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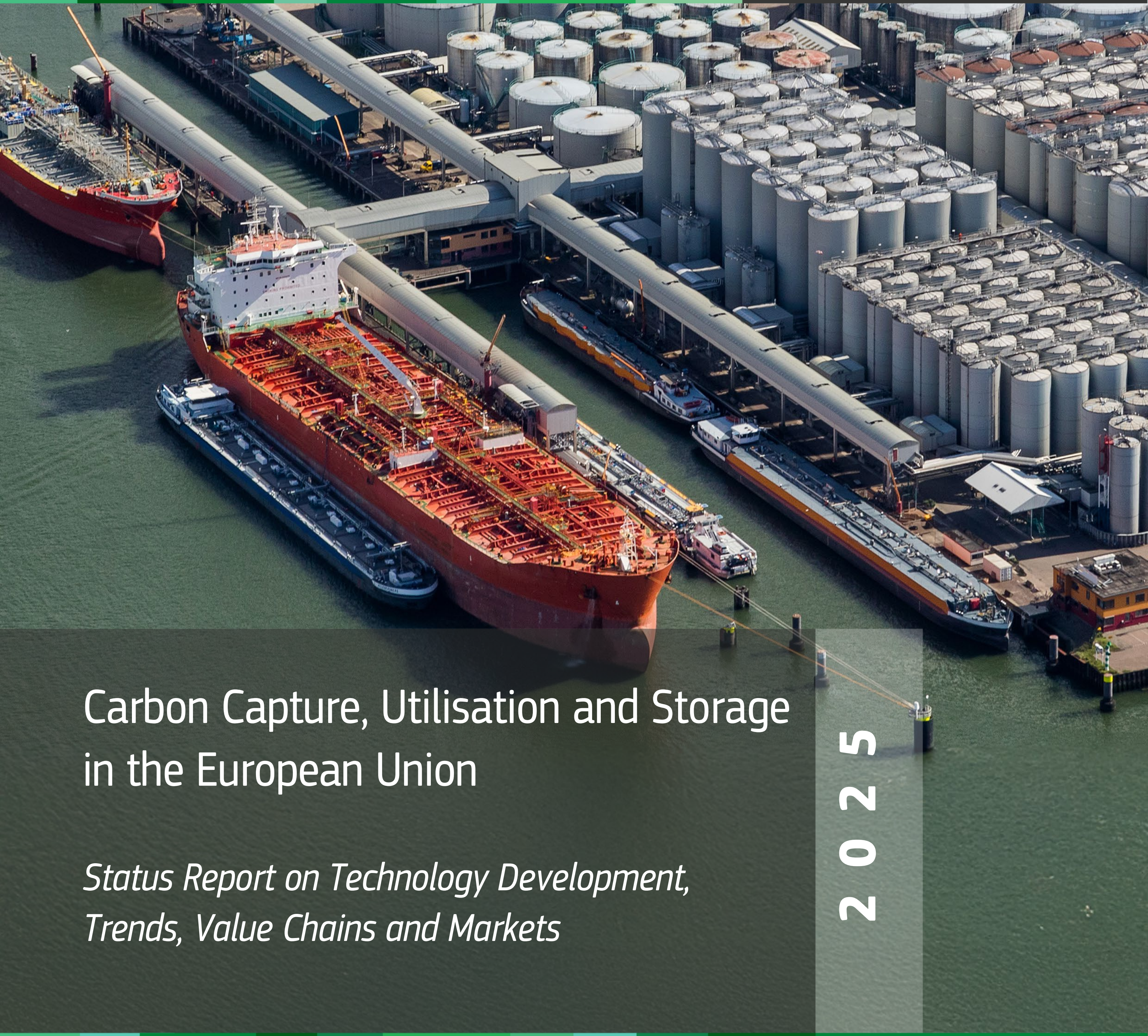

Carbon Capture, Utilisation and Storage in the European Union

Status Report on Technology Development, Trends, Value Chains and Markets

2025

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Abstract

This report provides a comprehensive assessment of carbon capture, utilisation and storage (CCUS) technologies within the European policy, research, and industrial landscape. In line with the European Union's 2050 climate objectives, CCUS has been designated as a Strategic Net-Zero technology under the 2024 Net-Zero Industry Act (NZIA), supported by complementary initiatives such as the Industrial Carbon Management strategy and the Clean Industrial Deal. The report examines the current state of CCUS technology readiness across capture, transport, utilisation, and storage phases, identifying mature solutions in absorption-based capture, pipeline transport, and saline formation storage, while highlighting integration challenges across industrial sectors.

An analysis of patenting and publication trends reveals Europe's global leadership in high-value CCUS inventions and in specialised areas such as bioenergy with carbon capture and storage (BECCS) and high-temperature looping, while China remains the top contributor to scientific literature. Investment trends show the United States as the historical leader in both public and private RD&I funding, with the EU maintaining a strong second position and significant growth in Member States such as Germany, France, and Belgium.

The report also explores the emerging CCUS value chain, noting limited industrial-scale operations and a need for dedicated manufacturing capacity in key components such as solvents, compressors, and column vessels. In the context of the NZIA, mapping and strengthening these value chains are critical to achieving the EU's 2030 CO_2 storage target of 50 million tonnes per year. Overall, Europe's coordinated policy framework, sustained RD&I investment, and cross-border collaboration are positioning it as the global frontrunner in CCUS technology deployment and industrial decarbonisation.

Foreword on the Clean Energy Technology Observatory

The European Commission set up the Clean Energy Technology Observatory (CETO) in 2022 to help address the complexity and multi-faced character of the transition to a climate-neutral society in Europe. The EU's ambitious energy and climate policies create a necessity to tackle the related challenges in a comprehensive manner, recognising the important role for advanced technologies and innovation in the process.

CETO is a joint initiative of the European Commission Joint Research Centre (JRC), who run the observatory, and Directorate Generals Research and Innovation (R&I) and Energy (ENER) on the policy side. Its overall objectives are to:

- monitor the EU research and innovation activities on clean energy technologies needed for the delivery of the European Green Deal
- assess the competitiveness of the EU clean energy sector and its positioning in the global energy market
- build on existing Commission studies, relevant information & knowledge in Commission services and agencies, and the Low Carbon Energy Observatory (2015-2020)
- publish reports on the Strategic Energy Technology Plan (SET-Plan) SETIS online platform

CETO provides a repository of techno- and socio-economic data on the most relevant technologies and their integration in the energy system. It targets in particular the status and outlook for innovative solutions as well as the sustainable market uptake of both mature and inventive technologies. The project serves as primary source of data for the Commission's annual progress reports on competitiveness of clean energy technologies. It also supports the implementation of and development of EU research and innovation policy.

The observatory produces a series of annual reports addressing the following themes:

- Clean Energy Technology Status, Value Chains and Market: covering advanced biofuels, batteries, bioenergy, carbon capture utilisation and storage, concentrated solar power and heat, geothermal heat and power, heat pumps, hydropower & pumped hydropower storage, novel electricity and heat storage technologies, ocean energy, photovoltaics, renewable fuels of non-biological origin (other), renewable hydrogen, solar fuels (direct) and wind (offshore and onshore).
- Clean Energy Technology System Integration: building-related technologies, digital infrastructure for smart energy system, industrial and district heat & cold management, standalone systems, transmission and distribution technologies, smart cities and innovative energy carriers and supply for transport.
- Foresight Analysis for Future Clean Energy Technologies using Weak Signal Analysis
- Clean Energy Outlooks: Analysis and Critical Review
- System Modelling for Clean Energy Technology Scenarios
- Overall Strategic Analysis of Clean Energy Technology Sector

More details are available on the CETO web pages

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Executive summary

Policy context

Carbon capture, utilisation and storage (CCUS) has been acknowledged in the context of the European Energy Union as a fundamental research and development priority in achieving the 2050 climate objectives in a cost-effective way. In May 2024, the EU adopted the Net-Zero Industry Act (NZIA), which not only lists CCUS technologies within the list of Strategic Net-Zero technologies but also sets an annual injection capacity target of at least 50 million tonnes of CO_2 by 2030 in storage sites located in the EU. In February 2024, the Commission published the Industrial Carbon Management (ICM) strategy, highlighting the role of CCUS in decarbonising the EU's hard-to-abate sectors and laying the groundwork for the measures to come. In the Clean Industrial Deal, published in 2025, CCUS technologies were recognised as essential for decarbonising hard-to-abate industrial sectors.

Technology status

The technology readiness level (TRL) of CCUS technologies varies across the steps of the value chain (capture, transport, utilisation and storage) and within sub-technology type. The review presented in this report reveals that while there are specific technologies commercially available across all the steps of the chain (specially capturing via absorption or adsorption, transporting via pipelines and storing in saline formations), there is still development work needed when it comes to interconnecting all the steps of the chain relating to industrial emission sources (much more development has been carried out in the power sector).

Patenting and scientific publication activity is a key metric for evaluating RD&I efforts towards enhancing the technology's TRL. Based on the latest data available, the EU leads the world with regard to high-value, CCUS-related inventions. Regarding publications, China has consistently been the leading contributor to scientific literature on CCUS, publishing more than 1 000 articles in 2024 alone. The EU leads the publication record on BECCS and high temperature looping research.

Investment and funding

Regarding public RD&I funding, the US has been the cumulative leader in the 2014-2024 period (with 34% of all funding). Japan is the second largest funder with 15% of the total funding over 2014 and 2024, while the EU Member States are third (14% of total cumulative investments). Note that the EU would be the second top funder if EU funding programmes were included. Within the EU, France and Belgium have seen their CCUS-related public funding significantly increased in recent years, although Germany remains at the front of public RD&I funding over the past decade.

The same three countries are also leading in private RD&I funding. In the last period assessed (2012-2021), the US was the leading country, surpassing EUR 1.8 billion. The EU ranks second globally with EUR 1.3 billion invested in private RD&I and Japan is third with EUR 1.2 billion. At Member State level, Germany is the EU leader, followed by France and the Netherlands.

Value chain

The CCUS industry is not yet operating at scale and or have specialised supply chains. Various CO_2 capture technologies employ different solvents, sorbents, membranes, and cryogenic systems. EU production data and trade is analysed in this report using amine solvents, CO_2 compressors and column vessels as proxies, but these components are currently manufactured for applications other than CCUS. Considering the potential ramp-up of manufacturing of CCUS technologies and the recent Net-Zero Industry Act, there is a need for thorough value chain identification and mapping.

EU positioning and global competitiveness

Europe is emerging as the global CCUS leader. Strong policies, consistent government support, and cross-border collaboration are driving deployment. Meanwhile, the US – though still holding the largest project pipeline – is losing momentum, allowing Europe to consolidate its leadership in the near term.

SWOT analysis

Table 1. CETO SWOT analysis for the competitiveness of CCUS technologies.

Strengths	Weaknesses
• Included in all cost-effective climate change mitigation scenarios of the IEA and IPCC. • Growing political support. • Commercially available technologies across all steps of the chain. • Strong pipeline of projects under development all over the globe including in Europe.	• Perceived deployment risks that lead to lack of investor confidence. • Relatively expensive and lack of clear business case. • Limited operational experience of full-scale value chains. • Environmental concerns especially for some kinds of storage.
Opportunities	**Threats**
• One of the only effective emission reduction solutions for some industrial process emissions. • Cost reductions can be achieved through increased project capacity and mass manufacturing. • International and cross-border collaboration can accelerate the development of full-scale value chains.	• Government regulations and/or lack of investment. • Public concern/public acceptance. • Potential disruptions in the supply chain due to economic/geopolitical circumstances.

Source: JRC

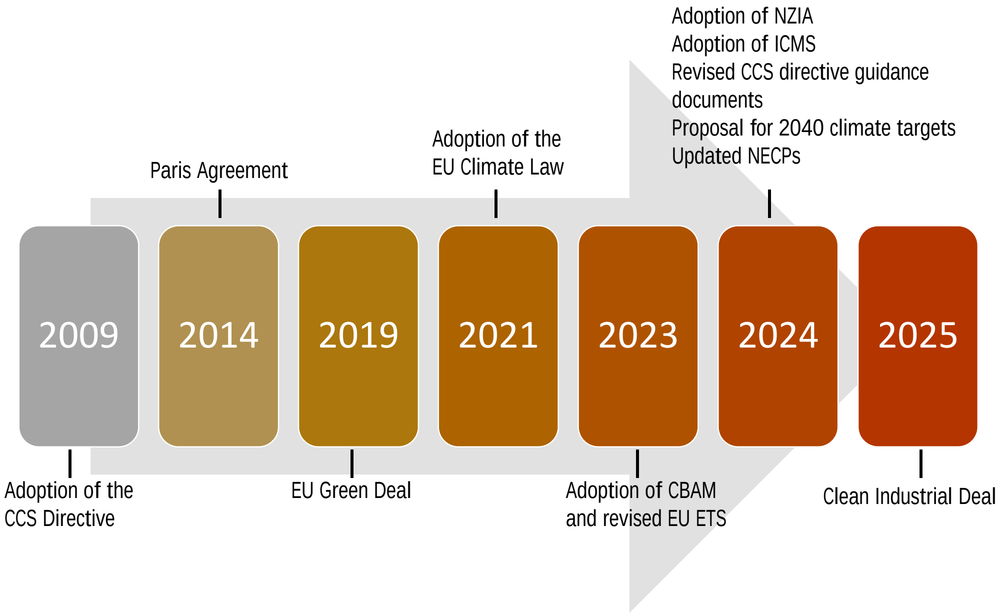
1. Introduction

1.1 Scope and context

This report on carbon capture, transport, utilisation and storage (CCUS) is part of the annual series of reports from the Clean Energy Technology Observatory (CETO). This report builds on previous EU studies in this field and updates the previous CETO report[1] [1]. It provides an overview of the current state of CCUS technologies, technology maturity status, development and trends, value chain analysis, and global market and EU positioning.

CCUS technologies play a crucial role in achieving the objectives of the European Green Deal and Clean Industrial Deal, among others. In fact, the EU has set ambitious targets for achieving climate neutrality [2], and as highlighted in the Industrial Carbon Management strategy [3], CCUS technologies are expected to contribute significantly to these efforts. In fact, CCUS technologies are gaining momentum within the European policy landscape, and as shown in the timeline of Figure 1, during the last two years, CCUS has been more present than ever before in EU policy.

Figure 1. Schematic timeline of relevant CCUS policies in the EU. CBAM: Carbon Border Adjustment Mechanism. ETS: European Trading Scheme. NZIA: Net-Zero Industry Act. ICMS: Industrial Carbon Management Strategy. NECP: National Energy and Climate Plans.



Source: JRC

The report is organised into five main chapters. Chapter 2 examines the state of the art and future developments of CCUS technologies focusing on advancements in technology readiness, energy capacity, costs, and research funding. Chapter 3 focuses on the value chain analysis, covering economic contributions, sustainability, and the role of EU companies in the market. Chapter 4 provides an overview of the EU's global position and competitiveness in the CCUS industry, analysing

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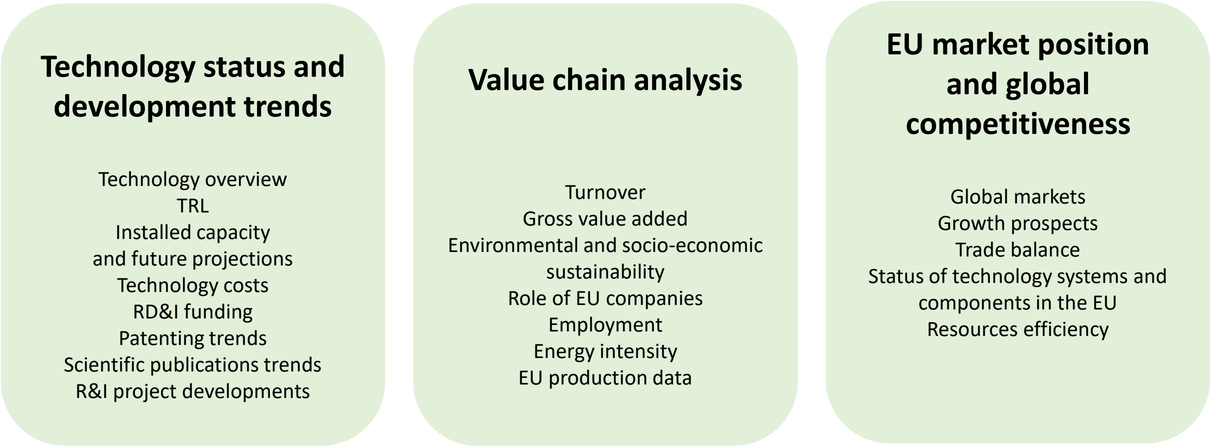
[1] CETO CCUS 2024, JRC139285

market status, trade dynamics, and resource efficiency. Chapter 5 concludes the report by synthesising key findings and highlighting strategic opportunities and challenges.

1.1. Methodology and data sources

The present report follows the general structure of all CETO technology reports and is divided into four sections with several indicators aiming to present and evaluate the EU CCUS technologies along their value chain. Figure 2 shows an overview of the content and what is included in each section.

Figure 2. Overview of the content of the report.



Technology status and development trends

Technology overview
TRL
Installed capacity
and future projections
Technology costs
RD&I funding
Patenting trends
Scientific publications trends
R&I project developments

Value chain analysis

Turnover
Gross value added
Environmental and socio-economic
sustainability
Role of EU companies
Employment
Energy intensity
EU production data

EU market position and global competitiveness

Global markets
Growth prospects
Trade balance
Status of technology systems and
components in the EU
Resources efficiency

Source: JRC

As a key addition from previous versions of this report, Chapter 4 now includes an analysis of net-zero technology systems and components in the EU, including a discussion on categorisation, manufacturing capabilities across the EU and the share in global manufacturing.

The report uses the following information sources:

- Eurostat data;
- Existing studies and reviews published by the European Commission and international organisations;
- Information from EU-funded research projects;
- EU and international databases;
- Specific CCUS commercial databases;
- EU trade data, trade reports, market research reports and others;
- JRC own review and data compilation;
- Stakeholders’ input.

Details of specific sources can be found in the corresponding sections and Annex 1 provides a summary of the indicators for each aspect, together with the main data sources.

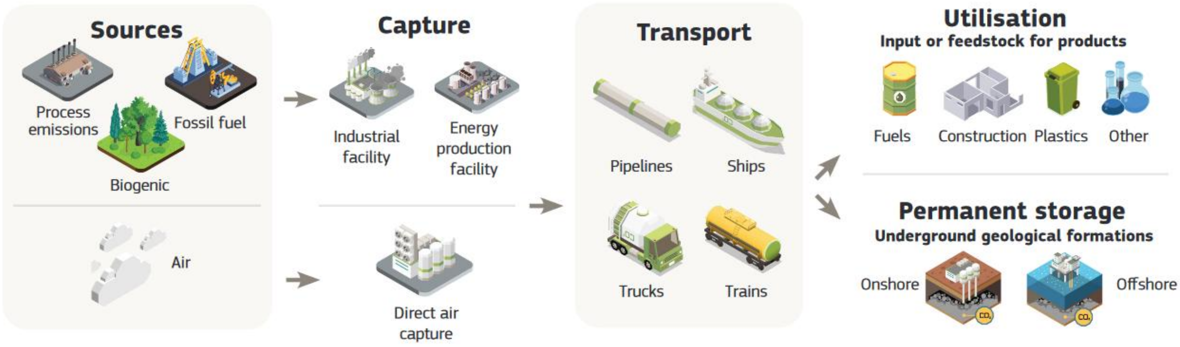
2. Technology status and development trends

2.1. Technology overview

The term CCUS comprises a chain of technologies, with each of the steps (capture, transport, utilisation and/or storage) being independent from the others and containing several sub-technology choices. A schematic of the different steps involved in CCUS chains is shown in Figure 3 and briefly explained below.

- Capture involves the extraction of CO_2 emissions from various sources (process, fossil fuels or biogenic when referring to industrial and energy production facilities and air when referring to direct air capture).
- Transport involves the movement of captured CO_2 from the capture sites to the storage or utilisation locations. Typically, compression and liquefaction of the captured CO_2 are considered within the transportation step.
- The utilisation step (one of the two alternative last steps of the chain, see Figure 3) involves converting captured CO_2 into valuable products, for example using it as feedstock for fuels, chemicals or construction materials.
- The alternative last step of the chain is permanent storage in onshore and offshore underground geological formations.

Figure 3. Steps of the CCUS chain including examples of some technological options.



Source: European Commission [3]

Thus, in this report, the technology status and development assessment are carried out in parallel for all the different technological options within each step of the chain. Table 2 summarises the main technologies and research fields identified for each of the steps of the CCUS value chain as defined in [4]. For a more detailed description of each technological option the reader is referred to the IEA [5] and a more recent publication from DNV [6].

Table 2. Technologies and research fields within each step of the CCUS chain.

Step in the CCUS chain	Technologies and research fields
Capture	Absorption
	Adsorption
	Membranes
	High-temperature looping cycles
	Oxy-combustion
	Direct separation
	Pre-combustion
	Cryogenic
	Hybrid
Utilisation	Direct CO_2 use without transformation
	Thermochemical conversion
	Electrochemical conversion
	Microbial conversion
	Mineralisation
Storage	Injection in geological sites
	Definition and characterisation of the storage site*
	CO_2 migration and improved storage management procedures*
	Monitoring: CO_2 leakage, CO_2 long-term behaviour, safety, cost and risk reduction*
Transport	CO_2 compression and liquefaction**
	Ship
	Pipeline
	Alternative transport methods (e.g., rail and truck).
	Safety aspects of transport*

*These research fields are required regardless of the technological choice.

** These sub-technologies are not strictly transport but for simplicity are here treated as such.

Source: JRC based on Kapetaki and Barbosa [4]

2.2. Technology readiness level

Despite the relatively low number of commercial facilities in operation (see Section 2.3), there are hundreds of projects across the different steps of the CCUS value chain, including research and development (R&D) of various technological options. This section discusses the key yearly updates regarding the TRL of capture technologies. For the TRLs of technologies within the rest of CCUS steps (i.e., transport, utilisation and storage), please refer to the 2024 edition of this report[2] [1] as no significant updates have been reported.

First, the average TRLs of different capture technologies across the main sources mapped (see Annex 1) have been updated with up-to-date technology and project data from Prescouter [7] and are shown in Figure 4 (note that the plotted results are the average TRLs across the mapped literature

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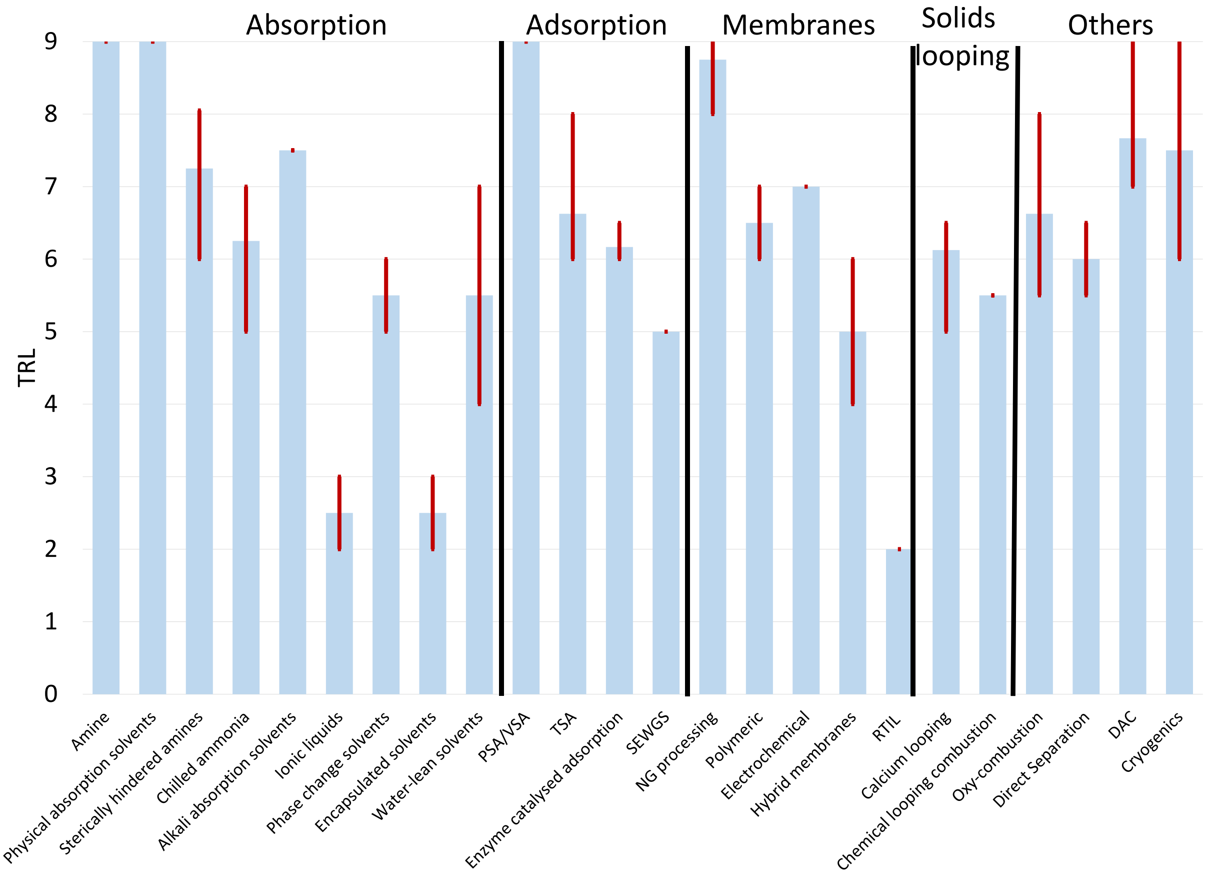
[2] CETO CCUS 2024, JRC139285

and can therefore result in non-exact TRLs). Figure 4 includes the minimum and maximum levels reported (red vertical lines), where it is seen that while several technologies are at TRL 9, the average TRL across all capture technologies is 6.

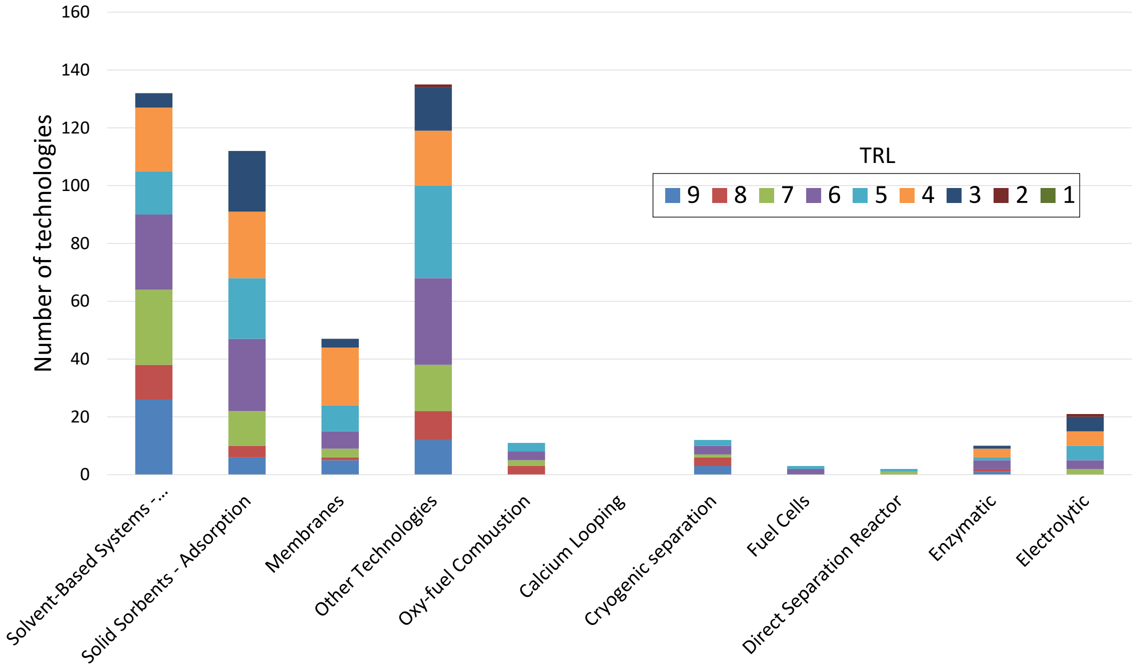
Figure 4. Average TRL of CO_2 capture technologies and sub-technologies (red vertical ranges represent maximum and minimum levels reported).



Source: JRC based on scientific literature, IEA, Global CCS Institute, IRENA, Prescouter

Figure 5 presents the distribution of TRLs across sub-technology groups, based on Prescouter dataset that tracks close to 400 capture technologies worldwide and is, to the author's knowledge, one of the most comprehensive and consistent coverage of CCUS projects and technologies. It should be noted that the categorisation of capture technologies in this figure differs slightly from that used in Figure 4. Furthermore, a significant share of the mapped technologies is classified under the category 'Other technologies,' which encompasses all sub-technologies not explicitly represented in Figure 5. Figure 5 reveals that solvent-based absorption is the capture technology with a largest share of TRL 9 technologies, and that, together with adsorption with solid sorbents (and other technologies) and to a lesser extent membranes, they are by far the categories with largest number of technologies (more than 100 for absorption and adsorption and around 50 for membranes).

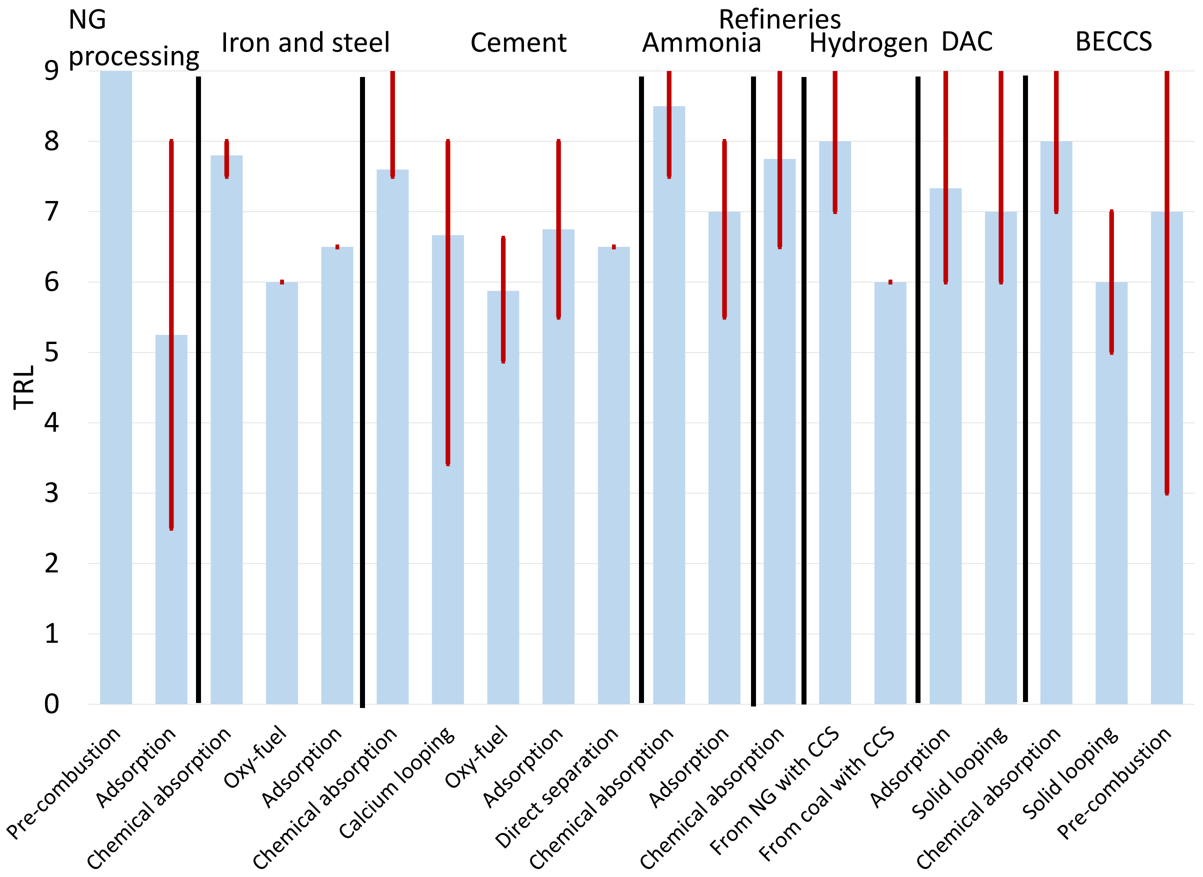
Figure 5. Number of capture technologies at various TRL grouped by capture technology type.



Source : JRC based on Prescouter.

Lastly, Figure 6 depicts the mapped TRLs where capture technologies are applied within specific industrial sectors. Figure 6 reveals that the number of technologies tested at industrial conditions is much lower than the number of technologies included in Figure 4, and that notably, capture in cement production has recently reached TRL 9 due to the beginning of operations at Brevik (see Section 2.3).

Figure 6. Average TRL of CO_2 capture technologies when applied to different emission sources (red vertical ranges represent maximum and minimum levels reported). NG: Natural Gas.

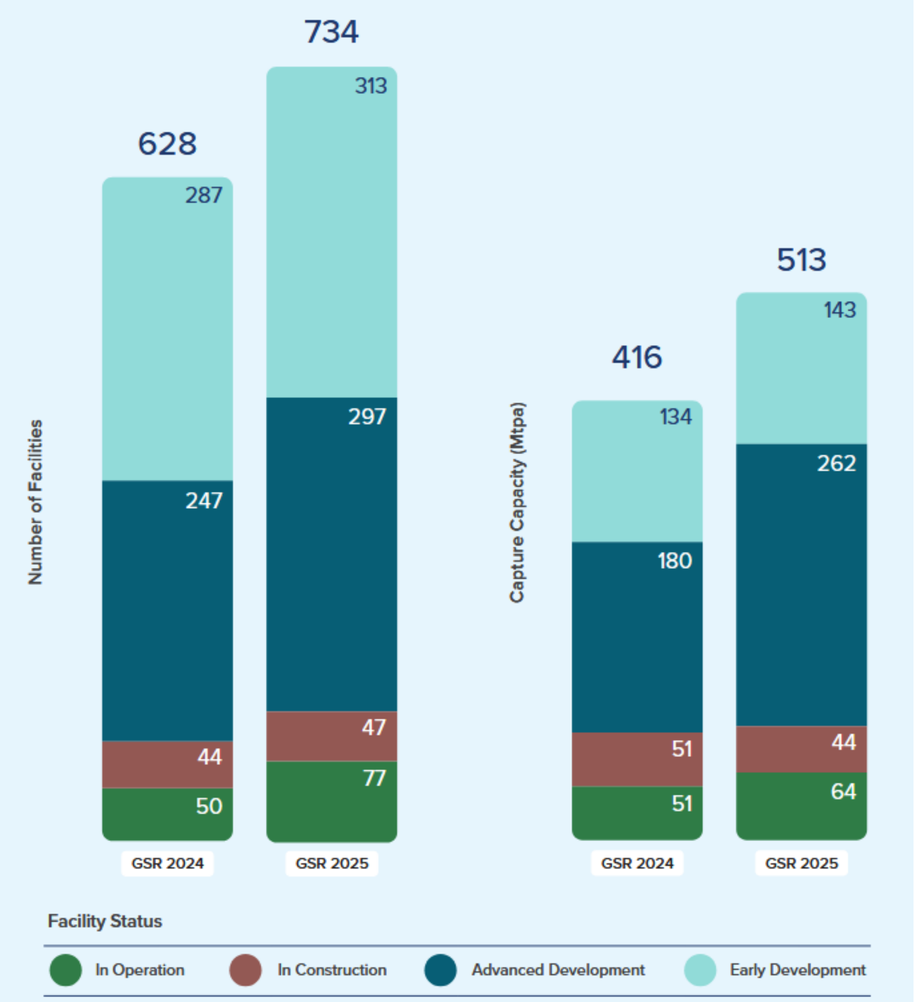


Source: JRC based on scientific literature, IEA, Global CCS Institute, IRENA, Prescouter.

2.3. Installed capacity and production

This section presents the installed capacity of CCUS plants at global and EU levels, focusing on commercial-scale projects and operations (see Section 2.9 for smaller project developments). Figure 7 illustrates the annual increase of CO_2 capture capacity at various development stages for commercial-scale carbon capture and storage (CCS) projects worldwide, as compiled by the Global CCS Institute (GCCSI) [8]. This includes projects involving CO_2 capture for enhanced oil recovery (EOR) but excludes those related to carbon capture and utilisation (CCU). As seen in Figure 7, the operational capacity (green colour) reached 64 Mt in 2025 (as compared to 51 Mt in the previous year), in a total of 77 installed captured facilities (vs 50 in 2024, i.e., a 54% yearly increase). It is also clear from the 2025 status report compiled by the GCCSI that the growth in project development remains high (46% increase in projects in advanced development) although it is stabilising (i.e., the growth is lower than that observed in previous years). The large number of projects in early phases of development is an indicator of the expected CCUS needs both in the EU and worldwide (see Section 4.1 for a detailed analysis of the projected needs).

Figure 7. Global pipeline of commercial CCS facilities in 2024 vs 2025 by number of facilities and by capture capacity (in annual Mt, i.e., Mtpa). Note that projects in early and advanced development are still in the planning phase and will not necessarily be realised.

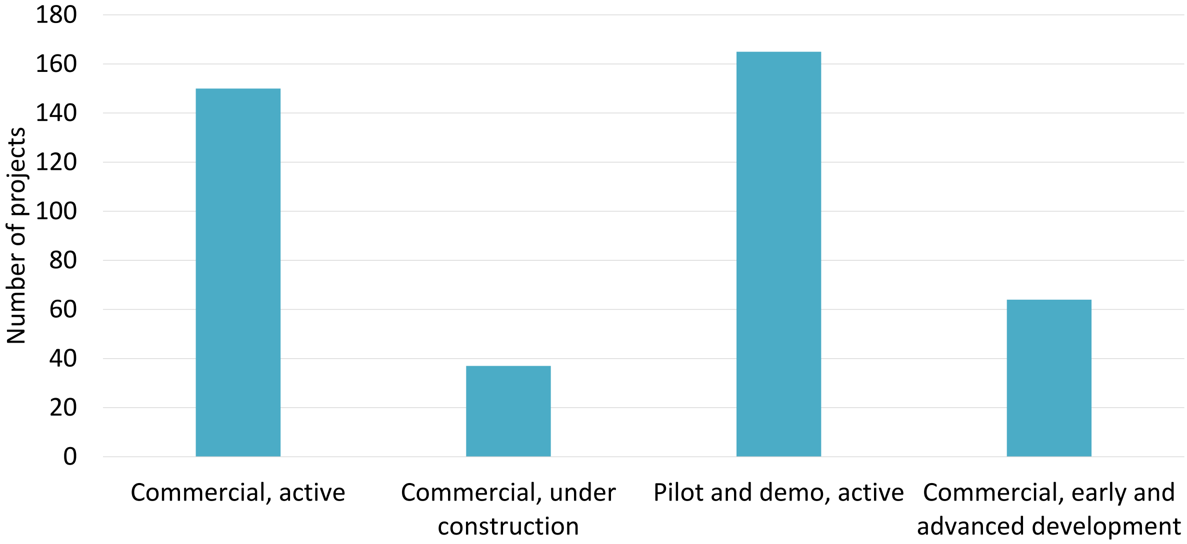


Source: Global CCS Institute.

It should be noted that due to the cost characteristics reviewed in Section 2.4, most of the existing CCS plants in operation are deployed in natural gas processing plants, and according to the GCCSI, deployment in hydrogen and ammonia sectors is anticipated to assume the top spot by 2030. The leading countries in CCS projects (across all four stages of development) are the US (with a 61% of project share), the UK (14%), Canada (13%), Norway and China (6% each) [9]. Norway is the only country in continental Europe to have built largescale capture and storage projects. To Sleipner and Snohvit, built in 1996 and 2008 respectively (an average of 1.8 million tonnes of CO_2 captured and stored per year), Norway adds the recent opening of the Brevik plant with 0.4 Mt of CO_2 captured and stored annually in the Aurora reservoir under the seabed of the North Sea.

Regarding all types of projects within the CCUS value chain (i.e., not only CCS but also utilisation and transport facilities), up-to-date data from Prescouter indicates a total of 150 commercial-scale projects active (see Figure 8), the majority being in the US, followed by China and Canada, and with 26 CCUS facilities located in the EU. According to Prescouter, 37 commercial-scale CCUS facilities are under construction and 64 in various phases of development. The number of active CCUS facilities at pilot or demonstration scale exceeds that of commercial-scale facilities, reaching 165 facilities worldwide. See Table 3 for a brief summary of selected operational flagship CCUS projects in continental Europe and refer to the 2024 edition of this report [3] [1] for a more comprehensive list.

Figure 8. Number of CCUS projects in various stages of development across the EU.



Source: JRC based on Prescouter.

Table 3. Summary of flagship CCUS projects in continental Europe.

Project	Description	Country	Status
Northern Lights	Joint venture between Equinor, Shell and TotalEnergies part of Norway's CCS initiative Longship. It involves capturing CO_2 from industrial sources and transporting it by ship and offshore pipeline to a storage site in the North Sea.	Norway	Operational and under further construction.
Brevik CCS	Owned by Heidelberg Materials, it is the world's first commercial-scale capture facility in a cement plant. It is also part of Longship initiative.	Norway	Operational
Twence CCU	A capture plant in Twence's waste-to-energy plant, the captured CO_2 is supplied to the greenhouse industry.	Netherlands	Operational
Porthos CCS	CO_2 from various industrial sources in the port of Rotterdam is captured and transported to depleted gas fields in the North Sea.	Netherlands	Under construction

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[3] CETO CCUS 2024, JRC139285

Ravenna CCS	After the initial phase capturing and storing the CO_2 from Eni's natural gas, the project aims to become the CCS reference hub for southern Europe and the Mediterranean.	Italy	Operational and under further construction.

Source: JRC

2.4. Technology costs

The costs associated with CCUS technologies are highly heterogeneous, reflecting both the diversity of technological options across the value chain and the wide range of potential applications (i.e., CO_2 sources). Given the absence of substantial new data since 2024, this section provides only a concise update, summarising the main cost characteristics and highlighting minor revisions relative to the previous edition. For a comprehensive review and harmonisation of the most recent cost estimates across the full CCUS value chain, and for a discussion on projected cost reductions, the reader is referred to the 2024 edition of this report[4] [1].

Capture

In most cases, capture costs represent the highest share of the entire CCUS value chain. They are primarily determined by the characteristics of the CO_2-rich stream – namely its volume, concentration, and pressure – which are typically process-specific. Additional determinants include the capture technology employed (with some options being more capital expenditure (CAPEX)-intensive and others dominated by operating expenditure (OPEX)), the feasibility of retrofitting the emitting facility, the potential for heat integration, and the design capture rate (i.e., the proportion of CO_2 emissions targeted for capture). While larger capture plants entail higher absolute capital costs, they generally achieve lower specific costs per tonne of CO_2 captured, provided that the system operates at a high utilisation rate.

The cost of CO_2 capture varies significantly depending on the characteristics of the emission source. For industrial processes that generate high-purity CO_2 streams – such as ammonia production or natural gas processing – capture costs are relatively low, typically in the range of EUR 10–30 per tCO_2. In contrast, processes with medium-concentration flue gas streams, including cement production, iron and steel manufacturing, and the pulp and paper industry, exhibit higher costs, generally ranging between EUR 25–120 per tCO_2 . The higher cost in these cases arises from the greater energy demand and more complex separation requirements associated with dilute CO_2 streams, as well as the need for additional process integration measures to supply heat and power for capture.

Regarding the capture costs of carbon dioxide removal (CDR) technologies, cost estimates for bioenergy with carbon capture and storage (BECCS) vary depending upon the sector of application (EUR 40–75 per tCO_2 according to the mapped sources). Prices for DAC currently range anywhere between EUR 100 to 800 per tCO_2. There is no clear pricing trend with larger DAC providers being necessarily cheaper. Many suppliers claim costs can be brought down to USD 300-500 per tCO_2 by

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[4] CETO CCUS 2024, JRC139285

2030 [10], while a recent publication [11] concluded that costs will not be below EUR 300 per tCO_2 when deployed at the gigaton scale.

Transport and conditioning

The cost of CO_2 transport can also vary greatly on a case-by-case basis, depending mainly on scale (CO_2 volumes), transport modes, geography, transport distances and quality levels of the transported gas. Nevertheless, a reasonable estimate for pipeline transport ranges between EUR 5 and 25 per tCO_2, while estimates for shipping, rail and truck lie within EUR 10-50 per tCO_2. In general, pipeline transport is more cost-effective for large volumes over short-to-medium distances (a few hundred kilometres) while liquid CO_2 transport methods (e.g., shipping) are better suited to longer distances, dispersed emitters and lower CO_2 volumes [6].

Regarding compression and conditioning, recent estimates from Prescouter [7] indicate a range of EUR 10-25 per tCO_2, which falls well within the range presented in 2024's edition of this report [1]. In this regard it is important to mention that these figures are highly dependent on CO_2 specifications, i.e., the maximum levels of various impurities that are necessary for ensuring safe and cost-efficient CCUS value chains. Defining CO_2 specifications is an ongoing discussion topic both at policy and technical levels, and the reader is referred to [6] for a more in-depth analysis.

Storage

Given that the number of operational storage projects is still limited, the majority of available studies are based on projects in the development phase and tend to provide cost estimates in the form of broad ranges. Storage costs can differ significantly between projects and regions (site- and region-specific), spanning from EUR 1 to 34 per tCO_2, with average costs below EUR 10 per tCO_2. Generally, onshore storage, including assessment, development, and operations, is usually less expensive than offshore storage, and the saline aquifers often necessitate more extensive and costly data collection compared to depleted oil and gas fields.

Utilisation

When captured CO_2 is used as a commodity for utilisation processes, the capture cost and therefore the selling cost of the CO_2 will influence the production cost of the final materials/fuels. Thus, the cost of CO_2 utilisation technologies shows extreme variations (even within the same product, e.g., methanol, variations can be in the range of EUR 300-2500 per tCO_2 depending on assumptions). In addition, other clean energy technologies outside the scope of the current work (such as electrolysers) play a crucial impact in the cost of these processes. Thus, the reader should refer to the CETO reports on Hydrogen[5] and Renewable fuels of non-biological origin [6] for further information on CO_2 utilisation costs.

2.5. Public RD&I funding

Public RD&I investment can positively impact technology development and deployment, promoting private initiatives and increasing the number of relevant publications and patent applications.

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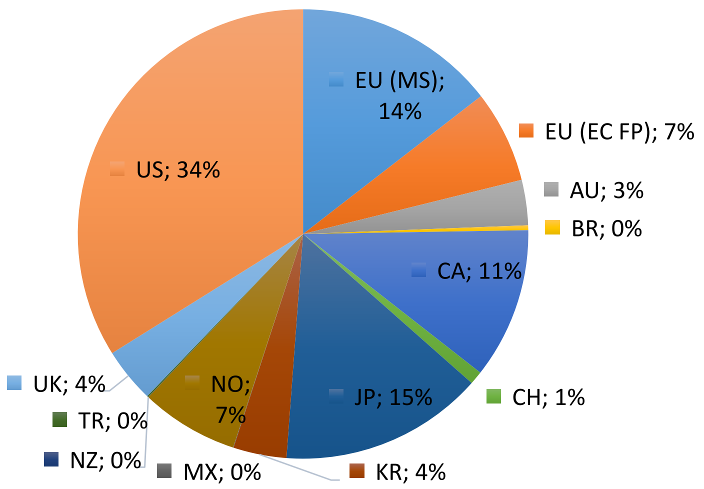
[5] https://setis.ec.europa.eu/water-electrolysis-and-hydrogen-european-union_en

[6] https://setis.ec.europa.eu/renewable-fuels-non-biological-origin-european-union-0_en

Therefore, it is an important indicator of the level of development and competitiveness in a given technological field. The information presented below is based on data obtained from the IEA [12].

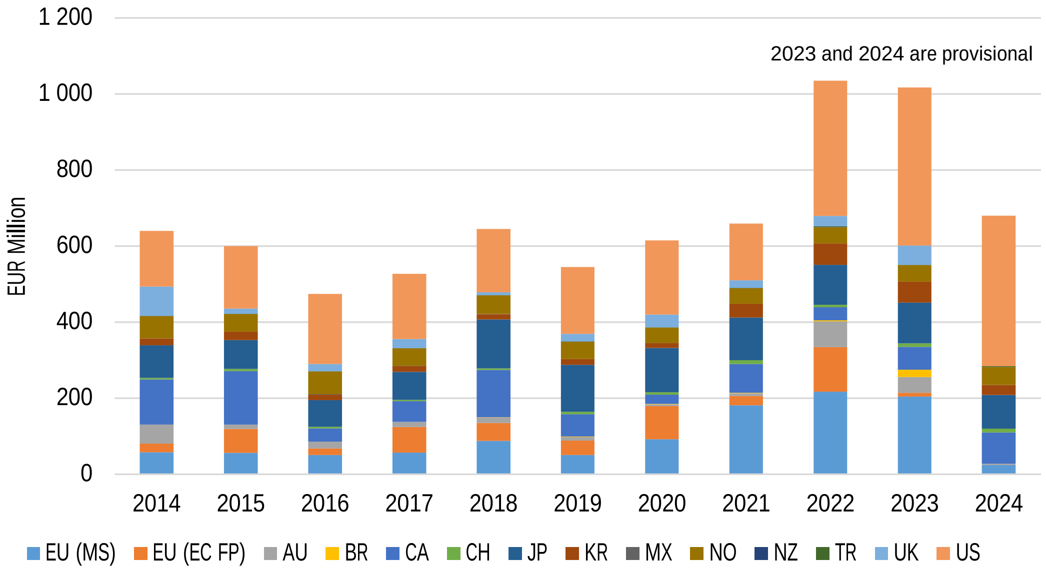
In contrast to the results presented last year, the US has settled as the clear leader in cumulative public RD&I funding of CCUS technologies within the period considered (2014-2024, see Figure 9), with 34% of all investment. This is due to the large increase in public funding in the years 2022, 2023 and 2024 (see yearly disclosure in Figure 10). Japan is the second largest funder (it was leading in the previous analysis) with 15% of the total funding over 2014 and 2024, while the EU Member States (MS) are third (14% of total cumulative investments). Note that the EU would be the second top funder if EU funding programmes were included (EU FP, 7% of total cumulative funding).

Figure 9. Share of public RD&I investment in CCUS technologies by OECD member country for the period 2014 to 2024.



Source: JRC based on IEA.

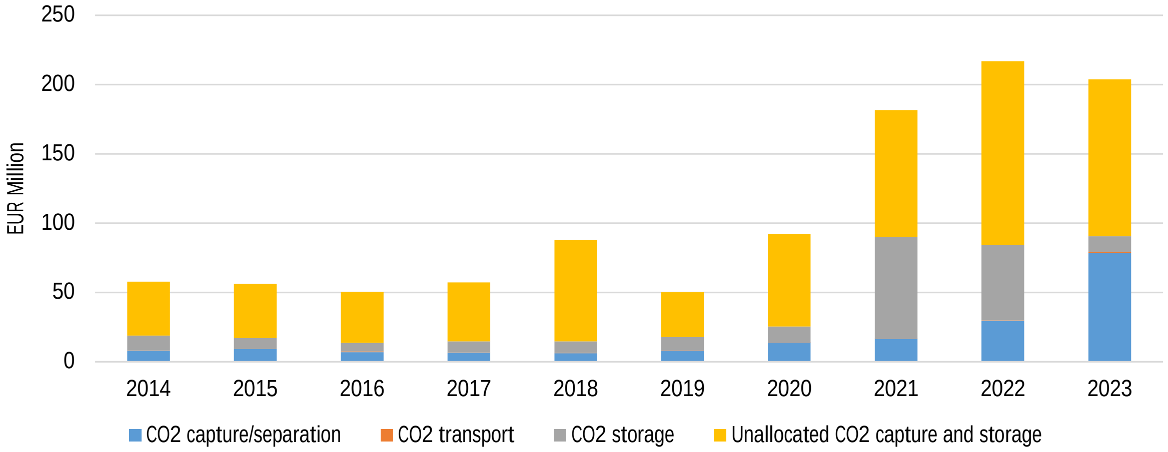
Figure 10. Public RD&I investment in CCUS technologies in the EU and rest of the world from 2014 to 2024.



Source: JRC based on IEA.

Public RD&I funding within the EU remained relatively stable in 2023 as compared to 2021 and 2022 levels (see Figure 11, where 2024 was removed from the dataset as many Member States have not reported yet). Nonetheless, funding is seen to decrease slightly as compared to 2022. As seen in Figure 11, this is partly because the storage-related funding decreased drastically, despite the increase in capture-related funding (where DAC is also included). Nonetheless, storage is still ahead of capture when it comes to public funding (19% vs 17% of the total funding in the last decade), although most of it is for unspecified CCS activities (64% of the cumulative public funding in the 2014-2024 period).

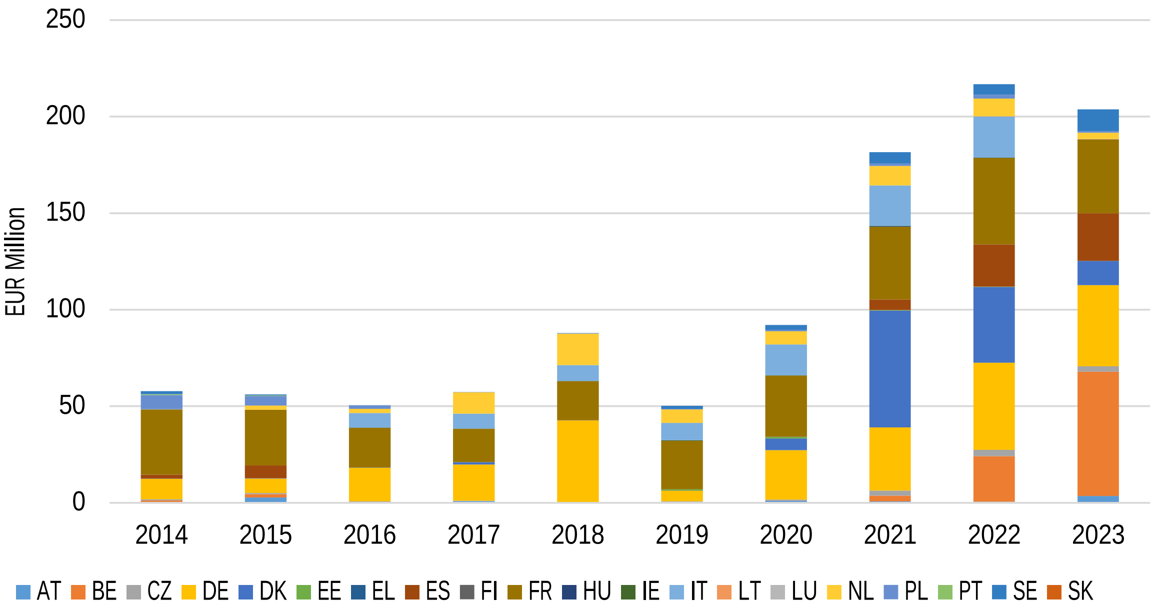
Figure 11. Public RD&I investments in CCUS technologies in the EU from 2014 to 2023 disclosed by topic.



Source: JRC based on IEA.

Regarding the distribution of funding across Member States, France and Belgium have seen their CCUS-related public funding greatly increased in recent years (see Figure 12), although Germany has remained at the forefront of public RD&I funding over the past decade due to its consistency over the years.

Figure 12. Public RD&I investments in CCUS technologies in the EU from 2014 to 2023 disclosed by MSs.



Source: JRC based on IEA.

2.6. Private RD&I funding

Comprehensive data on private-sector RD&I spending remains scarce, especially when examining small and medium-sized enterprises or companies operating across multiple technological domains. The analysis presented here draws on a dedicated in-house methodology developed by the JRC [13], [14] to estimate private-sector RD&I expenditures. This methodology is subsequently applied to evaluate investment patterns in Europe's private sector, with a particular focus on climate change mitigation technologies.

Our analysis (see Figure 13) shows that in the 2010-2021 period, the US has been the leading country in private CCUS RD&I funding, surpassing EUR 1.8 billion (see the 2024 edition of this report[7] [1] for a year-to-year analysis). The EU ranks second globally with EUR 1.3 billion invested in private RD&I, and Japan is third with EUR 1.2 billion. At Member State level, Figure 13 reveals that Germany leads within the EU, followed by France and Netherlands, with EUR 409, 393 and 229 million respectively.

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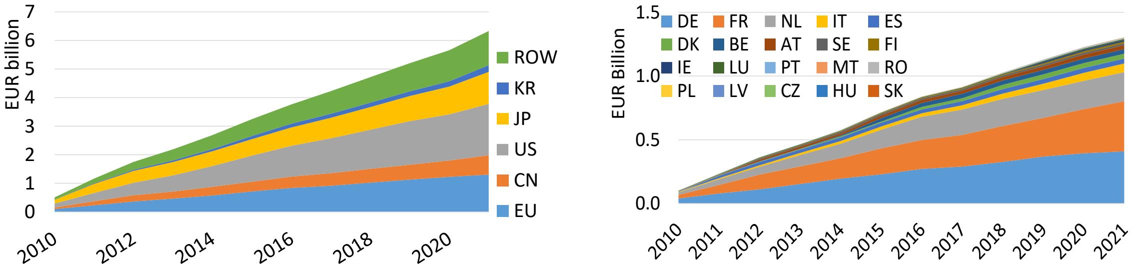
[7] CETO CCUS 2024, JRC139285

Figure 13. Cumulative 2010-2021 private RD&I investment (EUR billion) in CCUS, a) globally and b) in EU by MS.



a) Global

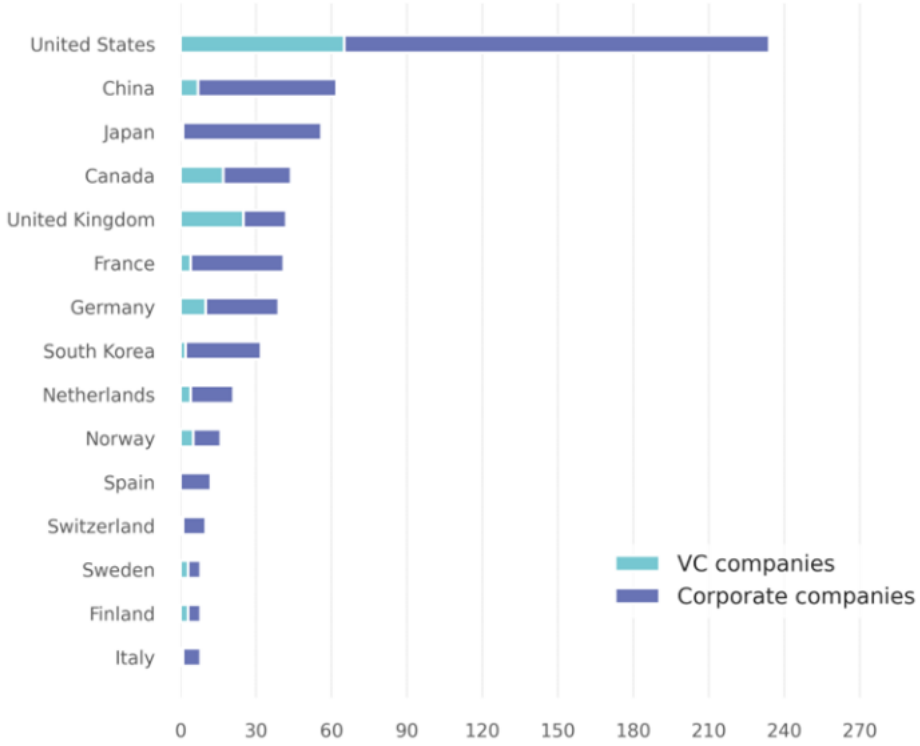
b) EU

Source: JRC

2.6.1. Venture capital and early and later-stage investments

Private equity refers to capital investment (ownership or interest) made in companies that are not publicly traded. Venture capital (VC) is a form of private equity and a type of financing that investors provide to start-up companies and small businesses that have long-term growth potential. Figure 14 provides an outlook of the countries that host the highest number of innovative companies active in the development of CCUS solutions between 2018 to 2023. The analysis includes both VC companies (i.e. start-ups and scale-ups that attracted VC funding or have been founded over the period) and corporate companies (i.e. subsidiaries of top RD&I investors with a relevant patenting activity over the 2017-2022 period). When accounting for both types, the US, China (which surpassed both Japan and Germany this year) and Japan are the leading countries hosting the largest number of companies. Three countries (the US, the UK and Canada) host most of VC companies and account together for 67% of all active VC companies identified worldwide.

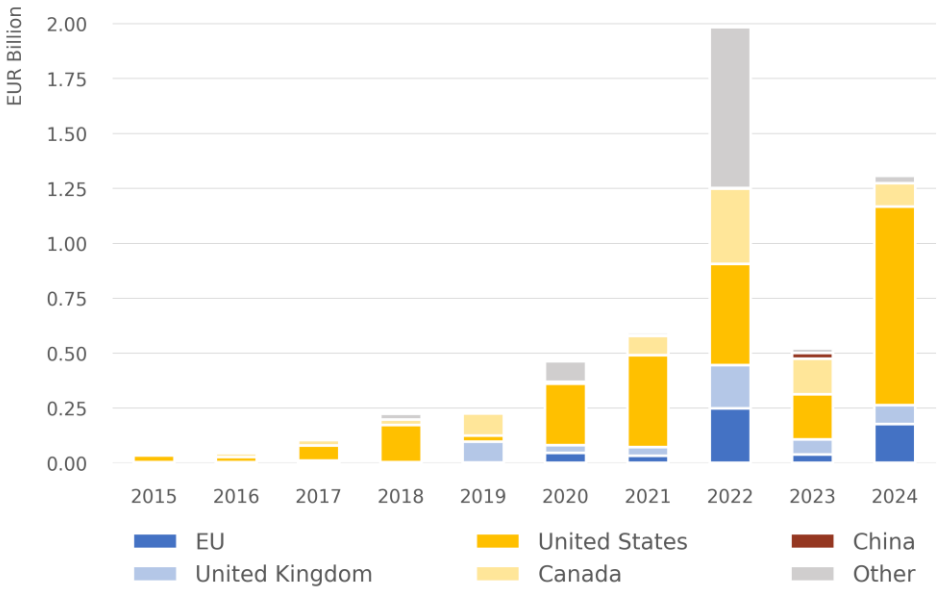
Figure 14. Number of active innovating companies by type over a 6-year period, ranking of top 15 countries. [VC companies count over 2019-24. Count of corporate companies over 2017-22].



Source: JRC based on PitchBook and PATSTAT

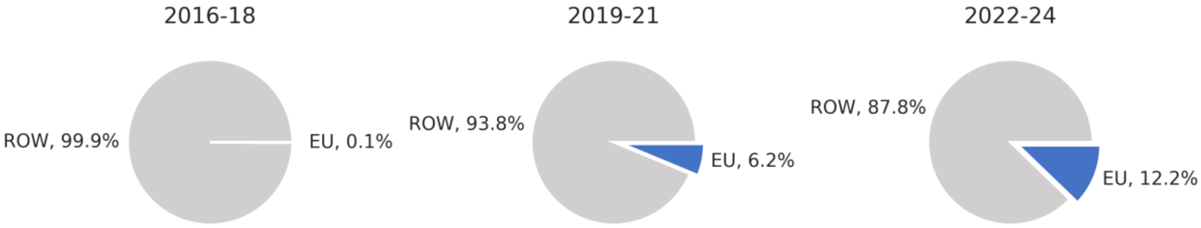
In 2024, global VC investment more than doubled from 2023, reaching EUR 1.25 billion (but not quite matching the all-time high of EUR 1.9 billion in 2022, see Figure 15). This was mainly due to major increases in investment in the EU and in the US. As yearly investments are highly volatile, to understand trends we should look at cumulative investments. As seen in Figure 16, the role of the EU has been increasing steadily over recent years, reaching a share of 12.2% of global VC/PE investment over the past three years. At country level, the United States, Canada, and Switzerland have emerged as the leading beneficiaries during the periods 2013-2018 and 2019-2024 (refer to Figure 17). Within the European Union, the three Member States which have received the most in recent years are Italy, Denmark, and Sweden.

Figure 15. Global Venture Capital / Private Equity investment by region showing all deal types



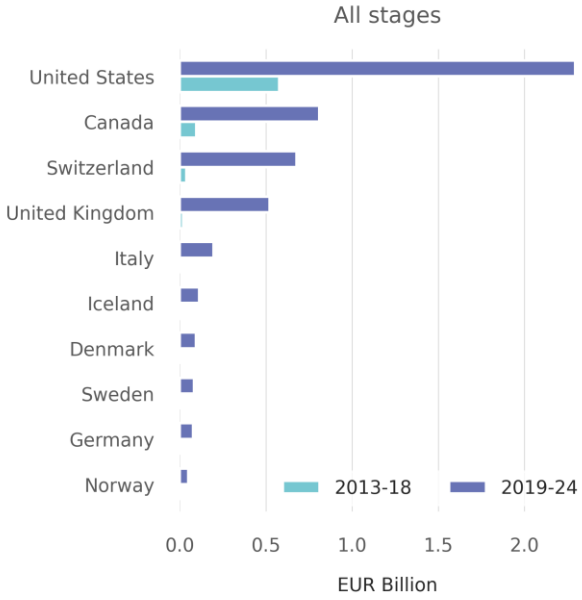
Source: JRC based on Pitchbook.

Figure 16. VC/PE investment in the EU and in the ROW for all deals over the 9 years, by period of 3 years



Source: JRC based on Pitchbook

Figure 17. VC/PE investment in top 10 beneficiary countries, by period for all deals.



Source: JRC based on Pitchbook.

2.7. Patenting trends

Patenting activity is an important indicator for evaluating technological development and competitiveness in a particular area. The analysis is based on data from the Worldwide Patent Statistical Database (PATSTAT[8]) and follows a method developed by the JRC[9]. Patents regarding CCUS are identified using the class Y (specifically subclass Y02C and Y02P) of the Cooperative Patent Classification (CPC) System, a partnership between the European Patent Office (EPO) and the United States Patent and Trademark Office (USPTO). We note that it can take up to 30 months from an initial patent application to subsequent filings in other countries. 2021 is the last year for which complete data are available, but our analysis includes partial data from 2022.

In the 2020-2022 period, the EU filed, in total[10], 186 CCUS-related inventions (versus 158 in the 2018-2020 period), with 74% being high-value[11] - the highest percentage compared to the other regions and to the rest of the world (ROW) (see Figure 18). Despite increased inventive activity in China (1 335 total inventions, a 70% increase compared to the 2018-2020 period), the high-value inventions account for only 6% of all inventions. The US, Japan and China have the most high-value

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[8] EPO - PATSTAT. Worldwide Patent Statistical Database

[9] Pasimeni, F., Fiorini, A., and Georgakaki, A. (2021). International landscape of the inventive activity on climate change mitigation technologies. A patent analysis. Energy Strategy Reviews, DOI: 10.1016/j.esr.2021.100677, https://www.sciencedirect.com/science/article/pii/S2211467X21000638#

Pasimeni, F. and Georgakaki, A. (2020). Patent-Based Indicators: Main Concepts and Data Availability. JRC121685, https://setis.ec.europa.eu/patent-based-indicators-main-concepts-and-data-availability_en

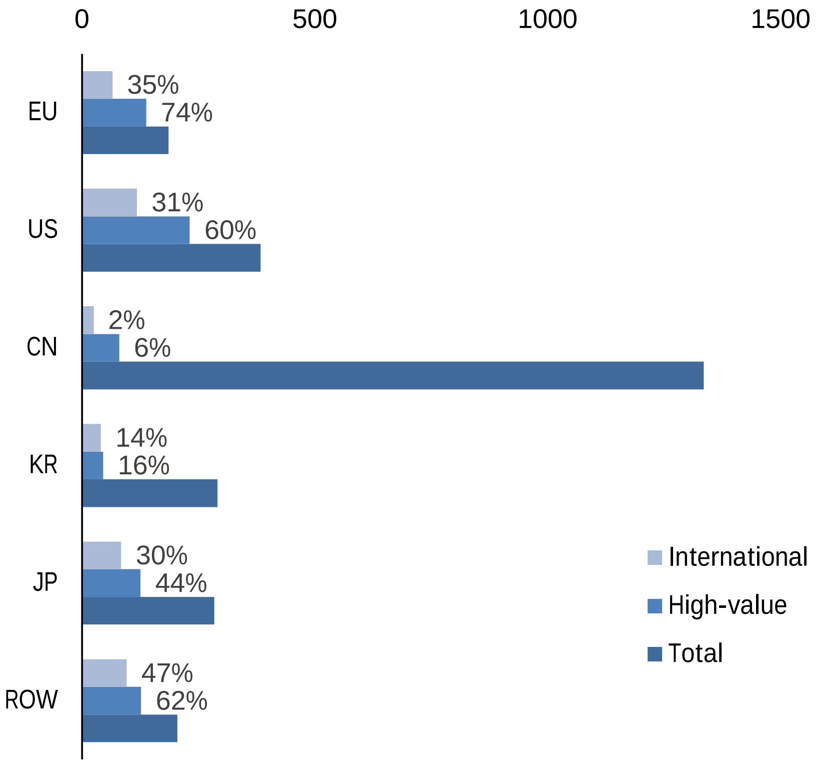
Pasimeni, F. (2019). SQL query to increase data accuracy and completeness in PATSTAT. World Patent Information, 57, 1-7. https://doi.org/10.1016/j.wpi.2019.02.001

[10] The total includes international, national, high-value patents etc.

[11] High-value inventions (or high-value patent families) refer to patent families that include patent applications filed in more than one patent office.

inventions in the decade (between 2011 and 2022, see Figure 19), while the EU has gone down in the ranking as compared to last year's results [12]. Among EU Member States, France remains the leader in terms of the number of CCUS-related high-value inventions (more than 40), followed by Germany and the Netherlands (30 and 22 respectively).

Figure 18. Number of inventions and share of high-value and international activity (2020-2022)



Source: JRC based on EPO Patstat

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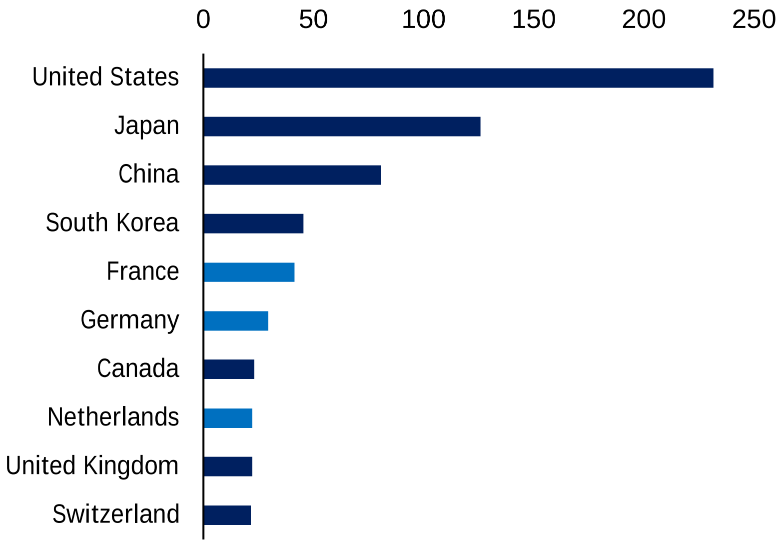
[12] CETO CCUS 2024, JRC139285

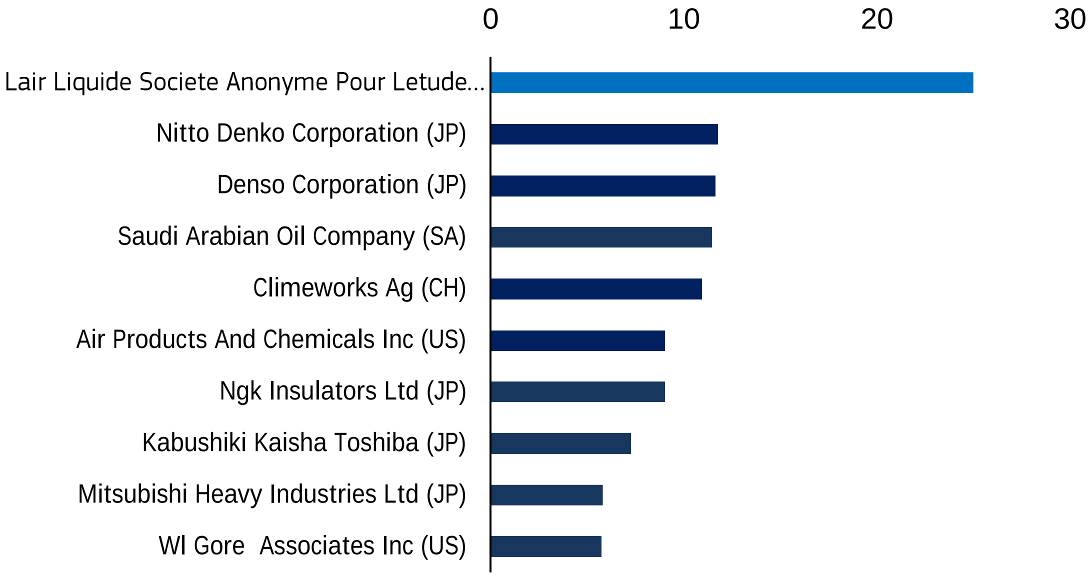
Figure 19. High-value inventions – Top 10 countries (2011-2022). Light blue refers to EU Member States and dark blue to other countries.



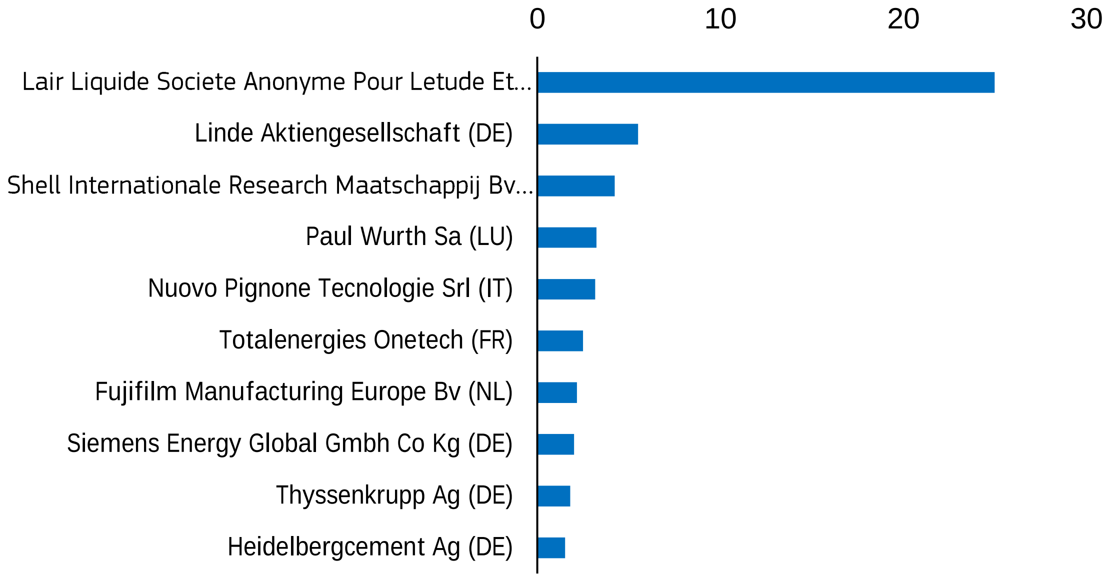
Source: JRC based on EPO Patstat

With regard to the companies that have been leading in high-value inventions from 2020 to 2022 (Figure 20), Air Liquide (FR) is once again the leading company globally and in the EU. Linde (DE), which ranks second in the EU, is no longer in the top 10 global companies by number of high-value inventions (having ranked sixth in last year's analysis).

Figure 20. High-value inventions (2019-2021), a) global top 10 companies and b) EU top 10 companies. Light blue refers to EU Member States and dark blue to other countries.



a)



b)

Source: JRC based on EPO Patstat

2.8. Scientific publication trends

To identify bibliometric trends in this study, we used the JRC Tools for Innovation Monitoring (TIM)[13] Scopus database. The keywords used to create the datasets were based on the technology classification presented in Table 2.

Publications addressing CO_2 capture technologies – including DAC and BECCS – have shown a steady increase over the past 11 years (see the 2024 CETO report [14] [1] for a detailed analysis of historical trends). Since 2013, China has consistently been the leading contributor to scientific literature on CCUS, publishing more than 1 000 articles in 2024 alone, compared to approximately 450 from the EU (see Figure 21 for the annual increase as compared to 2023). In addition to the annual increase presented in Figure 21, it is noticeable that the EU continues to lead in BECCS-related research, with Sweden, Germany, and the Netherlands ranking as the top three publishing countries in 2024. Similarly, the EU maintains leadership in high-temperature looping research, where Spain, Sweden, and Germany were the most active contributors in 2024. In contrast, the United States leads in DAC-related publications, followed by the EU and China. When viewed cumulatively over the past 15 years, China emerges as the dominant publisher across nearly all CCUS research domains, with the notable exception of CO_2 transport, where the EU maintains a clear lead.

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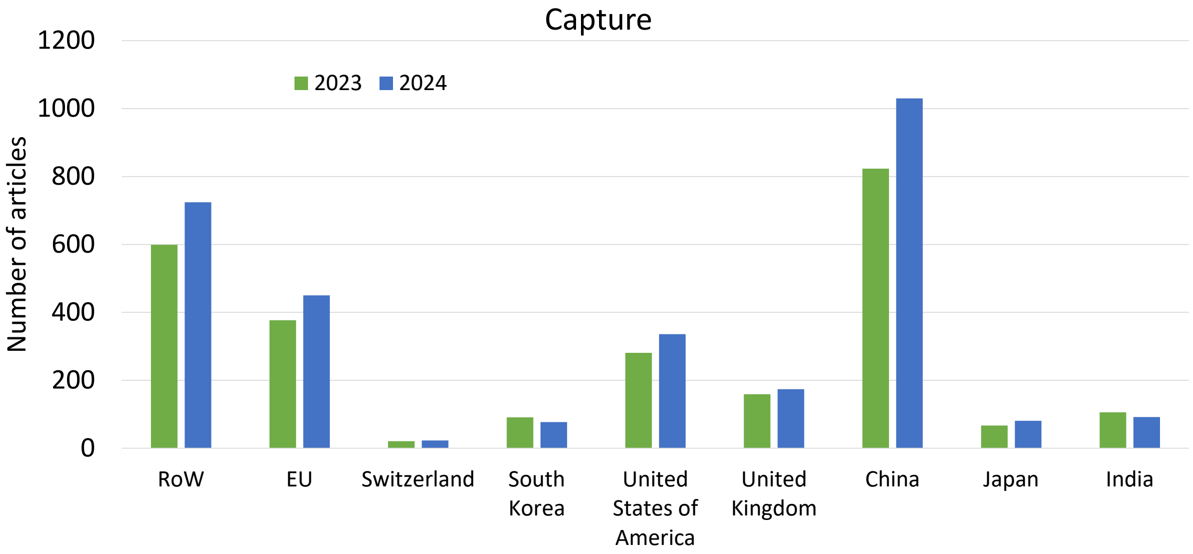
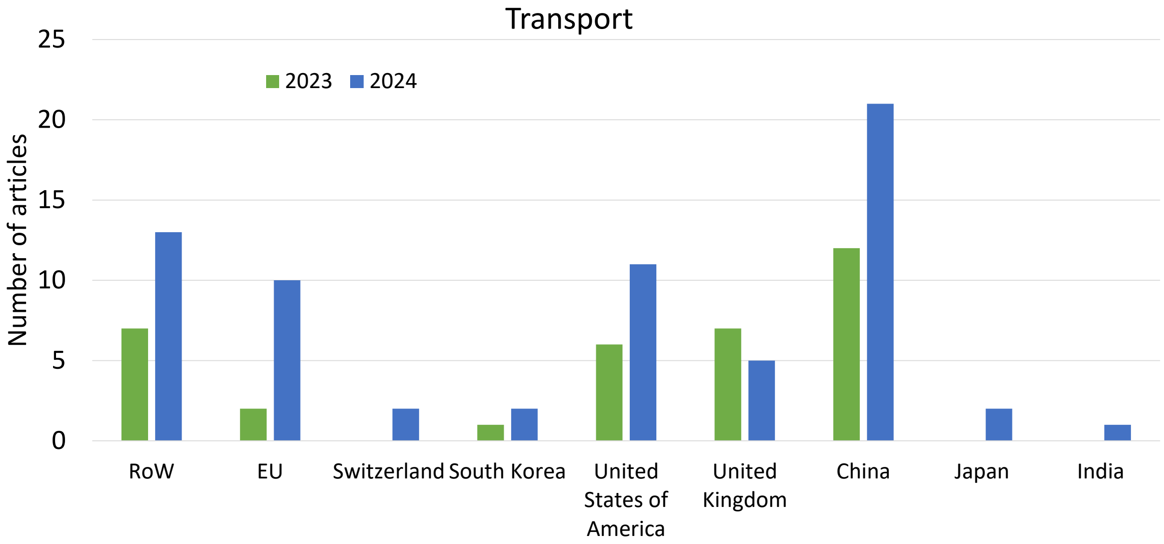
[13] https://knowledge4policy.ec.europa.eu/text-mining/topic/tim_analytics_en

[14] CETO CCUS 2024, JRC139285

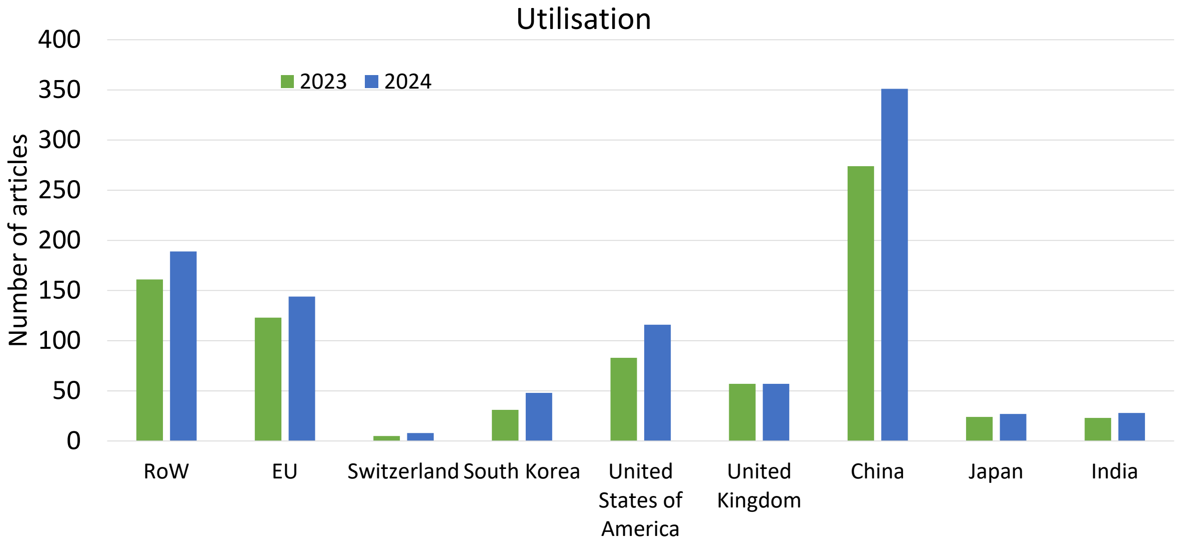
Figure 21. Worldwide yearly variation of peer-reviewed articles (2023 vs 2024) concerning a) CO_2 capture, b) CO_2 transport, c) CO_2 utilisation and d) CO_2 storage.



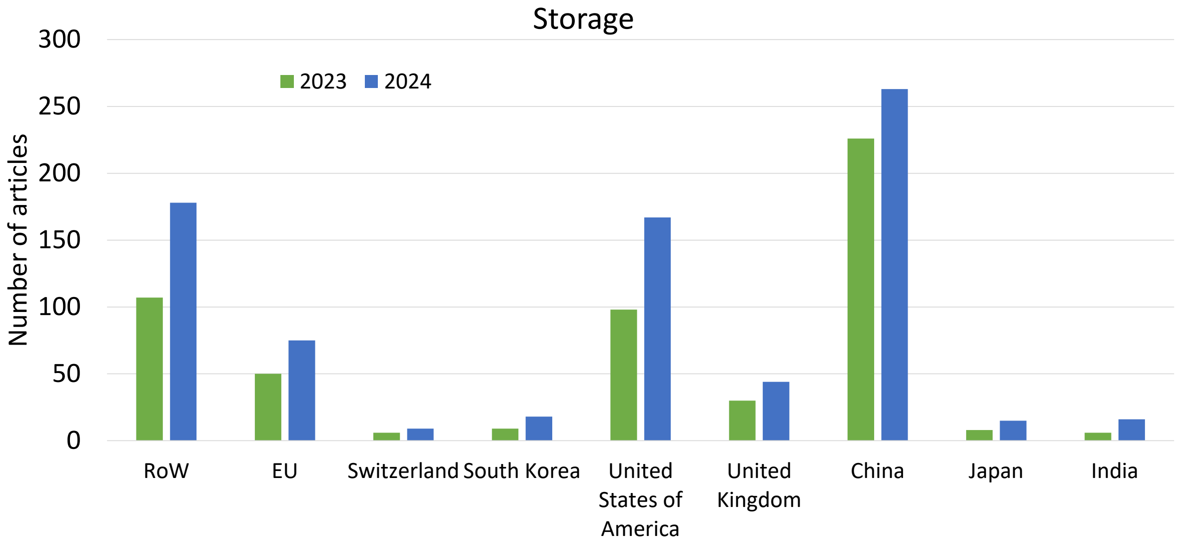
a)



b)



c)



d)

Source: JRC based on TIM

2.9. Assessment of R&I project developments

Since 2018, the European Climate, Infrastructure and Environment Executive Agency (CINEA) has built up a portfolio of 103 projects involving EUR 4.5 billion in EU contributions across the entire CCUS value chain [15]. These are funded by three EU programmes: the Connecting Europe Facility for Europe (CEF Energy), Horizon Europe (HE) and the Innovation Fund (IF). In addition, the SET Plan [16] and Mission

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[15] Industrial carbon management: interactive stories

[16] SET plan progress report 2024

Innovation[17] also support the development of CCUS value chains. An overview of the selected research, demonstration and de-risking projects is given below.

Horizon Europe and Horizon 2020

- HERCCULES: full CCUS chain demonstrations for cement and waste to energy in southern Europe, aiming for replicable, industry-scale capture, transport and storage solutions.
- AURORA: advancing the open CESAR1 solvent to TRL 7-8 with pilot units in the refining, cement and material recycling sectors, targeting up to 98% capture rates and halving the costs of conventional amine solvent MEA.
- CaLby2030: will construct three pilot plants, in Sweden, Germany and Spain, to test calcium looping using circulating fluidised bed technology. These pilots will investigate the decarbonisation of hard-to-abate CO_2 sources: flue gases from modern and future steel-making processes as well as emissions from modern cement plants that use limestone and from waste-to-energy and biothermal power plants.
- ACCSESS: aims to provide safe, cost-efficient, flexible and replicable CCUS addressing a range of sectors – from pulp and paper to bio-refining. The project will demonstrate cost-efficient CO_2 capture and use in industrial facilities. It will provide access routes for CO_2 captured from European industries to transport and storage infrastructures under development in the North Sea.
- COREu: brings together over 40 key partners from industry and science. The project will develop new demonstration projects connecting CO_2 sources with potential storage sites and focusing on developing regional CCUS clusters.

Innovation Fund and CEF Energy

A total of 25 ongoing projects funded by the IF are based on industrial carbon management solutions (16 CCS and 9 CCU). See Figure 22 for an overview of the distribution of CO_2 volumes and projects per country and type, developed by CINEA [15].

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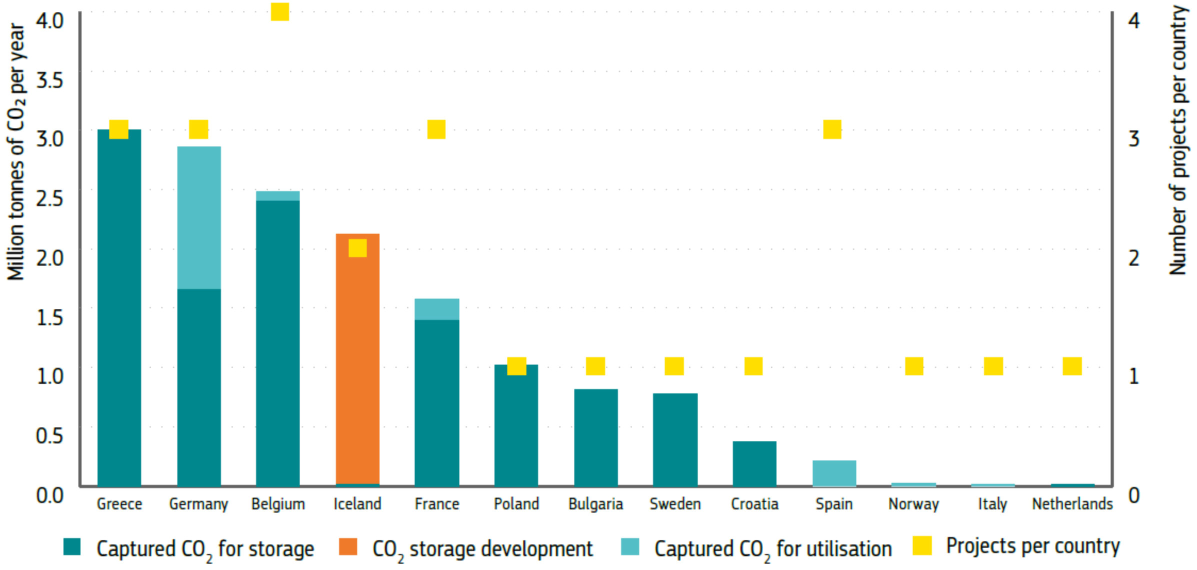
[17] Mission innovation

Figure 22. Number of CCUS projects per EU country including the amount of CO_2 flows involved, grouped by project type.



Source: CINEA

Regarding CO_2 capture, the first volumes are expected to be captured by Silverstone and CFCPILOT4CCS (both expected to start operations in 2025), followed by large-scale projects such as BECCS Stockholm, Kairos@C, IRIS and KOdeCO in 2028.

- Silverstone: upgrading the Hellisheiði geothermal plant in Iceland to the world's first near-zero-carbon geothermal facility by capturing CO_2 and mineralising it underground with Carbfix's basalt storage method.
- CFCPILOT4CCS: aims to develop and pilot a carbonate fuel cell (CFC) technology to capture CO_2 from dilute industrial streams. CFC technologies are especially attractive as they have the ability to generate electricity, hydrogen and useful heat while capturing CO_2, which largely enhances the economics of the process.
- Kairos@C: A BASF–Air Liquide project in Antwerp to create the first large-scale, cross-border CCS chain, capturing and transporting CO_2 from industry for permanent storage. Expected to prevent 14 million tonnes of CO_2 emissions in its first ten years.
- IRIS: aims to transform the Agioi Theodoroi refinery by implementing carbon capture on its steam methane reformer, producing ultra-low-carbon hydrogen and using captured CO_2 plus renewable H_2 to make e-methanol – one of the first synthetic methanol plants in Europe. The project is set to cut refinery CO_2 emissions by 25%.
- KOdeCO: aims to build the Mediterranean's first net-zero cement plant by capturing CO_2 from Holcim's Koromano site, liquefying it, and transporting it to an offshore storage site. Expected to cut 3.7 million tonnes CO_2 in its first decade.

Most of the captured CO_2 is compressed and transported via infrastructure partly supported by CEF Energy and IF. Some of these are located in Dunkirk, France (CalCC and K6 connected to D'Artagnan hub), in Antwerp, Belgium (Kairos@C connected to Antwerp@C), in Rotterdam, Netherlands (CFCPILOT4CCS connected to Porthos) and in Gdansk, Poland (GO4ECOPLANET connected to 4CCS Interconnector) [18].

IF supports three CO_2 storage projects: ANRAV, CODA (see below) and Silverstone (see description above).

- ANRAV: aims to be the first full chain (capture to storage) project in eastern Europe, linking the emitter in Bulgaria with the storage in a depleted gas field in the Black Sea through on- and off-shore pipelines.
- CODA: aims to be the world's first carbon mineral storage terminal. Using sustainable propulsion, captured CO_2 will be shipped to Iceland for injection into basaltic rocks and permanent storage.

IF includes nine projects that utilise CO from various sources to create fuels or materials. Some projects like TRISKELION utilise CO_2 together with renewable hydrogen to produce synthetic methanol, while others like AGGREGACO2 focus on producing cement-free building materials for the construction sector.

- TRISKELION: will capture CO_2 emissions from a cogeneration plant and combine them with renewable hydrogen produced via electrolysis to synthesise green methanol in a single reactor – alongside liquefied oxygen as a valuable by-product.

- AGGREGACO2: will pilot the first commercial-scale production of carbon-negative construction aggregates by integrating CO_2 captured from refinery operations with waste to energy residues using accelerated carbonation technology.

In their annual knowledge-sharing platform, CINEA highlights as a key milestone the approved State Aid from the Swedish government to BECCS Stockholm, which will collaborate with Northern Lights. Despite the progress made, CINEA also discusses the main challenges to developing CCUS projects [15]:

- Shortage and delays in developing storage sites and hubs.

- Rising CAPEX and operating costs.

- Uncertainties in CO_2 purity specifications.

- Net carbon removal projects face monetisation challenges as EU ETS does not yet cover them.

- Public perception is still a major risk, requiring communication and engagement efforts.

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[18] Industrial carbon management: interactive stories

3. Value chain analysis

3.1. Turnover and Gross Value Added

There is no new data regarding turnover and gross value added at the time of writing. For the most recent data available the reader is referred to the 2023 edition of this report [16].

3.2. Environmental and socio-economic sustainability

There is no new data regarding environmental and socio-economic sustainability at the time of writing. For the most recent data available the reader is referred to the 2023 edition of this report [16].

3.3. Role of EU companies

While the companies originally involved in CCUS value chains were oil and gas enterprises (which still remain heavily involved in CCUS projects), new players are emerging as a consequence of the business model shift, from the outdated full value chain model to the recently developed partial value chain models (see the 2024 edition of this report [19] [1] for an overview of the existing CCUS business models). These, according to the IEA [17], involve:

- chemical companies developing proprietary capture technologies and offering capture solutions to third parties (e.g., BASF);
- engineering companies and original equipment manufacturers, both developing proprietary capture solutions and capture-as-a-service (e.g., Aker Carbon Capture);
- infrastructure companies providing CO_2 management, both building and operating e.g., CO_2 pipelines (e.g., Gasunie); and
- liquefied natural gas carriers and shipping companies expanding their operations to CO_2 shipping (e.g., Capital Maritime).

A recent publication by the Global CCS Institute [18] presents a comprehensive technology compendium highlighting commercially available carbon capture and storage (CCS) solutions worldwide. For CO_2 capture, the report identifies 22 companies with technologies at or near full commercial readiness (TRL 8 and 9). Of these, six are based in the EU – Air Liquide (FR), Axens (FR), BASF (DE), Linde (DE), Shell (NL), and Siemens Energy (DE) – with a further two European providers: Aker Carbon Capture (NO) and Carbon Clean (UK). According to Prescouter [7], which carries out an analysis of top vendors in terms of business strength and technology strength, there are five EU companies within the top 10: Linde (DE), Technip Energies (FR), BASF (DE), Shell (NL) and Air Liquide (FR) (and one Norwegian, SLB Capturi).

In the CO_2 transport category, Global CCS Institute reports eight companies with commercially available solutions, of which three are EU-based: Air Liquide (FR), Linde (DE), and Shell (NL). For CO_2

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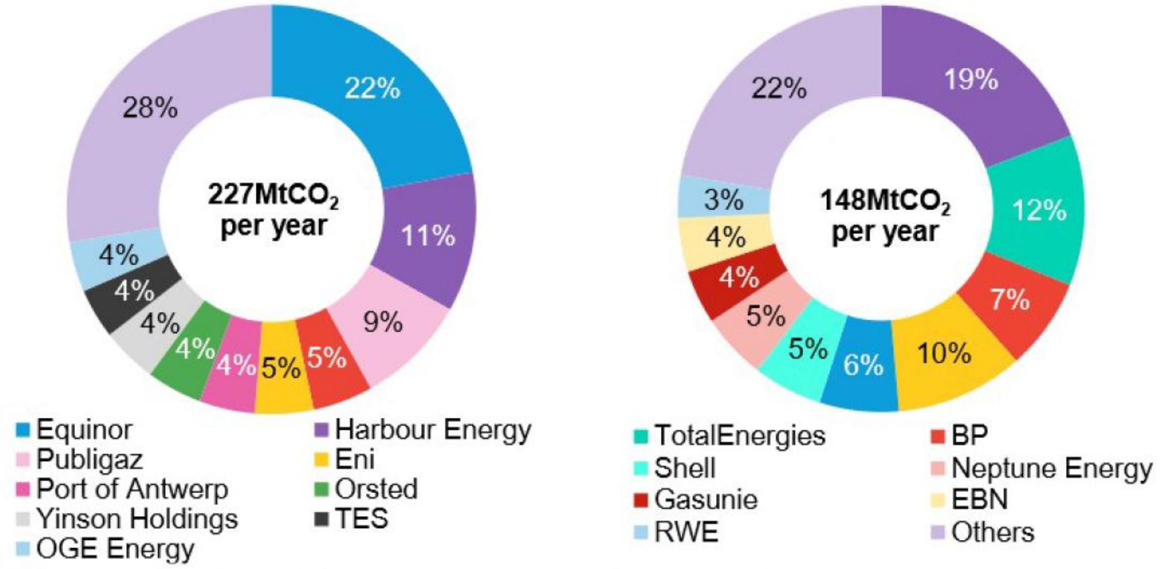
[19] CETO CCUS 2024, JRC139285

storage, only Shell (NL) and TotalEnergies (FR) appear among the 12 providers with market-ready technologies, joined by other European actors such as Equinor (NO), BP (UK), and the Northern Lights (NO) joint venture. Finally, the GCCS compendium lists a separate category for conditioning and other CCS-related equipment, where BASF (DE) and Linde (DE) are the only EU companies featured with fully commercial offerings.

Figure 23 displays the companies involved in the planned transport and storage projects across Europe, sorted by planned capacity [19]. It can be seen that the largest actors are Equinor (NO), Harbour Energy (UK), Publigaz (BE) and TotalEnergies (FR).

Figure 23. Ownership share of proposed European CO_2 transport (left) and storage (right) capacity in 2035, by company.



Source: BloombergNEF.

3.4. Employment

There is no new data regarding employment at the time of writing. For the most recent data available the reader is referred to the 2023 edition of this report [16].

3.5. Energy intensity and labour productivity

There is no new data regarding energy intensity and labour productivity at the time of writing. For the most recent data available the reader is referred to the 2024 edition of this report [1].

3.6. EU production data

Absorption by amine solvents is the most industrially mature process for large scale CCUS projects currently in operation [20]. Thus, the following components are used here as proxy to map the EU capabilities in terms of production of key CCUS components:

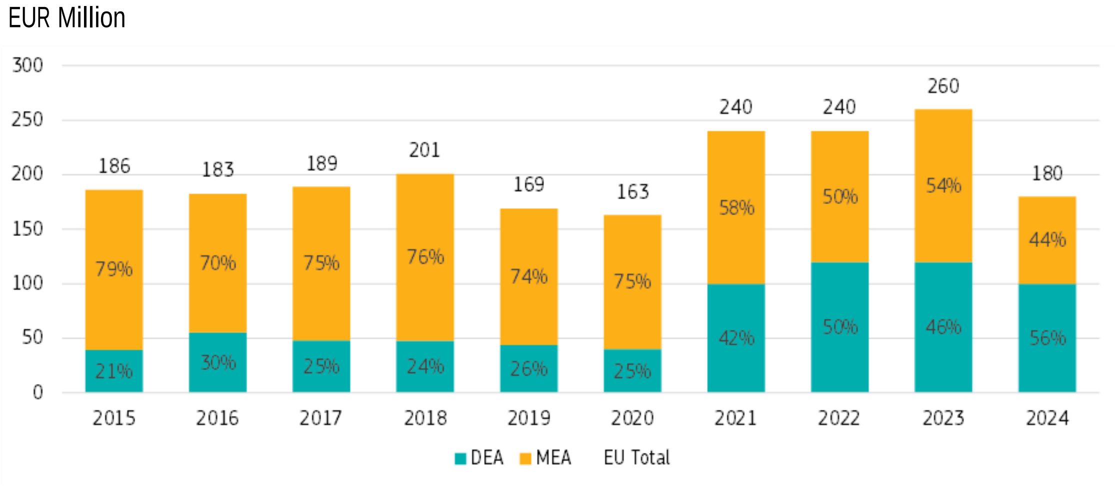
- Amine-based solvents[20]
- CO_2 compressors[21]
- Column vessels[22]

However, uses of amine solvents also extend to feedstock for detergent, emulsifier, polishes, pharmaceuticals, corrosion inhibitors, and chemical intermediates [21], while CO_2 compressors and column vessels are used for a wide variety of industrial applications (chemical, energy and manufacturing, among others). Thus, it is important to note that Prodcom[23] codes can offer only limited insight into the CCUS technology trends.

Regarding solvents, in 2024 the total EU production value of amines (MEA and DEA) fell by nearly one-third compared to 2023, reaching EUR 180 million (Figure 24). This decline was driven by a 17% drop in DEA production value and a 43% decrease in MEA. Most Member States keep their production data confidential; therefore, there are no insights about the leading EU producers.

Over the past decade (2015-2024), the overall EU production value of these proxy commodities remained relatively stable, with an average annual value of EUR 200 million. Historically, MEA accounted for 66% of EU production, while DEA represented 34%. Notably, this trend has shifted over the last three years (2022-2024), with the EU production becoming more balanced in terms of value.

Figure 24. EU production value of solvents per commodity [EUR Million]. MEA: Monoethanol amine. DEA: Diethanol amine



Source: JRC based on PRODCOM data.

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[20] Prodcom codes monitored were 20144233 Monoethanolamine and its salts (MEA) and 20144235 Diethanolamine and its salts (DEA). No codes for Methyldiethanolamine (MDEA) were identified.

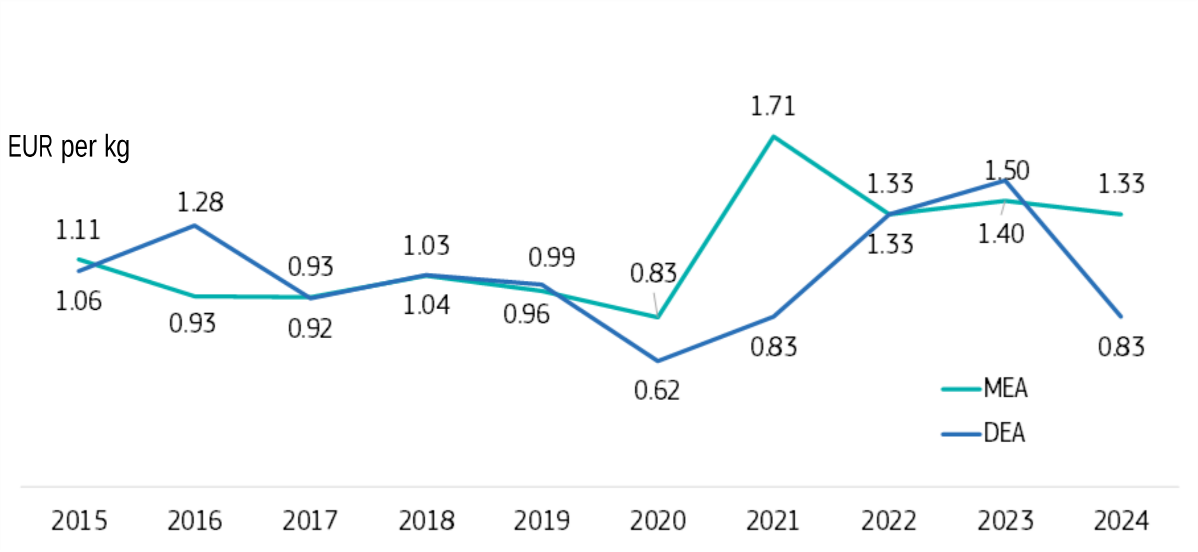
[21] Prodcom codes monitored were *28132550* (Turbo-compressors, multistage), *28132670* (Reciprocating displacement compressors having a gauge pressure capacity > 15 bar, giving a flow per hour ≤ 120 m^3), *28132690* (Reciprocating displacement compressors having a gauge pressure capacity > 15 bar, giving a flow per hour > 120 m^3), *28132753* (Multi-shaft screw compressors), *28132755* (Multi-shaft compressors (excluding screw compressors)).

[22] Prodcom codes monitored were *28291270* (Machinery and apparatus for solid-liquid separation/ purification excluding for water and beverages, centrifuges and centrifugal dryers, oil/petrol filters for internal combustion engines).

[23] Prodcom provides statistics on the production of manufactured goods carried out by enterprises on the national territory of the reporting countries. https://ec.europa.eu/eurostat/web/prodcom (accessed 08-08-2023).

The average unitary production value over the past decade (2015-2024) was EUR 1.04 per kg for DEA and EUR 1.16 per kg for MEA. In 2024, the unitary production value of DEA decreased by -80% compared to 2023, reaching EUR 0.83 per kg. In contrast, MEA maintained a unitary production value of EUR 1.33 per kg, reflecting a modest -5% decrease compared to 2023 (Figure 25).

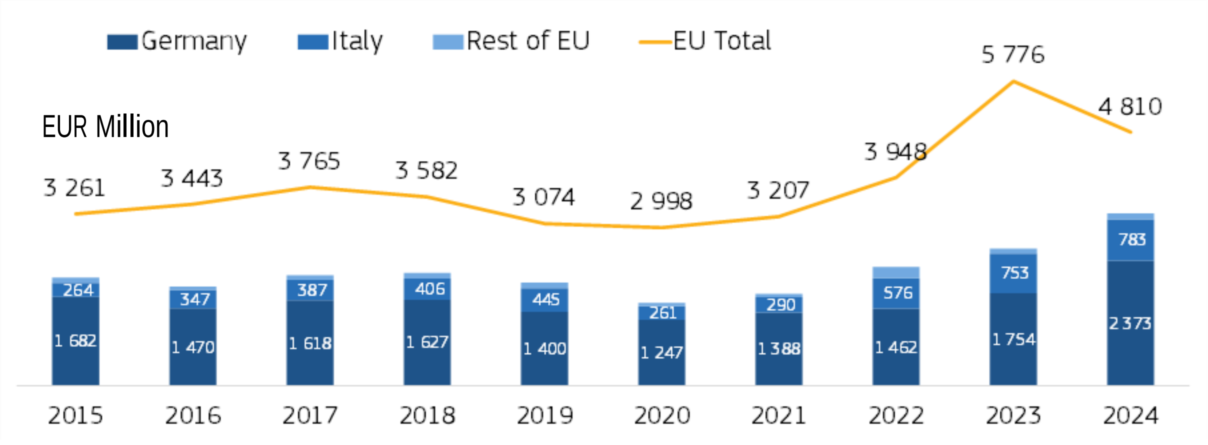
Figure 25. EU production unitary value of solvents per commodity [EUR per kg]



Source: JRC based on PRODCOM data.

Regarding CO_2 compressors, in 2024 the total EU production value declined by 17% compared to 2023, falling to under EUR 5 billion (Figure 26). Germany and Italy were the leading EU producers, accounting for 49% and 16% of total 2024 production, respectively. Over the past decade (2015-2024), the overall EU production value of these proxy commodities grew by 48%, with an annual compound growth rate of 4% and an average annual value of almost EUR 4 billion. Multi-shaft screw compressors (Prodcom 28132753) constituted nearly half of EU production, followed by multistage turbo-compressors (Prodcom 28132550) at 27%.

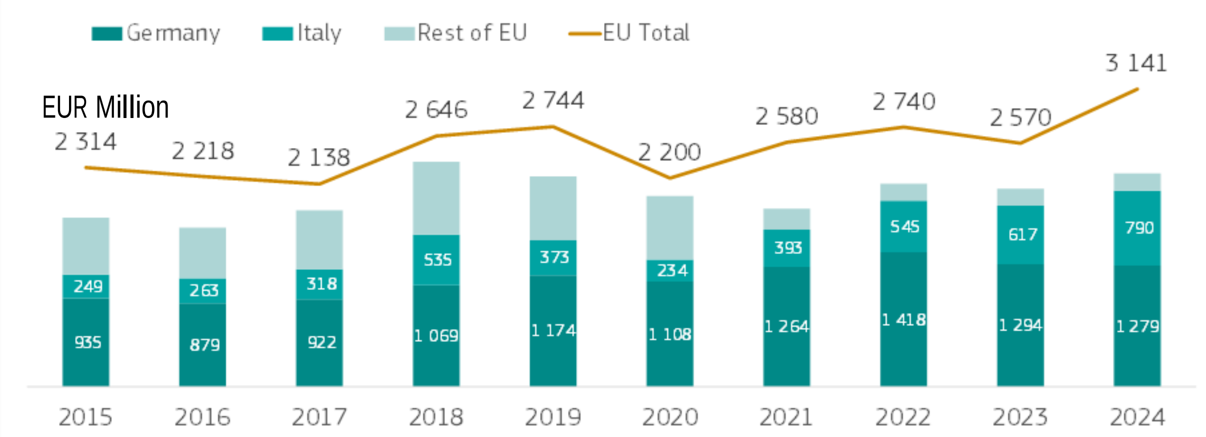
Figure 26. Total production value of CO_2 compressors in the EU and top producer countries [EUR Million].



Source: JRC based on PRODCOM data.

In 2024, the total EU production value of column vessels rose by 22% compared to 2023, reaching over EUR 3 billion (Figure 27). Germany and Italy were the leading EU producers, contributing 41% and 25% of total 2024 production, respectively. Over the same decade (2015-2024), the overall EU production value grew by 36%, with an annual compound growth rate of 3% and an average annual value of around EUR 2.5 billion.

Figure 27. Total production value of column vessels in the EU (yellow line) and top producer countries (columns) [EUR Million].



Source: JRC based on PRODCOM data.

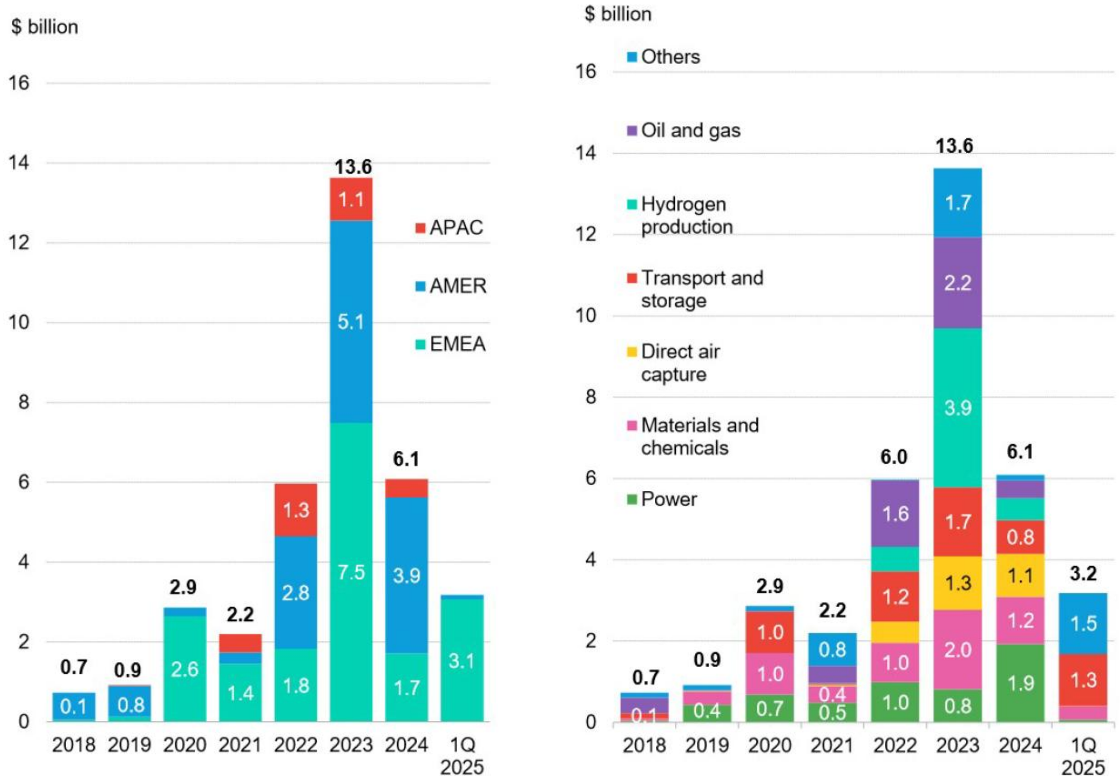
4. EU market position and global competitiveness

4.1. Global markets and growth prospects

4.1.1. Current EU positioning in the global market

Figure 28 shows global annual investments in CCUS across the world, which fell 55% in 2024 after two consecutive years of record spending. Nonetheless a total of USD 3.2 billion was invested during the first quarter of 2025, a figure that according to BNEF should inspire confidence in a market plagued recently by slow movement [22].

Figure 28. Global investment (in Billion USD) in CCUS (left) by region and (right) by sector from 2018 until Q1 2025.



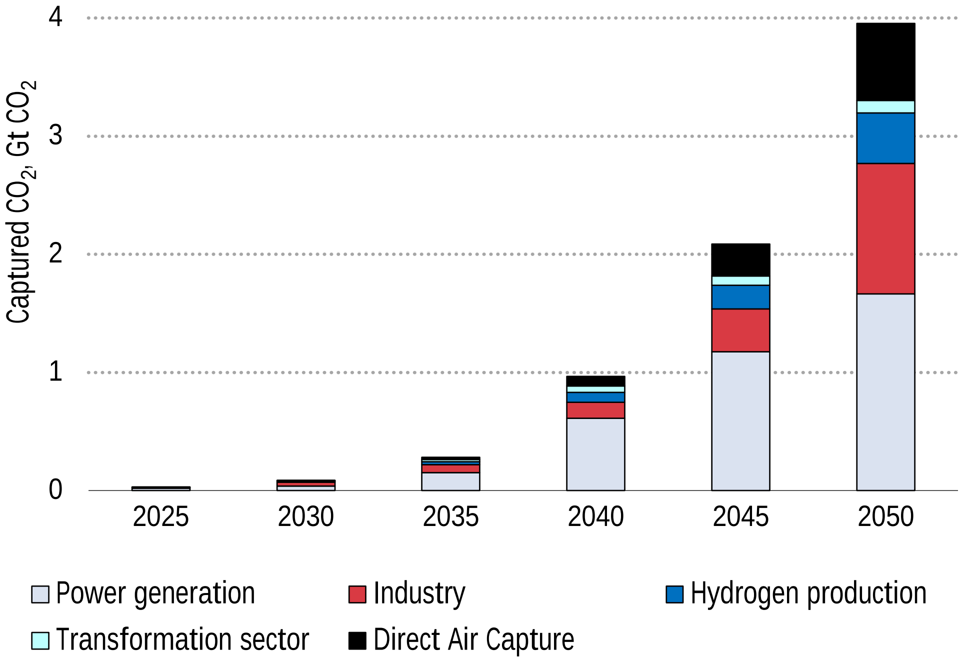
Source: BloombergNEF

The global CCUS market is increasingly fragmented. According to BNEF [22], Europe is emerging as the clear frontrunner, propelled by robust policy frameworks, sustained government backing, and coordinated cross-border initiatives that are accelerating project deployment. In contrast, the United States – historically a CCUS leader – is currently facing mounting challenges. Proposed funding cuts, rising trade barriers, and heightened political uncertainty are undermining investor confidence, slowing project development, and putting future growth at risk. While the U.S. still holds the largest pipeline of proposed CCUS capacity, its momentum is faltering, creating space for Europe to consolidate its leadership and set the pace for global CCUS deployment – at least in the near term. In fact, BNEF's market overview [22] claims that Europe has established itself as the global engine of CCUS deployment, combining innovative technologies, pioneering business models, and rapid progress in CO_2 transport and storage infrastructure. It has also mobilised financing at a scale unmatched anywhere else, bringing an unprecedented number of projects to life. Yet, Europe now finds itself advancing largely in isolation, as markets in Canada and the U.S. stall. Over the past six months, America has pulled back, shelving critical market-shaping measures such as carbon pricing schemes and key government funding programmes – undermining momentum and widening the gap with Europe.

4.1.2. Market prospects

At global level, the *Global CETO 2°C scenario 2025*[24] generated by the POLES-JRC model, projects that the global amount of annually captured CO_2 reaches 85 Mt by 2030 and 3960 Mt by 2050 (see Figure 29). According to the *Global CETO 2°C scenario 2025*, global CO_2 capture from power generation experiences steady growth over the decades and emerges as the primary application for CCS by 2050. Furthermore, CO_2 capture in industry assumes a significant role after 2040, with DAC and hydrogen production holding the third and fourth largest shares in capture deployment, respectively. Consequently, and due to the relatively low share of DAC in the global expected CO_2 capture capacity (partly caused by the recent increases in DAC cost projections [11]), the *Global CETO 2°C scenario 2025* estimates that around 90% of the total CO_2 captured in 2050 will be stored in permanent storage with the remaining used to manufacture synthetic fuels.

Figure 29. Projected global CO_2 capture by source, 2025-2050 according to the *Global CETO 2°C scenario 2025*.



Source: JRC analysis based on the POLES-JRC model.

At the EU level, Figure 30a illustrates the projected volumes of CO_2 capture by source under the POTEnCIA CETO 2025 scenario, as modelled with the POTEnCIA[25] energy system model (see Annex 2).

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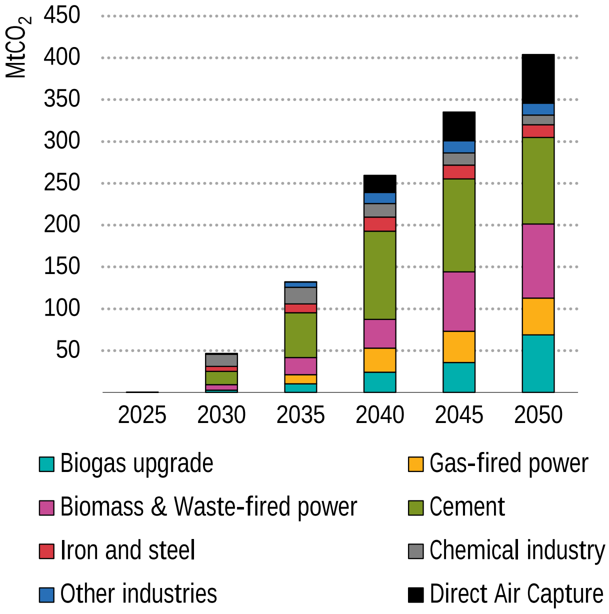
[24] A short description of the Global CETO 2°C scenario 2025 and the POLES-JRC model can be found in Annex 2.

[25] POTEnCIA (Policy Oriented Tool for Energy and Climate Change Impact Assessment) is a modelling tool that allows a robust assessment of the impact of different policy futures on the EU energy system developed by the JRC. A short description of the model and the scenarios are given in Annex 2.

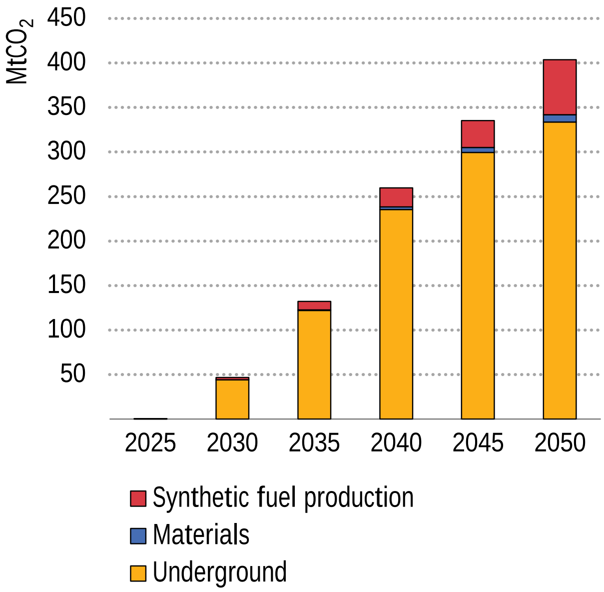
The results indicate that industrial carbon management across the EU is expected to reach approximately 400 $MtCO_2$ per year by 2050, consistent with the needs identified in the EU Climate Target Plan 2040 [23]. In contrast to the POLES-JRC results at global level, industry is expected to be the largest source for captured CO_2. More specifically, cement production is projected to be the largest contributor, with capture volumes of up to 103 $MtCO_2$ annually by 2050, followed by emissions from the combustion of solid biomass and waste – around half of which can be assumed to be of biogenic origin. Furthermore, Figure 30a shows that while CO_2 capture from bioenergy and waste continues to expand significantly through 2050, capture in the cement and iron and steel sectors is projected to peak around 2045 before declining slightly by 2050. This reduction is primarily attributed to (i) the increasing adoption of hydrogen-based direct reduction of iron (H_2-DRI) in the steel sector and (ii) the deployment of electric kilns, which substantially reduce fossil fuel-related emissions.

Figure 30b presents the distribution of captured CO_2 across three pathways: geological storage, material utilisation, and conversion into synthetic fuels. The POTEnCIA model projects that the overwhelming majority of captured CO_2 will be directed towards geological storage, reaching approximately 333 $MtCO_2$ per year by 2050. In contrast, the contribution of material utilisation remains marginal, with capture volumes of only about 8 $MtCO_2$ per year by 2050. This outcome underscores the central role of geological storage in meeting large-scale carbon management needs, while highlighting the limited potential of material-based utilisation under the scenario assumptions.

Figure 30. Projected CO_2 capture in the EU, 2025-2050.



a) Projected annual capture in the EU (from 2025 to 2050) grouped by CO_2 source.



b) Projected annual capture in the EU (from 2025 to 2050) grouped by fate of the carbon.

Source: JRC analysis based on the POTEnCIA model

A recent publication from the JRC [24] analysed and compared the main projections available in the open literature for the main industrial sectors, and concluded that, like POTEnCIA, most projections agree on cement being the sector with the highest captured volumes by 2050, followed by the chemical industry and the iron and steel sector. In addition, the study highlights that the variability across projections is the highest for the iron and steel sector.

Regarding transport infrastructure, the JRC published a report on 2024 on the potential extent and evolution of the most effective main transport network configuration within the EU that transports projected CO_2 captured amounts to the storage sites at the lowest possible investment costs [25]. Based on the modelling results, the European CO_2 transport network could reach a length up to 19 000 km and require investment up to EUR 23.1 billion by 2050. The extent and the cost of the network could be reduced by developing storage capacities in regions where current capacities are insufficient (e.g. southern and eastern Europe) to avoid transporting CO_2 over long distances. The modelling further indicates that the transport infrastructure could evolve into a large network that links numerous countries, as well as into several regional networks. It could also see the development of interconnections exclusively between pairs of countries, along with substantial transport routes that connect specific capture and storage sites. This underscores the imperative for establishing uniform CO_2 transport standards across Europe and a shared regulatory framework to guide such developments.

4.2. Trade (Import/export) and trade balance

International trade is monitored using six-digit codes of the Harmonised System (HS) classification[26], based on Eurostat's Comext[27] and the United Nations' Comtrade[28] databases.

Considering that CCUS technologies do not have mass production in place yet, amine solvents[29], potassium carbonate (HS 283640), ethylene glycol (HS 290531) and CO_2 compressors[30] and column vessels[31] have been used as a proxy for the trade of CCUS technologies. However, we note that the components with the HS codes used here are mainly used for applications other than CCUS (only a marginal share could be attributed to CCUS applications). Hence, a direct correlation between EU imports and carbon capture capacity cannot be established, and the data shown here serves to understand the trends and to exemplify the situation in the case their CCUS-use ramps up.

Figure 31 illustrates that the EU trade of amines fluctuates between deficit and surplus. In 2024, extra-EU imports dropped by 18% compared to 2023, reaching a total of EUR 79 million, and extra-EU exports increased by 34% reaching EUR 134 million, improving the trade surplus almost 14-fold from EUR 4 million to EUR 55 million. This was mainly because the demand for MEA and DEA softened due to a downturn in key consuming markets like construction and textiles, while there was adequate feedstock availability to boost the exports[32], despite the production reduction due to upstream plant shutdowns and maintenance of major European production sites, like BASF (Germany) and Ineos (France)[33].

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[26] World Customs Organization (WCO), HS Nomenclature 2022 Edition https://www.wcoomd.org/en/topics/nomenclature/instrument-and tools/hs-nomenclature-2022-edition.aspx

[27] https://ec.europa.eu/eurostat/web/international-trade-in-goods/data/focus-on-comext

[28] https://comtradeplus.un.org/

[29] HS codes: 292211 Monoethanolamine and its salts - MEA
292212 Diethanolamine and its salts - DEA
292213 Triethanolamine and its salts, discontinued in 2017 - TEA
292215 Triethanolamine, as of 2017 – TEA
292217 Methyldiethanolamine and ethyldiethanolamine, as of 2017 – MDEA

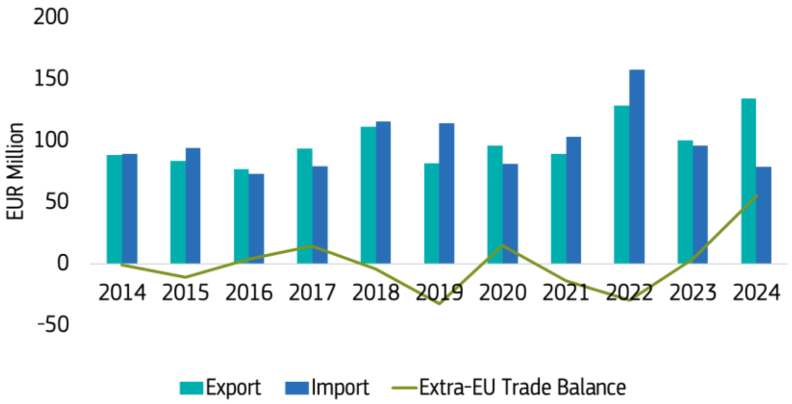
[30] Prodcom codes monitored were *28132550* (Turbo-compressors, multistage), *28132670* (Reciprocating displacement compressors having a gauge pressure capacity > 15 bar, giving a flow per hour ≤ 120 m^3), *28132690* (Reciprocating displacement compressors having a gauge pressure capacity > 15 bar, giving a flow per hour > 120 m^3), *28132753* (Multi-shaft screw compressors), *28132755* (Multi-shaft compressors (excluding screw compressors)).

[31] Prodcom codes monitored were *28291270* (Machinery and apparatus for solid-liquid separation/ purification excluding for water and beverages, centrifuges and centrifugal dryers, oil/petrol filters for internal combustion engines).

[32] Procurement Resource, Monoethanolamine Price Trend and Forecast https://www.procurementresource.com/resource-center/monoethanolamine-price-trends (accessed on 2025/09/08)

[33] Chemanalyst, Peter Schmidt 14-May-2024 European triethanolamine Prices sees a Surge Amidst Extended Supply Disruptions https://www.chemanalyst.com/NewsAndDeals/NewsDetails/european-triethanolamine-prices-sees-a-surge-amidst-extended-supply-disruptions-27821 (accessed on 2025/09/08)

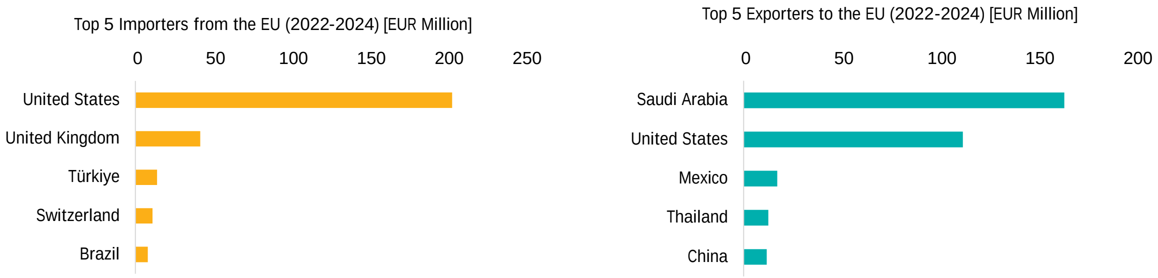
Figure 31. Extra-EU trade of amines for 2014-2024 [EUR Million].



Source: JRC based on COMEXT data.

During the 2022-2024 period, the US was the largest importer from the EU, receiving 56% of the extra-EU exports, followed by the UK and Türkiye with 11% and 4%, respectively. Saudi Arabia was the largest exporter to the EU, accounting for 49% of extra-EU imports, followed by the US (34%) (Figure 32). Regarding the growing markets[34] of amines during 2021-2023[35], the US had the largest net import increase, followed by Canada and Brazil, where the EU held 57%, 0% and 24% of each country's growing market, respectively.

Figure 32. Top five countries (left) importing from and (right) exporting amines to the EU for 2022-2024 [EUR Million].



Source: JRC based on COMEXT data.

Regarding ethylene glycol and potassium carbonate (see Figure 33), the extra-EU trade situation has not changed considerably as compared to the analysis presented in the 2024 edition of this report [1], with the EU being a net importer of ethylene glycol and exporter of potassium carbonate (although the imports have increased notably compared to 2023). Regarding CO_2 compressors and column vessels, the EU is a net exporter, with the exports of CO_2 compressors being on the rise for the past 5 years and Germany being responsible for about half of the exports. It is important to note in Figure 33, the different scale used in the y-axis: the total value of potassium carbonate trade is about ten

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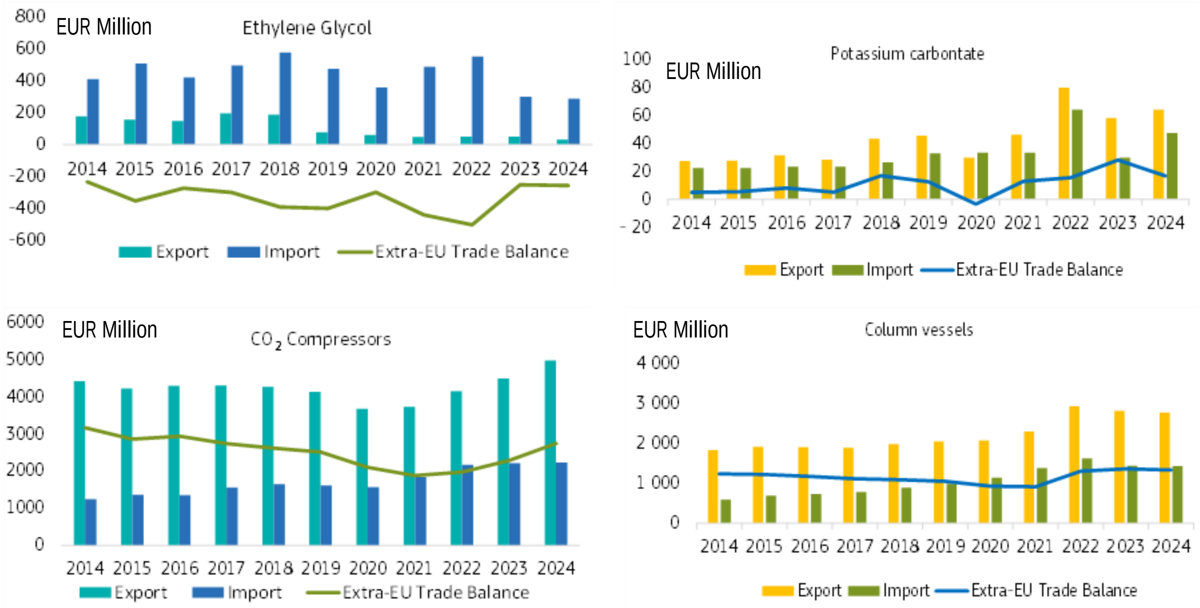
[34] Calculated as $net\ import\ change = [(import_{2022} - import_{2021}) + (import_{2023} - import_{2022})]/2$

[35] Latest year data (2024) is incomplete for Comtrade, because it does not provide estimates for the missing values as Comext does.

times lower than that of ethylene glycol and about hundred times lower than that of compressors and column vessels. If the EU consumption of potassium carbonate were to increase, then imports would increase, turning the EU trade balance negative, unless internal production could follow up.

Figure 33. Extra-EU trade during 2014-2024 for ethylene glycol (top left), potassium carbonate (top right), CO_2 compressors (bottom left) and column vessels (bottom right) [EUR Million, note scale differences in y-axis].



Source: JRC based on COMEXT data

4.3. Status of net-zero technology systems and components in the EU

4.3.1. Relevant final products and primarily used components

As already highlighted throughout this report, CCUS is in fact a chain of various steps, each of which is independent from the others and should therefore be assessed as a separate technology. In addition, each of the steps (but especially the capture and utilisation steps) can be realised with many, very different, technological choices. Thus, the list of relevant final products and primarily used components included in NZIA regulation [26] is split between each of the steps of the CCUS value chain. As seen in Table 4, the list of final products in CO_2 capture is indeed each of the technological capture choices (see Section 2.1). Regarding the primarily used components, the main difficulty lies in the fact that most of the components of the CCUS value chain are manufactured for other applications such as oil and gas installations and petrochemical processes. Thus, only a short selection is qualified to be included in NZIA [26] (see Table 4).

Table 4. List of final products and primarily used components of CCUS technologies included in the Net Zero Industry Act (NZIA).

		Final products	Primarily used components
CCUS	CO_2 capture	Absorption capture Adsorption capture Membranes capture Solid cycles capture Cryogenics capture Direct air capture	Solvents optimised for carbon capture Sorbents optimised for carbon capture
	CO_2 transport	CO_2 transport infrastructure	CO_2 compressors
	CO_2 storage		
	CO_2 utilisation	Thermochemical utilisation Electrochemical utilisation	Catalysts tailored for CO_2 conversion CO_2 electrolysers

Source: JRC based on NZIA

It is also important to mention the fact that as of 2025, there is not a supply chain in place for CCUS technologies, as mass production has not yet begun. Therefore, monitoring manufacturing capacity remains a challenge as 1) there is not an obvious source for retrieving such data and 2) manufacturers of primarily used components (e.g., CO_2 compressors) mainly produce them for applications other than CCUS.

4.3.2. EU manufacturing benchmark

The manufacturing capacity of each primarily used component across the EU is the first required input for establishing a benchmark of EU manufacturing readiness for CCUS technologies (see Table 4). However, this information is difficult to determine. CCUS components are not yet produced through dedicated, large-scale manufacturing processes, and no reliable estimates exist on the share of current production capacity that could be allocated to CCUS applications. At the time of writing, the JRC does not have access to an up-to-date inventory of EU manufacturing capacities for these components; this remains unknown (see Table 5).

The second step involves estimating the EU's CO_2 capture deployment needs by 2030. In this preliminary assessment, we estimate with 11.8 Mt the need of annual new capture installations[36] by 2030 as computed by POTEnCIA. Assuming an average capture plant capacity of 1 Mt per year, this corresponds to approximately 12 new capture plants to be built by 2030.

The distribution of capture technologies (e.g. absorption, adsorption, membranes or calcium looping) expected to contribute to this capacity is not clear and largely unknown. For simplicity, and in order to track the two technologies included in the list shown in Table 4, we here apply the technology distribution in currently active projects as mapped by Prescouter's database [7]:

- 35% liquid-based absorption

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[36] it is important to note that while this is the best estimate available at the time of writing, this figure does not reflect the retirement of capacity that was retrofitted with CCUS, and thus it is a lower bound on the actual capacity additions.

- 47% solid-based adsorption
- 18% other

Assuming standard solvent and sorbent requirements for MEA and zeolite 13X, respectively [27], the projected EU deployment needs amount to 4 kt and 17 kt of MEA and zeolite 13X per year by 2030. For context, the current EU production level of amine solvents (for applications other than CCUS) is approximately 30 kt per year (see Section 3.6).

For CO_2 compressors, it is not necessary to distribute deployment requirements across different technological options, as it can be assumed that the entire 11.8 Mt of new annual CCUS capacity will depend on CO_2 compression systems. The estimation of compressor requirements encompasses the conditioning and compression stages, including any booster stations needed for transport. To assess these requirements, standard design parameters for dense-phase CO_2 transport were applied for pipeline distances of 100 km, 500 km, and 1 000 km between the conditioning and storage sites. Based on estimates from Prescouter [7], an annual deployment of approximately 125–150 MW of compression power would be required, depending on the system configuration (±15%).

The forecasted role of CO_2 utilisation in 2030 is rather limited according to results from POTENCiA (see Section 4.1.2), indicating approximately 5% of the captured CO_2 being destined for material and fuel production. Thus, assuming all utilisation processes require a catalyst, and using conventional catalysts and yields from [28] for methanol and Fischer-Tropsch production, the estimated deployment needs for catalysts are about 12-50 tonnes per year. CO_2 electrolysers are still a very incipient technology, and various technological variations exist [29], which makes the assessment of deployment needs too unreliable at the time of writing.

Table 5. Summary of the preliminary results for the EU manufacturing benchmark of CCUS technologies per primarily used components (PUC).

PUC	EU Manufacturing Capacity	EU Deployment needs 2030	2030 EU Manufacturing Capacity Benchmark, %
Solvents	-	4 kt	-
Sorbents	-	17 kt	-
CO_2 compressors		125-150 MW	-
Catalysts	-	12-50 t	-
CO_2 electrolysers	-	-	-

Source: JRC

In addition to the exercise presented above, Prescouter [7] reveals that there are 15 capture technologies developed by EU companies that are part of an active project and with TRLs of 8 and 9 (these are assumed to be the only ones playing a role before 2030). These 15 technologies can be compared against the 66 total technologies worldwide with similar characteristics (active projects and TRLs of 8 and 9). It should be noted of course that the fact that companies are based in the EU does not give any indication regarding manufacturing capacity or location of the manufacturing processes.

4.3.3. EU share in global manufacturing benchmark

NZIA targets an increased EU share for the corresponding technologies with a view to reaching 15% of world production by 2040, except where the increased EU manufacturing capacity would be significantly higher than its deployment needs for the corresponding technologies necessary to achieve its 2040 climate and energy targets. Thus, the production target for each primarily used component (PUC) can be estimated as follows:

$$Production\ \text{Target}\ \ 2040_{\ PUC} \\ = \min\left(Union\ deployment\ needs\ in\ 2040\ for\ 2040\ policies, 15\%\ of\ Global\ production\ for\ 2040\right)$$

The same limitations identified for the EU manufacturing benchmark in Section 4.3.2 also apply in this context. Consequently, only global production targets for each component are estimated (see Table 6). To this end, the analysis combines POTEnCIA projections for EU annual deployment needs in 2040 with POLES-JRC model results for projected global annual production in 2040, under the assumption that production scales in line with deployment requirements. Finally, the conversion of CCUS deployment into component demand is carried out using the methodological assumptions outlined in Section 4.3.2. The results obtained are included in Table 6, with around 9 kt of liquid solvent, 35 kt of solid sorbents, 40-150 t of catalyst and between 245 and 300 MW of compressor power required to be produced annually in the EU by 2040.

Table 6. Summary of the preliminary results for the EU share in global manufacturing benchmark of CCUS technologies per primarily used components (PUC).

PUC	EU Manufacturing Capacity	Production target 2040	2040 EU Production Capacity Benchmark, %
Solvents	-	60 kt	-
Sorbents	-	35 kt	-
CO_2 compressors		245-300 MW	-
Catalysts	-	40-150 t	-
CO_2 electrolysers	-	-	-

Source: JRC

4.4. Resource efficiency and dependence in relation to EU competitiveness

There is no new data regarding resource efficiency at the time of writing. For the most recent data available the reader is referred to the 2024 edition of this report [1].

5. Conclusions

There is broad consensus at both the global and EU levels on the critical role of CCUS technologies in enabling the transition to a climate-neutral economy. This report provides an annual update on the status of CCUS technologies, their development trajectories, and the evolution of the value chain, while also assessing the EU's market position and global competitiveness in the field. The key conclusions derived from the analysis are summarised below.

- From a technological point of view, CCUS technologies are ready to be scaled up to the levels foreseen by bodies such as the International Energy Agency, the Intergovernmental Panel on Climate Change and the European Commission. Particularly relevant is capture via absorption, adsorption and membranes, which has the largest number of technologies at TRL 9.
- The growth in CCS project development remains high (46% annual increase in global CCS projects in advanced development), although stabilising. The large number of projects in early phases of development is an indicator of the expected CCUS needs both in the EU and worldwide. Notable European projects that went online this year include Brevik CCS, the world's first commercial-scale CCS plant in the cement industry; Twence CCU, capturing CO_2 from a waste-to-energy facility, which is being used in nearby industries; and phase 1 of Ravena CCS.
- However, project development is currently falling short of projected targets, both at the EU and global levels. According to these projections, 50 Mt of annual CO_2 capture capacity need to be deployed annually in the EU, and 80 Mt globally, by 2030.Europe is emerging as the global CCUS leader, driven by strong policies, consistent government support, and cross-border collaboration that accelerate deployment. Meanwhile, the US – though it still has the largest project pipeline – is losing momentum amid funding cuts, trade barriers, and political uncertainty, allowing Europe to consolidate its leadership in the near term.
- From a scientific standpoint, China has consistently been the leading contributor to scientific literature on CCUS, publishing more than 1 000 articles in 2024 alone. The EU leads the publication record on BECCS and high temperature looping research.
- EU production data and trade is analysed using amine solvents, CO_2 compressors and column vessels as proxies, but these components are currently manufactured for applications other than CCUS. Considering the potential ramp-up of manufacturing of CCUS technologies and the recent Net-Zero Industry Act, there is a need for thorough value chain identification and mapping.

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List of abbreviations and definitions

Abbreviations	Definitions
ASU	Air Separation Unit
BECCS	Bioenergy with CCS
CAPEX	Capital Expenditure
CCS	Carbon Capture and Storage
CCUS	Carbon Capture, Utilisation and Storage
CEF	Connecting Europe Facility
CLC	Chemical Looping Combustion
DAC	Direct Air Capture
DEA	Diethanol amine
EHR	Enhanced Hydrocarbon Recovery
EOR	Enhanced Oil Recovery
EU	European Union
EPO	European Patent Office
IEA	International Energy Agency
JRC	Joint Research Centre
LCA	Life Cycle Analysis
MEA	Monoethanol amine
MS	Member State
Mtpa	Million tons per annum
NG	Natural gas
OPEX	Operational Expenditure
PE	Private Equity

Abbreviations	Definitions
PSA	Pressure Swing Adsorption
PUC	Primarily Used Components
ROW	Rest of the World
SET	Strategic Energy Technologies
SEWGS	Sorption Enhanced Water Gas Shift
TRL	Technology Readiness Level
TSA	Temperature Swing Adsorption
VC	Venture Capital
VSA	Vacuum Swing Adsorption
ZEP	Zero Emissions Platform

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Annex 1 Summary Table of Data Sources for the CETO Indicators

Theme	Indicator	Main data source
Technology status and development and trends	Technology readiness level	JRC based on Global CCS Institute, IEA, Prescouter, IRENA and scientific literature.
	Installed capacity & production	JRC based on Global CCS Institute and Prescouter.
	Technology costs	JRC based on Global CCS Institute, IEA, Prescouter, DNV, CCSA, IRENA and scientific literature.
	Public and private RD&I funding	JRC based on IEA and Pitchbook
	Patenting trends	JRC based on EPO Patstat
	Scientific publication trends	JRC based on Tools for Innovation Monitoring (TIM)
	Assessment of R&I project developments	JRC based on CINEA
Value chain analysis	Turnover and Gross Value Added	Not assessed for 2025
	Environmental and socio-economic sustainability	Not assessed for 2025
	Role of EU companies	JRC based on IEA, Global CCS Institute, Prescouter and Polaris Market Research
	Employment	Not assessed for 2025
	Energy intensity and labour productivity	Not assessed for 2025
	EU production	JRC based on Prodcom data
EU market position and global competitiveness	Global markets and growth prospects	JRC based on BNEF, POTEnCIA, POLES
	EU trade (imports, exports) and trade balance	JRC based on COMEXT
	Status of net-zero technology systems and components in the EU	JRC based on scientific literature.
	Resource efficiency and dependencies (in relation EU competitiveness)	Not assessed for 2025

Source: JRC

Annex 2 Energy System Models and Scenarios: POTEnCIA and POLES-JRC

AN 2.1 POTEnCIA CETO 2025 Scenario

The *POTEnCIA CETO 2025 Scenario* has been generated with the Policy Oriented Tool for Energy and Climate Change Impact Assessment (POTEnCIA). Developed in-house by the European Commission's Joint Research Centre (JRC) to support EU policy analysis, POTEnCIA is an energy system simulation model designed to compare alternative pathways for the EU energy system. The core modelling approach of POTEnCIA (detailed in Mantzos et al., 2019) focuses on the economically-driven operation of energy markets and corresponding supply-demand interactions, based on a recursive dynamic partial equilibrium method.

The technology projections provided in the *POTEnCIA CETO 2025 Scenario* are obtained under a climate neutrality scenario aligned with the broad GHG reduction objectives of the European Green Deal. As such, this scenario reduces net EU GHG emissions by 55% by 2030 and 90% by 2040, both compared to 1990, and reaches net zero EU emissions by 2050. To model the uptake of different technologies under this decarbonisation trajectory, the scenario includes a representation at EU level of general climate and energy policies such as emissions pricing under the Emissions Trading System, as well as key policy instruments that have a crucial impact on the uptake of specific technologies. For instance, the 2030 energy consumption and renewable energy shares reflect the targets of the EU's Renewable Energy Directive (RED) and of the Energy Efficiency Directive (EED). Similarly, the adoption of alternative powertrains and fuels in transport is consistent with the updated CO2 emission standards in road transport and with the targets of the ReFuelEU Aviation and FuelEU Maritime regulations.

Compared to the *POTEnCIA CETO 2024 Scenario* (Neuwahl et al, 2024), the *POTEnCIA CETO 2025 Scenario* incorporates many model enhancements and scenario-specific updates, most notably:

- The usage of the more recent JRC-IDEES 2023 data (Rózsai et al, 2025).
- Closer alignment to the National Energy and Climate Plans (NECPs) of the individual MS, which have been published in recent months.

A more detailed description of the *POTEnCIA CETO 2025 Scenario* will be available in the forthcoming report (Neuwahl et al., 2025).

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Rózsai, M., Jaxa-Rozen, M., Salvucci, R., Sikora, P., Gea Bermudez, J., Wegener, M. and Neuwahl, F., *JRC-IDEES-2023: the Integrated Database of the European Energy System – Data update and technical documentation,* Forthcoming.

AN 2.2 Global CETO 2°C Scenario 2025

The *Global CETO 2°C Scenario 2025* has been generated by the global energy model *POLES-JRC* (Prospective Outlook for the Long-term Energy System).

POLES-JRC covers the entire global energy system with a high level of regional detail, encompassing 66 countries and regions, from primary supply (fossil fuels, renewables) to transformation (power, biofuels, hydrogen, and hydrogen-derived fuels, such as e-fuels and ammonia) and final consumption sectoral demand (industry, buildings, transport). International markets and energy fuel prices are calculated endogenously. The model comprises a comprehensive portfolio of technologies, with technology dynamics and interactions across sectors modelled using endogenous technology learning.

Detailed documentation of the *POLES-JRC* model is provided in (Després et al., 2018). Techno-economic assumptions used in the current version of the model are provided in (Schmitz et al., 2025). The latter report provides also a comprehensive overview of the dynamics and interaction of various clean energy technologies until the end of the century. POLES-JRC results are published in the annual "Global Climate and Energy Outlooks" (GECO) report, which provides detailed country energy and GHG balances, and an online visualisation interface.

The *Global CETO 2°C scenario 2025* is designed to limit global temperature increase to 2°C at the end of the century. It is driven by a single global carbon price. The *Global CETO 2°C scenario 2025* builds on the *POLES-JRC* model version used for GECO 2024 (European Commission, 2025) and has been enhanced as following:

- Cost optimisation for electrolysers powered by renewables (PV, wind) has been implemented considering an over-sizing of renewable capacities and battery storage.
- Electrolyser investment costs have been increased reflecting recent literature revisions.
- Updated investment costs for renewable technologies and utility battery according to (IRENA, 2025) as well as updated installed capacities for power generating technologies.
- Revised global wind profiles (off-shore and on-shore).
- Updated data on new vehicles and vehicle stock by transport mode (battery and fuel cell vehicles, ICE, hybrid) and vehicle type (passenger cars, light and heavy trucks, buses).
- Updated hydrogen infrastructure cost related to road transport.

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