need (e.g., to get from home to work), how this need can be satisfied (e.g., with a tram), and the kind of energy required to provide this service (in this case, electricity). This basic logic is the foundation for the energy demand calculation across all sectors: buildings, transport, services, and industry. Furthermore, the energy services required are defined: electricity, heat (broken down into four heat levels: < 100°C, 100–500°C, 500–1000°C, > 1000°C), and fuels for processes that cannot (yet) be electrified. Synthetic fuels, such as hydrogen, are part of both the demand module, because electricity is required to produce it, and the supply module, because it is an energy source for other processes, such as manufacturing.

Input Parameters

As in basic energy models, the main drivers of the energy demand are the development of the population and economic activity, measured in GDP. Figure 15 shows the basic methodology of the OECM demand module. The tier 1 inputs are population and GDP by region and sector. Whereas 'population' defines the number of individual energy services, which determines the energy required per capita, the economic activity (in GDP) defines the number of services and/or products manufactured and sold. The tier 1 demand parameters are determined by the effect that a specific service requires. The demand parameters for population are defined by the need for food, shelter (buildings), and mobility, and – depending on the economic situation and/or lifestyle of the population – the demand for goods and services.

Figure 15: Tier 1 and tier 2 input parameters for the assessment of energy demand



Economic activity (measured in GDP) is a secondary input and is directly and indirectly dependent upon the size of the population. However, a large population does not automatically lead to high economic activity. Both population and projected GDP are inputs from external sources, such as the United Nations or the World Bank. The tier 1 input parameters themselves are strictly non-technical. For instance, the need to produce food can be satisfied without electricity or (fossil) fuels. Food production is a service, which can be provided by the human workforce. The tier 2 demand parameters are energy-relevant factors, and describe technical applications, their energy intensities, and the extent to which the application is used. For example, if passenger road transport is required, the technical application 'light duty vehicle (LDV)' can be chosen to satisfy the demand. In this example, the energy intensity for an LDV with an internal combustion engine (ICE) is, for example, 1.5 MJ/km.

The energy intensity multiplied using by the application (vehicle) defines the total energy demand (e.g., if the use is 15,000 km per year, the total energy demand will be 1.5 MJ/km × 15,000 km/yr = 22,500 MJ/yr). The application – in this example, an LDV with ICE – can be replaced with another application, such as an electric vehicle with a reduced energy intensity of 0.5 MJ/km. The transport energy demand decreases, whereas the transport service (15,000 km) remains stable. In a second step, the actual transport service can be reduced or increased, or shifted to another transport mode altogether (such as light rail) by the modeller. This very basic and simple principle is used for every application in each of the main sectors: *Buildings* (*Residential + Commercial*), *Industry*, and *Transport*. Those sectors are broken down into multiple sub-sectors, such as aviation, shipping, rail, and road for *Transport*, and further into applications, such as vehicle types. The modular programming allows the addition of as many sub-sectors and applications as required.

Structure of the Demand Module

Each of the three sectors, *Residential Buildings (R)*, *Industry (I)*, and *Transport (T)*, has standardised sub-structures and applications. The residential sector *R* (first layer) has a list of household types (second layer) and each household type has a standard set of services (third layer), such as 'lighting', 'cooling', and 'entertainment'. Finally, the applications for each of the services are defined (fourth layer), such as refrigerator or freezer for 'cooling'. The energy intensity of each application can be altered by the modeller to reflect the status quo in a certain region and/or to reflect improvements in energy efficiency. An illustrative example of the residential sector layers is shown in Figure 16.

Figure 16: Residential sector sub-structures

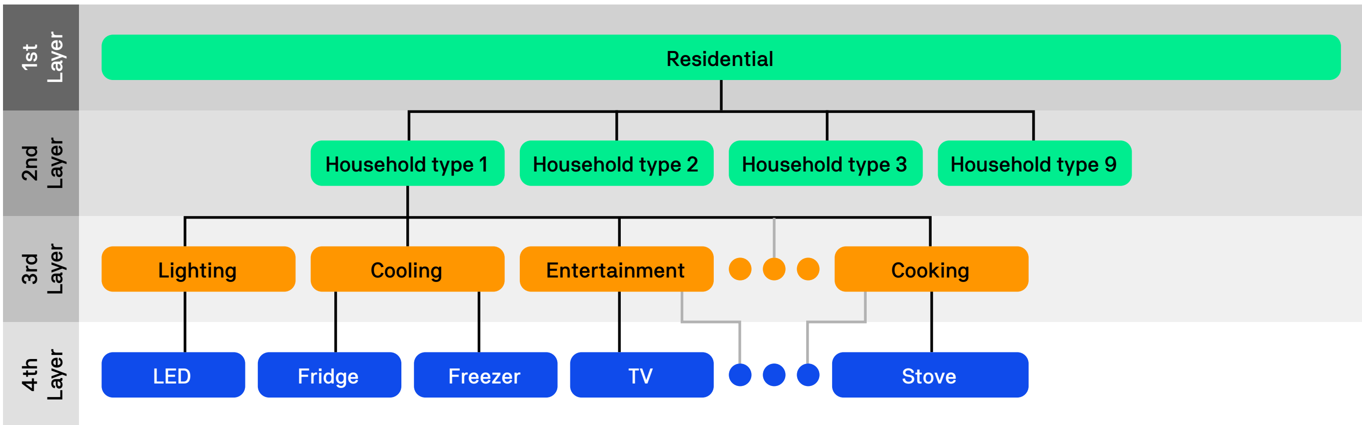


Figure 17 shows an example of the model structure of the *Industry* sector. In the second layer, there are different industries – the OECM 2.0 uses the GICS classification system for sub-industries. The quantity of energy for each sub-industries is driven by either GDP or the projected quantity of product, such as the tonnes of steel produced per year. The market shares of specific manufacturing processes are defined, and each process has a specific energy intensity for electricity, (process) heat, and fuels.

Figure 17: Calculation of Industry energy demand

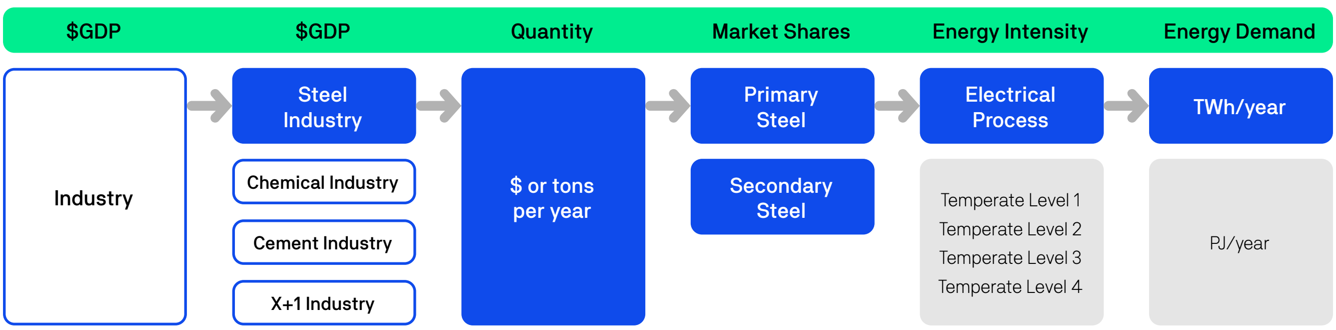
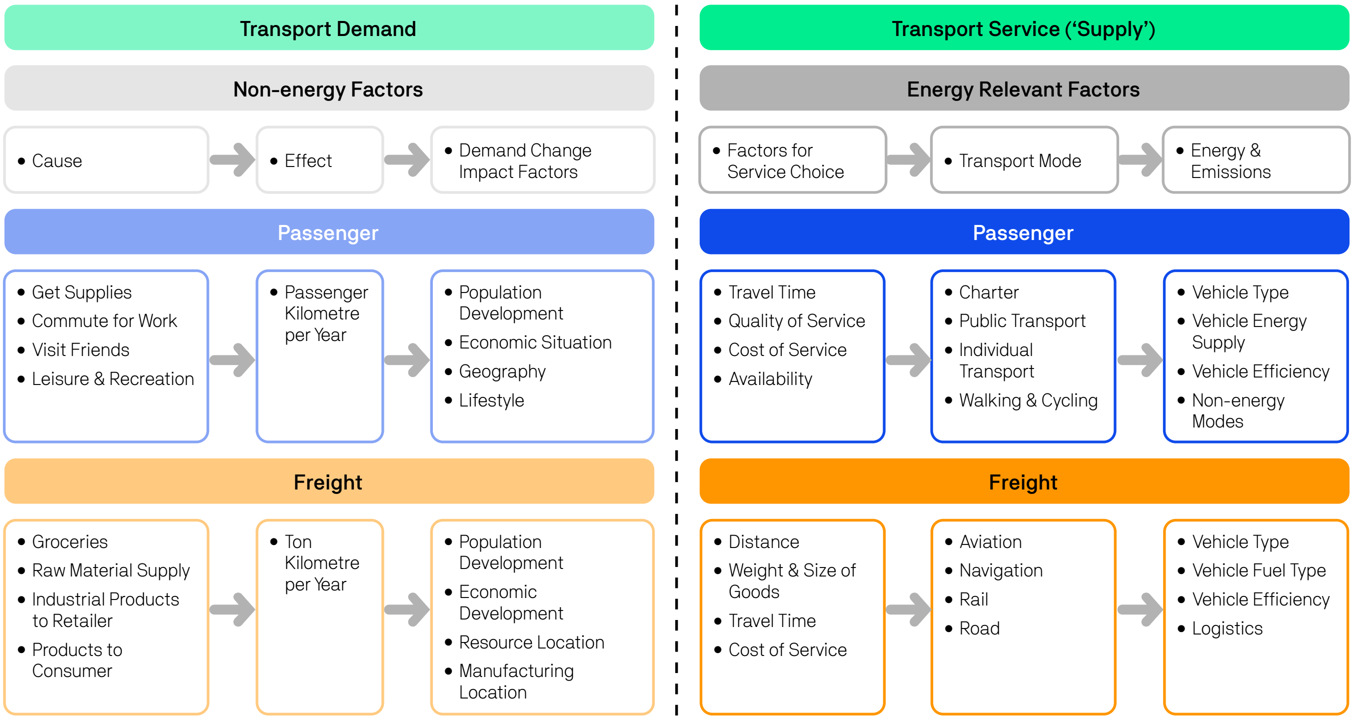


Figure 18 shows the structure for the *Transport* sector. Again, the demand is driven by 'non-energy' factors, such as passenger kilometres or freight kilometres, and energy-related factors, such as the transport mode or the energy intensity for the different vehicle options.

Figure 18: Calculation of Transport energy demand



7.5 Supply module

After the demand has been calculated, the supply of electricity, heat, and fuels is calculated. The supply does not differentiate between the demand sectors. Therefore, the electricity demand for all sectors – *Residential*, *Industry*, and *Transport* – is aggregated and is provided as a total value. Consequently, no specific electric generation mix for the *Transport* sector, for example, is considered.

The supply module consists of three main elements: i) supply technologies, ii) storage technologies, and iii) the infrastructure for the power supply (the capacities of power lines). For the generation of electricity and heat, the model considers all the technologies of the energy market, from both renewable and non-renewable sources. In addition to the generation of pure electricity and heat, the entire range of combined heat and power systems is covered.

Storage technologies include batteries and the use of hydrogen from electrolysers. The calculation of heat storage is possible but has not yet been used in the OECM scenarios, because heat demand profiles with hourly resolution for whole countries are not available from open-source databases. A dispatch strategy is defined for electricity and heat generation that reflects market and policy factors. Whether electricity from photovoltaics (PV) or onshore and offshore wind turbines have priority dispatch ahead of fossil-fuel power plants and how storage systems are used can be determined. Each technology has a specific conversion efficiency. Heat generation technologies are also defined by the temperature levels they can provide. For example, residential solar collectors can only supply low-temperature heat and will therefore not be considered for high-temperature process heat. A power sector analysis with hourly resolution to analyse the storage demand was beyond the scope of the research.

Table 65: Examples of generation and storage technologies

Generation			Storage		
Power plants	**Combined heat and power plants**	**Heating plants**	**Electrical**	**Thermal**	**Hydrogen**
Hard coal	Hard coal	Coal	Lithium battery	Water tank	Tank
Lignite	Lignite	Lignite	Pumped hydro	Molten salt	Pipeline
Gas	Gas	Gas			
Oil	Oil	Oil			
Diesel	Biomass	Biomass			
Biomass	Geothermal	Solar collectors			
Hydro	Hydrogen	Geothermal			
Wind		Hydrogen			
PV					
Solar					
Geothermal					
Solar thermal					
Ocean energy					
Hydrogen					

7.6 OECM 2.0 output and areas of use (including all sectors)

Commodities and/or GDP are the main drivers of the energy demand for industries. The projection of, for example, the global steel demand in tonnes per year over the next decades is discussed with the industry and/or client. The OECM 2.0 can calculate either a single specific sector only, or a whole set of sectors. In the case of this work, various industry projections are combined to estimate both the total energy supply required and the potential energy-related emissions. Thus, the emissions involved in achieving a specific target or budget can be broken down by specific industries. Table 66 provides an overview of the main parameters that can be used to set specific targets for industries.

Energy intensities are both input data for the base year and a key performance indicators (KPI)s for future projections. The effect of a targeted reduction in the energy intensity each year and the resulting energy demand and carbon emissions can be calculated, e.g., for the *Transport* service industry.

All sector demands are supplied by the same energy supply structure in terms of electricity, process heat (for each temperature level), and total final energy. Finally, specific carbon intensities, such as CO_2 per tonne kilometre, CO_2 per tonne of steel or per cubic metre of wastewater treatment, are calculated (and can be used to set industry targets).

Table 67 provides an overview of all individually developed sectoral scenarios for the 39 calculated OECM sectors.

Table 66: Examples of energy-related key performance indicators (KPIs) for setting net zero targets, calculated with OECM

Sector	Parameter	Units	Base year 2019	Projection 2025, 2030, 2035, 2040, 2045, 2050
Commodities				
Water Utilities	Water withdrawal	[billion m^3/yr]	Input	Calculated projection with annual growth rates discussed with client
Chemical Industry	Economic development	[$GDP/yr]	Input	
Steel industry	Product-based market projection	[tonnes steel/yr]	Input	
Aviation	Passenger kilometres	[million passenger km/yr]	Input	
Energy Intensities				
Water Utilities	Waste-water treatment	[kWh/m^3]	Input	Technical target (KPI) Calculated with annual progress ratio based on technical assessment
Chemical Industry	Industry-specific energy intensity	[MJ/$GDP]	Input	
Steel Industry	Energy intensity	[MJ/tonne steel]	Input	
Aviation	Energy intensity per transport service	[MJ/passenger km]	Input	
Energy Demand				
Water Utilities	Final energy demand	[PJ/yr]	Input	Output – industry-specific scenario(s)
Chemical Industry	Electricity demand	[TWh/yr]	Input	
Steel Industry	Process heat demand by temperature level	[PJ/yr]	Input	
Aviation	Final energy demand	[PJ/yr]	Input	
	Total final energy demand	[PJ/yr]	Input	
Energy Supply				
Water Utilities	Electricity generation by technology	[TWh/yr]	Input	Output – based on developed scenario Supply for all (sub-)sectors.
Chemical Industry	(Process) heat by technology	[PJ/yr]	Input	
Steel Industry	Fuel supply by fuel type	[PJ/yr]	Input	
Aviation	Fuel supply by fuel type	[PJ/yr]		
	Total final energy supply by fuel type	[PJ/yr]	Input	
Energy -related Emissions				
	Electricity – specific CO_2 emissions	[gCO_2/kWh]	Calculated	Output – KPI for utilities
	Electricity – total CO_2 emissions	[t CO_2/yr]	Calculated	Output – KPI for utilities
	(Process) heat – specific CO_2 emissions	[gCO_2/kWh]	Calculated	Output – KPI for industry
	Transport service energy	[g CO_2/kilometre]	Calculated	Output – KPI for industry
	(Process) heat – total CO_2 emissions	[tCO_2/yr]	Calculated	Output – KPI for industry
Product-specific Emission				
Water Utilities	Emissions intensity	[kgCO_2/m^3]	Calculated	KPI – water utilities
	Total energy-related CO_2 emissions	[tCO_2]	Calculated	KPI – water utilities
Chemical Industry	Emissions intensity	[kgCO_2/$GDP]	Calculated	KPI – chemical industry
	Total energy-related CO_2 emissions	[tCO_2]	Calculated	KPI – chemical industry
Steel Industry	Emissions intensity	[kgCO_2/t steel]	Calculated	KPI – steel industry
	Total energy-related CO_2 emissions	[tCO_2]	Calculated	KPI – steel industry
Aviation	Emission intensity	[kgCO_2/passenger km]	Calculated	KPI – aviation industry
	Total energy-related CO_2 emissions	[tCO_2]	Calculated	KPI – aviation industry

All input and output OECM data are available as MATLAB-based tables or graphs, or as standard Excel-based reports.

Table 67: Overview – calculated OECM scenario sectors

No.				
1	**Primary Energy**	Coal	Energy	Non-energy
2		Lignite	Energy	Non-energy
3		Gas	Energy	Non-energy
4		Oil	Energy	Non-energy
5	**Secondary Energy**	Power Utilities	Power	Power & Heat (CHP)
6		Gas Utilities	Power	Heat
7	**End-use**	Transport	Aviation	Freight Transport
8				Passenger Transport
9			Navigation	Freight Transport
10				Passenger Transport
11			Road	Freight Transport
12				Passenger Transport
13				Transport Equipment Manufacturing
14		Buildings		Residential Buildings
15				Commercial Buildings
16				Construction Buildings
17		Services	Agriculture, Food Processing & Tobacco	Agriculture
18				Food Processing
19				Tobacco
20			Fishing Industry	
21			Forestry, Wood Products	Forestry
22				Wood Products
23			Water Utilities	
24		Industry	Cement	Clinker
25				Cement Production
26			Steel	Iron Ore mining
27				Primary Steel
28				Secondary Steel
29			Aluminium	Bauxite Mining
30				Alumina
31				Primary Aluminium
32				Secondary Aluminium
33			Chemicals	Ethylene Production
34				Ammonia Production
35				Aromatics Extraction
36				Methanol Production
37				Chlorine Alkali Production
38			Textile & Leather	Textile
39				Leather

7.7 Model dynamics

A detailed assessment of energy demand based on industry products, such as the amount of steel or aluminium used and/or the economic projections (for example, for sub-sectors of the chemical industry) – combined with very high technical resolution – allows the development of the electricity and fuel demands to be comprehensively mapped with steadily increasing sector coupling. A high degree of electrification for heating and transport, to replace fuels, requires an energy scenario to be modelled that includes an electricity system analysis that assesses the infrastructure changes required (e.g., the power grid). OECM 2.0 combines an integrated energy assessment tool with a system analysis module. Net-zero pledges for specific industries lead to more-detailed energy scenarios for specific industry sectors. The steel industry, for example, favours hydrogen-based steel production, which will have a significant impact on the hydrogen demand and the electricity required to produce it. OECM 2.0 takes this development into consideration and allows the modeller to change from yearly to hourly resolution when developing load curves for industries and/or the entire power system when simulating an electricity supply with high shares of variable renewable power plants. Another example in which a long-term scenario analysis must be combined with a system analysis is the *Chemical* industry. The switch to electrical process heat will not only significantly increase the power requirement, but also the power load. The decision to use electric or hydrogen-based process heat requires the analysis of the regional infrastructure to allow the development of a cost-effective solution. OECM 2.0 is modular and currently includes 20 different industry sectors and sub-sectors. Its expansion to more sectors and sub-sectors is possible without great effort, and will thus increase the accuracy of the analysis of electricity and fuel requirements. This interaction between a technology change in one sector (e.g., to move to electrically generated process heat) and the technical and cost implications for other sectors (e.g., power utilities and grid operators) is a central component of the model dynamics.

7.8 Methodologies for identifying and reporting Scope 1, 2, and 3 emissions

Analysing and reporting GHG emissions is important, and the focus is no longer simply on direct energy-related CO_2 emissions but includes other GHGs emitted by industries. These increasingly include the indirect emissions that occur in supply chains[97]. The Greenhouse Gas Protocol, a global corporate GHG accounting and reporting standard[98], distinguishes between three 'scopes':

- **Scope 1** – emissions are the direct emissions from owned or controlled sources.
- **Scope 2** – emissions are the indirect emissions from the generation of purchased energy.
- **Scope 3** – emissions are all the indirect emissions (not included in *Scope 2*) that occur in the value chain of the reporting company, including both upstream and downstream emissions.

The United States Environmental Protection Agency (US EPA) defines *Scope 3* emissions as 'the result of activities from assets not owned or controlled by the reporting organisation, but that the organisation indirectly impacts in its value chain. They include upstream and downstream of the organisation's activities'[99]. According to the US EPA, *Scope 3* emissions include all sources of emissions not within an organisation's *Scope 1* and *2* boundaries, and the *Scope 3* emissions of one organisation are the *Scope 1* and *2* emissions of another organisation. *Scope 3* emissions, also referred to as 'value chain emissions' or indirect emissions, often represent the majority of an organisation's total GHG emissions.

97 Hertwich EG, Wood R. The growing importance of scope 3 greenhouse gas emissions from industry. Environmental Research Letters. 2018;13:104013.

98 WRI & WBCSD. Greenhouse Gas Protocol. WRI & WBCSD. https://ghgprotocol.org/

99 EPA. Scope 3 Inventory Guidance

Whereas the methodologies of *Scope 1* and *Scope 2* are undisputed, the method of calculating *Scope 3* emissions is an area of ongoing discussion and development[100,101,102]. The main issues discussed are data availability, reporting challenges, and the risk of double counting. MSCI, for example, avoids double counting by using a 'de-duplication multiplier of approximately 0.205'[103]. This implies that the allocation of emissions based on actual data is not possible. Accounting methodologies for *Scope 3* emissions have been developed for entity-level accounting and reporting[104].

Ducoulombier (2021)[105] found that the reporting of *Scope 3* emissions ('indirect emissions') is incomplete and that reporting standards to support the comparison of companies are missing. Schulman et al. (2021)[106] showed that over 80% of emissions in the food industry are *Scope 3* emissions, and that the data reported by the Carbon Disclosure Project (CDP), a global data service for investors, companies, cities, states, and regions, are incomplete and inconsistent throughout.

In 2009, Huang et al. suggested that 'Protocol organisations should actively make more specific *Scope 3* guidelines available for their constituents by developing sector-specific categorisations for as many sectors as they feasibly can and create broader industry-specific protocols for others'.

Therefore, the accounting methodology for *Scope 3* emissions requires significant improvement and has been under discussion for more than a decade. The OECM model focuses on the development of 1.5°C net zero pathways for industry sectors classified under the GICS for countries or regions or at the global level. Methodologies for entity-level *Scope 3* emissions require bottom-up entity-level data to arrive at exact figures. Therefore, data availability and accounting systems for whole industry sectors on a regional or global level present significant challenges.

Consequently, the *Scope 3* calculation methodology had to be simplified for country-, regional-, and global-level calculations and to avoid double counting. In the Greenhouse Gas Protocol, *Scope 3* emissions are categorised into 15 categories, shown in Table 68.

100 Baker B. Scope 3 Carbon Emissions: Seeing the Full Picture. MSCI. 2020

101 Lombard Odier. Debunking 7 misconceptions on scope 3 emissions. Lombard Odier. 2021.

102 Liebreich M. Climate and Finance – Lessons from a Time Machine | Bloomberg NEF. 2021. https://about.bnef.com/blog/liebreich-climate-and-finance-lessons-from-a-time-machine/.

103 MSCI. Global Industry Classification Standard (GICS®) Methodology Guiding Principles and Methodology for GICS. 2020

104 WRI & WBCSD. Technical Guidance for Calculating Scope 3 Emissions, Supplement to the Corporate Value Chain (Scope 3) Accounting & Reporting Standard. 2013.

105 Ducoulombier F. Understanding the Importance of Scope 3 emissions and the Implications of data limitations. Journal of Impact and ESG Investing. 2021;1:63–71.

106 Schulman DJ, Bateman AH, Greene S. Supply chains (Scope 3) toward sustainable food systems: An analysis of food & beverage processing corporate greenhouse gas emissions disclosure. Cleaner Production Letters. 2021;1:100002.

Table 68: Upstream and downstream Scope 3 emissions categories

Upstream			Downstream		
Greenhouse Gas Protocol Scope 3		OECM 2.0 – emissions included in the following sectors	Greenhouse Gas Protocol *Scope 3*		OECM 2.0 – emissions included in the following sectors
U1	Business travel	Part of the respective transport mode (aviation, road, rail, etc.)	D1	Use of solid products	All sector uses of solid products are included
U2	Purchased goods and services	All sector-specific goods and services are included	D2	Downstream transportation and distribution	Sector-specific transportation and distribution and end-of-life treatment are included. This includes the actual use of the product, e.g., emissions when driving a manufactured car.
U3	Waste generated in operations	All waste generated in sector-specific operations are included	D3	End-of-life treatment of solid products	
U4	Fuel- and energy-related activities	All sector fuel- and energy-related activities are included	D4	Investments	Not included
U5	Employee commuting	Part of the respective transport mode (aviation, road, rail, etc.)	D5	Downstream leased assets	Not included
U6	Upstream transportation and distribution	Part of the respective transport mode (aviation, road, rail, etc.)	D6	Processing solid products	All sector processing of solid products is included
U7	Capital goods	Not included	D7	Franchises	Not included
U8	Upstream-leased assets	Not included			

To include all the upstream and downstream categories shown in Table 68 for an entire industry sector is not possible because firstly, complete data are not available – for example, how many kilometres employees in the agricultural or forestry sector commute – and secondly, it is impossible to avoid double counting (for example, when calculating *Scope 3* for the car industry).

Table 67 identifies how the 15 categories are handled in the OECM 2.0 methodology.

The OECM methodology is based on the *Technical Guidance for Calculating Scope 3 Emissions* of the World Resource Institute[107], but is simplified to reflect the higher level of industry- and country-specific pathways. The OECM defines the three emissions scopes, as follows:

Scope 1

All direct emissions from the activities of an organisation or under its control, including fuel combustion on site (such as gas boilers), fleet vehicles, and air-conditioning leaks.

Limitations of the OECM Scope 1 analysis: Only economic activities covered under the sector-specific GICS classification are counted for the sector and included. All energy demands reported by the IEA *Advanced World Energy Balances* for the specific sector are included.

Scope 2

Indirect emissions from electricity purchased and used by the organisation. Emissions are created during the production of energy and are eventually used by the organisation.

Limitations of the OECM Scope 2 analysis: Due to poor data availability, the calculation of emissions focuses on the electricity demand and 'own consumption', reported for power generation by the International Energy Agency (IEA)[108].

107 Baker B (2020) Scope 3 carbon emissions: seeing the full picture, online article, Brendan Baker, Senior Associate, MSCI Research. https://www.msci.com/www/blog-posts/scope-3-carbon-emissions-seeing/02092372761

108 IEA. World Energy Balances. IEA. 2021. https://www.iea.org/data-and-statistics/data-product/world-energy-balances

Scope 3

GHG emissions caused by the analysed industry that are limited to sector-specific activities and/or products classified in the GICS.

Limitations of the OECM Scope 3 analysis: Only sector-specific emissions are included. Travelling, commuting, and all other transport-related emissions are reported under '*Transport*'. The lease of buildings is reported under '*Buildings*'. All other financial activities, such as '*capital goods*', are excluded because no data are available for the GICS industry groups and including them would lead to double counting. The OECM is limited to energy-related CO_2 and energy-related methane (CH_4) emissions. All other GHGs are calculated outside the OECM model by Meinshausen et al. 2019[109].

The main difference between OECM 2.0 and the World Resources Institute (WRI) concept is that the interactions between industries and/or other services are kept separate in OECM 2.0. OECM 2.0 reports only emissions directly related to the economic activities classified by the GICS. However, the industries are broken down into three categories: Primary Class, Secondary Class, and End-use Activity Class.

Table 69: Schematic representation of OECM Scopes 1, 2, and 3 according to GICS classes to avoid double counting

Primary Class					Secondary Class					End-use Activity Class			
	GICS 10 Energy	Scope 1	Scope 2	Scope 3		GICS 55 Utilities	Scope 1	Scope 2	Scope 3	All other Industries & Services	Scope 1	Scope 2	Scope 3
CO_2					CO_2								
CH_2 AFOLU					CH_2 AFOLU								
CH_4					CH_4								
N_2O					N_2O								
					CFCs								
Total GHG		Sum of Scopes 1, 2, & 3 equals total emissions			Total GHG		Sum of Scopes 1, 2, & 3 equals total emissions				Sum of Scopes 1, 2, & 3 equals total emissions		

Table 69 shows a schematic representation of the OECM *Scope 1*, *2*, and *3* calculation method according to GICS sector, which is used to avoid double counting. The sum of *Scopes 1*, *2*, and *3* for each of the three categories is equal to the actual emissions. Example: The total annual global energy-related CO_2 emissions are 35 Gt each year.

- The sum of *Scope 1*, *2*, and *3* for the primary class (primary energy industry) is 35 Gt CO_2
- The sum of *Scope 1, 2,* and *3* for the secondary class (secondary energy industry/utilities) is 35 Gt CO_2
- The sum of *Scope 1, 2,* and *3* for end-use activities (all end-use sectors) is 35 Gt CO_2

Double counting can be avoided by defining a primary class for the primary energy industry, a secondary class for the supply utilities, and an end-use class for all the economic activities that use the energy from the primary- and secondary-class companies. Furthermore, the separation of all emissions by defined industry categories – such as GICS – streamlines the accounting and reporting systems. The volume of data required is reduced and reporting is considerably simplified with the OECM methodology. Achieving the global target of 1.5°C and net zero emissions by 2050 under the Paris Agreement for a specific industry sector requires all its business activities with other sectors to also commit to a 1.5°C–net zero emissions target.

109 Meinshausen M, Dooley K. Mitigation Scenarios for Non-energy GHG. In: Teske S, editor. Achieving the Paris Climate Agreement Goals. Global and Regional 100% Renewable Energy Scenarios with Non-energy GHG Pathways for +1.5°C and +2°C. SpringerOpen; 2019.

8 Appendix 2: Economic Activities – EU Taxonomy

8.1 Economic activities – complete list

EU Taxonomy Navigator

Sector No.	Sector	Act. No	Activities by sectors
1	Accommodation activities	1.1	Hotels, holiday, camping grounds and similar accommodation
2	Arts, entertainment and recreation	2.1	Creative, arts and entertainment activities
2	Arts, entertainment and recreation	2.2	Libraries, archives, museums and cultural activities
2	Arts, entertainment and recreation	2.3	Motion picture, video and television programme production, sound recording and music publishing activities
3	Construction and real estate	3.1	Acquisition and ownership of buildings
3	Construction and real estate	3.2	Construction of new buildings
3	Construction and real estate	3.3	Demolition and wrecking of buildings and other structures
3	Construction and real estate	3.4	Installation, maintenance and repair of charging stations for electric vehicles in buildings (and parking spaces attached to buildings)
3	Construction and real estate	3.5	Installation, maintenance and repair of energy efficiency equipment
3	Construction and real estate	3.6	Installation, maintenance and repair of instruments and devices for measuring, regulation and controlling energy performance of buildings
3	Construction and real estate	3.7	Installation, maintenance and repair of renewable energy technologies
3	Construction and real estate	3.8	Maintenance of roads and motorways
3	Construction and real estate	3.9	Renovation of existing buildings
4	Disaster risk management	4.1	Emergency Services
4	Disaster risk management	4.2	Flood risk prevention and protection infrastructure
4	Disaster risk management	4.3	Nature-based solutions for flood and drought risk prevention and protection
5	Education	5.1	Education
6	Energy	6.1	Cogeneration of heat/cool and power from bioenergy
6	Energy	6.2	Cogeneration of heat/cool and power from geothermal energy
6	Energy	6.3	Cogeneration of heat/cool and power from renewable non-fossil gaseous and liquid fuels
6	Energy	6.4	Cogeneration of heat/cool and power from solar energy
6	Energy	6.5	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
6	Energy	6.6	District heating/cooling distribution
6	Energy	6.7	Electricity generation from bioenergy
6	Energy	6.8	Electricity generation from fossil gaseous fuels
6	Energy	6.9	Electricity generation from geothermal energy
6	Energy	6.10	Electricity generation from hydropower
6	Energy	6.11	Electricity generation from nuclear energy in existing installations
6	Energy	6.12	Electricity generation from ocean energy technologies
6	Energy	6.13	Electricity generation from renewable non-fossil gaseous & liquid fuels
6	Energy	6.14	Electricity generation from wind power
6	Energy	6.15	Electricity generation using concentrated solar power (CSP) technology
6	Energy	6.16	Electricity generation using solar photovoltaic technology
6	Energy	6.17	High-efficiency co-generation of heat/cool and power from fossil gaseous fuels
6	Energy	6.18	Installation and operation of electric heat pumps
6	Energy	6.19	Manufacture of biogas and biofuels for use in transport and of bioliquids
6	Energy	6.20	Pre-commercial stages of advanced technologies to produce energy from nuclear processes with minimal waste from the fuel cycle

EU Taxonomy Navigator

Sector No.	Sector	Act. No	Activities by sectors
6	Energy	6.21	Production of heat/cool from bioenergy
6	Energy	6.22	Production of heat/cool from fossil gaseous fuels in an efficient district heating and cooling system
6	Energy	6.23	Production of heat/cool from geothermal energy
6	Energy	6.24	Production of heat/cool from renewable non-fossil gaseous and liquid fuels
6	Energy	6.25	Production of heat/cool from solar thermal heating
6	Energy	6.26	Production of heat/cool using waste heat
6	Energy	6.27	Storage of electricity
6	Energy	6.28	Storage of hydrogen
6	Energy	6.29	Storage of thermal energy
6	Energy	6.30	Transmission and distribution networks for renewable and low-carbon gases
6	Energy	6.31	Transmission and distribution of electricity
7	Environmental protection and restoration activities	7.1	Conservation, including restoration, of habitats [1], ecosystems[2] and species
7	Environmental protection and restoration activities	7.2	Restoration of wetlands
8	Financial and insurance activities	8.1	Non-life insurance: underwriting of climate-related perils
8	Financial and insurance activities	8.2	Reinsurance
9	Forestry	9.1	Afforestation
9	Forestry	9.2	Conservation forestry
9	Forestry	9.3	Forest management
9	Forestry	9.4	Rehabilitation and restoration of forests, including reforestation and natural forest regeneration after an extreme event
10	Human health and social work activities	10.1	Residential care activities
11	Information and communication	11.1	Computer programming, consultancy and related activities
11	Information and communication	11.2	Data processing, hosting and related activities
11	Information and communication	11.3	Data-driven solutions for GHG emissions reductions
11	Information and communication	11.4	Programming and broadcasting activities
11	Information and communication	11.5	Provision of IT/OT data-driven solutions
11	Information and communication	11.6	Provision of IT/OT data-driven solutions for leakage reduction
11	Information and communication	11.7	Software enabling physical climate risk management and adaptation
12	Manufacturing	12.1	Manufacture of active pharmaceutical ingredients (API) or active substances
12	Manufacturing	12.2	Manufacture of aluminium
12	Manufacturing	12.3	Manufacture of anhydrous ammonia
12	Manufacturing	12.4	Manufacture of automotive and mobility components
12	Manufacturing	12.5	Manufacture of batteries
12	Manufacturing	12.6	Manufacture of carbon black
12	Manufacturing	12.7	Manufacture of cement
12	Manufacturing	12.8	Manufacture of chlorine
12	Manufacturing	12.9	Manufacture of electrical and electronic equipment
12	Manufacturing	12.10	Manufacture of energy efficiency equipment for buildings
12	Manufacturing	12.11	Manufacture of equipment for the production and use of hydrogen
12	Manufacturing	12.12	Manufacture of hydrogen
12	Manufacturing	12.13	Manufacture of iron and steel
12	Manufacturing	12.14	Manufacture of low carbon technologies for transport

EU Taxonomy Navigator

Sector No.	Sector	Act. No	Activities by sectors
12	Manufacturing	12.15	Manufacture of medicinal products
12	Manufacturing	12.16	Manufacture of nitric acid
12	Manufacturing	12.17	Manufacture of organic basic chemicals
12	Manufacturing	12.18	Manufacture of other low carbon technologies
12	Manufacturing	12.19	Manufacture of plastic packaging goods
12	Manufacturing	12.20	Manufacture of plastics in primary form
12	Manufacturing	12.21	Manufacture of rail rolling stock constituents
12	Manufacturing	12.22	Manufacture of renewable energy technologies
12	Manufacturing	12.23	Manufacture of soda ash
12	Manufacturing	12.24	Manufacture, installation and associated services for leakage control technologies enabling leakage reduction and prevention in water supply systems
12	Manufacturing	12.25	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
12	Manufacturing	12.26	Manufacturing of aircraft
13	Professional, scientific and technical activities	13.1	Close to market research, development and innovation
13	Professional, scientific and technical activities	13.2	Consultancy for physical climate risk management and adaptation
13	Professional, scientific and technical activities	13.3	Engineering activities and related technical consultancy dedicated to adaptation to climate change
13	Professional, scientific and technical activities	13.4	Professional services related to energy performance of buildings
13	Professional, scientific and technical activities	13.5	Research, development and innovation for direct air capture of CO_2
14	Services	14.1	Marketplace for the trade of second-hand goods for reuse
14	Services	14.2	Preparation for re-use of end-of-life products and product components
14	Services	14.3	Product-as-a-service and other circular use- and result-oriented service models
14	Services	14.4	Repair, refurbishment and remanufacturing
14	Services	14.5	Sale of second-hand goods
14	Services	14.6	Sale of spare parts
15	Transport	15.1	Air transport ground handling operations
15	Transport	15.2	Airport infrastructure
15	Transport	15.3	Freight rail transport
15	Transport	15.4	Freight transport services by road
15	Transport	15.5	Infrastructure enabling low carbon water transport
15	Transport	15.6	Infrastructure enabling low-carbon road transport and public transport
15	Transport	15.7	Infrastructure enabling road transport and public transport
15	Transport	15.8	Infrastructure for personal mobility, cycle logistics
15	Transport	15.9	Infrastructure for rail transport
15	Transport	15.1	Infrastructure for water transport
15	Transport	15.11	Inland freight water transport
15	Transport	15.12	Inland passenger water transport
15	Transport	15.13	Leasing of aircraft
15	Transport	15.14	Low carbon airport infrastructure
15	Transport	15.15	Operation of personal mobility devices, cycle logistics
15	Transport	15.9	Infrastructure for rail transport

EU Taxonomy Navigator

Sector No.	Sector	Act. No	Activities by sectors
15	Transport	15.1	Infrastructure for water transport
15	Transport	15.11	Inland freight water transport
15	Transport	15.12	Inland passenger water transport
15	Transport	15.13	Leasing of aircraft
15	Transport	15.14	Low carbon airport infrastructure
15	Transport	15.15	Operation of personal mobility devices, cycle logistics
15	Transport	15.16	Passenger and freight air transport
15	Transport	15.17	Passenger interurban rail transport
15	Transport	15.18	Retrofitting of inland water passenger and freight transport
15	Transport	15.19	Retrofitting of sea and coastal freight and passenger water transport
15	Transport	15.2	Sea and coastal freight water transport, vessels for port operations and auxiliary activities
15	Transport	15.21	Sea and coastal passenger water transport
15	Transport	15.22	Transport by motorbikes, passenger cars and light commercial vehicles
15	Transport	15.23	Urban and suburban transport, road passenger transport
16	Water supply, sewerage, waste management and remediation	16.1	Anaerobic digestion of bio-waste
16	Water supply, sewerage, waste management and remediation	16.2	Anaerobic digestion of sewage sludge
16	Water supply, sewerage, waste management and remediation	16.3	Collection and transport of hazardous waste
16	Water supply, sewerage, waste management and remediation	16.4	Collection and transport of non-hazardous and hazardous waste
16	Water supply, sewerage, waste management and remediation	16.5	Collection and transport of non-hazardous waste in source segregated fractions
16	Water supply, sewerage, waste management and remediation	16.6	Composting of bio-waste
16	Water supply, sewerage, waste management and remediation	16.7	Construction, extension and operation of wastewater collection and treatment
16	Water supply, sewerage, waste management and remediation	16.8	Construction, extension and operation of water collection, treatment and supply systems
16	Water supply, sewerage, waste management and remediation	16.9	Depollution and dismantling of end-of-life products
16	Water supply, sewerage, waste management and remediation	16.10	Desalination
16	Water supply, sewerage, waste management and remediation	16.11	Landfill gas capture and utilisation
16	Water supply, sewerage, waste management and remediation	16.12	Material recovery from non-hazardous waste
16	Water supply, sewerage, waste management and remediation	16.13	Phosphorus recovery from wastewater
16	Water supply, sewerage, waste management and remediation	16.14	Production of alternative water resources for purposes other than human consumption
16	Water supply, sewerage, waste management and remediation	16.15	Recovery of bio-waste by anaerobic digestion or composting

EU Taxonomy Navigator

Sector No.	Sector	Act. No	Activities by sectors
16	Water supply, sewerage, waste management and remediation	16.16	Remediation of contaminated sites and areas
16	Water supply, sewerage, waste management and remediation	16.17	Remediation of legally non-conforming landfills and abandoned or illegal waste dumps
16	Water supply, sewerage, waste management and remediation	16.18	Renewal of wastewater collection and treatment
16	Water supply, sewerage, waste management and remediation	16.19	Renewal of water collection, treatment and supply systems
16	Water supply, sewerage, waste management and remediation	16.20	Sorting and material recovery of non-hazardous waste
16	Water supply, sewerage, waste management and remediation	16.21	Sustainable urban drainage systems (SUDS)
16	Water supply, sewerage, waste management and remediation	16.22	Transport of CO_2
16	Water supply, sewerage, waste management and remediation	16.23	Treatment of hazardous waste
16	Water supply, sewerage, waste management and remediation	16.24	Underground permanent geological storage of CO_2
16	Water supply, sewerage, waste management and remediation	16.25	Urban wastewater treatment
16	Water supply, sewerage, waste management and remediation	16.26	Water supply

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