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Technical brief

# Chemicals and CCS/U

## Exploring the role of carbon capture in the sector's transition to 'circularity'

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## Author

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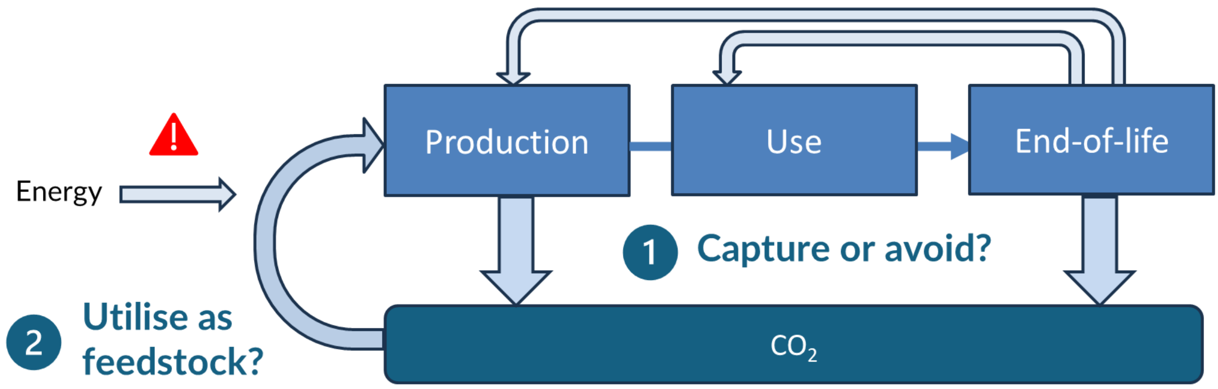
# Executive Summary

Europe's chemicals sector must reduce greenhouse gas emissions from its production processes, transition away from fossil feedstocks, and address the growing climate impact of its downstream products at the end-of-life stage. Within this context, the sector has positioned itself as "*the carbon managers*", emphasising carbon capture, storage and utilisation (CCS/U) as central solutions for the sector.

This technical brief assesses how far that claim holds up under a full lifecycle and system-wide analysis. We find that while CCS/U will likely find some deployment in Europe's chemicals sector, fundamental techno-economic constraints mean the **overall emissions savings from these technologies are expected to be limited, in the context of the sector's current footprint.** CCS/U must be considered as one option for installations carrying out specific processes to reduce their emissions rather than a general decarbonisation strategy for the sector.




**The assessment centres around two main questions related to the capture and utilisation of $CO_2$ :**

## ❶ To what extent is carbon capture needed to reduce emissions from the sector, considering alternative abatement measures?

For **chemicals production**, around two thirds of emissions stem from fuel combustion for heat generation. Carbon capture may play a role as a transitional solution, most notably where processes produce concentrated $CO_2$ streams, such as in hydrogen and ammonia production, and where facilities are located close to $CO_2$ transport and storage infrastructure. For diffuse, low-concentration flue gases, however, capture costs are likely to be prohibitively high. In key processes such as steam cracking, electrification offers the most robust, future-proof pathway to deep decarbonisation and efforts should be focused on accelerating their deployment.

Modelling estimates, based on conservative electrification assumptions, foresee 35 Mt captured in 2050 (less than 8% of the total amount projected to be captured in the EU and just 9% of current lifecycle emissions of the sector) and just 5 Mt utilised for chemicals production (of which only 1 Mt is expected to come from the chemical industry).

The majority of lifecycle emissions from chemical products arise downstream, particularly from plastics at the **end-of-life** stage. Addressing these emissions requires a shift toward greater circularity, but not all circular solutions deliver equivalent climate benefits. Demand reduction, reuse, repair and design-for-recycling are the cheapest and most energy-efficient ways to reduce emissions and policies to incentivise these practices should be enacted as a first priority. Even under optimistic assumptions, recycling yields mean that substantial volumes of virgin polymer production will remain unavoidable, reinforcing the importance of waste prevention. Mechanical recycling should, however, still be maximised due to the low cost and energy requirements of this process. Carbon capture could be implemented in some end-of-life applications such as gasification and waste incineration facilities, but these processes should be treated as last-resort options rather than cornerstones of circularity in the sector.

## ❷ Will carbon capture and utilisation (CCU) for chemicals production be feasible at scale?

Technology costs and efficiencies may evolve, but current evidence suggests that **CCU will be a niche complement, rather than a pillar of decarbonisation.** While the idea of converting captured $CO_2$ into chemicals is appealing, CCU faces fundamental thermodynamic and economic constraints. Meeting European demand with chemicals produced from $CO_2$ would require prohibitively large quantities of green hydrogen and low-carbon electricity, locking in energy-intensive value chains, for what could amount to only a temporary delay of emissions into the atmosphere. We therefore urge caution in how non-permanent fossil CCU is accounted for under the EU ETS. Weak accounting rules risk turning the ETS into a subsidy for delayed emissions rather than genuine mitigation. Care should be taken not to over-incentivise CCU relative to other measures which can achieve greater emission reductions.

## To enable a resilient, competitive and low emission chemicals sector, EU policymakers must ensure the right policy framework is put in place.

**Underpinning decision-making on investments in emission reductions should be a strong, predictable carbon price in the EU supported by protection from carbon leakage by coverage of chemicals under a robust CBAM**. This will create the conditions needed for cost-efficient emission reductions, with carbon capture competing alongside other abatement options on a level-playing field (provided upstream fugitive emissions are properly accounted for). Utilisation of captured carbon (CCU) will be part of the solution, but only a small part. Attempts to create a circular chemicals sector centred around the capture and utilisation of $CO_2$ would see energy demand and costs skyrocketing.

**Europe's chemicals transition must be achieved through avoiding emissions, strengthening demand-side measures and waste prevention and aligning industrial policy with physical and thermodynamic realities.**

# Chemicals and CCS/U: Exploring the role of carbon capture in the sector's transition to 'circularity'

**Within the context of the Commission's industrial carbon management framework, Europe's chemical industry is positioning itself as "*the carbon managers*". But how relevant will carbon capture, storage and utilisation technologies actually be to mitigation efforts and future production routes in the sector?**

The use of Carbon Capture and Storage or Utilisation (CCS/U) technologies will be necessary to meet climate objectives, but, crucially, only in limited and targeted applications. CCS/U will not necessarily be relevant as a technological solution to decarbonise all industrial processes. It is therefore key to identify what processes are likely to rely on CCS/U, so that **resources can be dedicated for scaling up necessary $CO_2$ transport and storage infrastructure where it is most needed**.

Following on from our assessment of CCS/U in the iron and steel and aluminium sectors, we conduct another sectoral deep dive into the potential of CCS/U, this time focusing on the chemicals sector. The chemicals sector is inherently centred around the transformation of carbon and so the utilisation of captured $CO_2$ to produce chemicals is an appealing notion. However, we find that **not all chemical production processes are well suited to carbon capture while utilisation of $CO_2$ presents sizeable technical, economic and energetic challenges for limited climate benefits.**

## The European chemicals industry: A sector in need of transformation

**European industrial policy is currently characterised by a tension between the need to reduce emissions to meet climate goals while boosting economic competitiveness and maintaining production sovereignty**. Within this context, the chemical sector has become increasingly vocal in its criticisms of European climate policy. This criticism has come in spite of the petrochemicals sector enjoying profits higher than other industries over the past two decades, while it has been protected from facing a cost of carbon by free allocation of EU allowances (EUAs) within the Emissions Trading Scheme (ETS).

Now the European chemical industry is facing structural competitive disadvantages in the face of global overcapacity, leading to a soul-searching through initiatives like the Critical Chemicals Alliance, set up by the Commission in a bid to bolster the sector's competitiveness. Within this context, **it is vital to build a common understanding of the current state-of-play of technological solutions for reducing the sector's emissions, including CCS/U.**

**The discussion considers**:

1. **Carbon capture at both production and end-of-life stages**, also considering alternative abatement options
2. A discussion of the relevance and potential of **$CO_2$ utilisation (CCU) for chemicals production**

# Chemicals production: Decarbonising heat generation the key

While the chemicals sector is often characterised by its complexity, a large share of GHG emissions come from just a few processes. Furthermore, while the sector is often considered difficult to decarbonise, it is estimated that **two thirds of GHG emissions from the chemical industry are associated with fuel combustion**,[1] for which alternatives to carbon capture are nearing commercial deployment. We will focus on the applicability of carbon capture to the key processes of **steam cracki**ng and **steam methane reforming**, considering also alternative mitigation strategies.

## Basic chemicals production

**Steam cracking** is an energy-intensive process that 'cracks' refinery products into the 'basic' organic chemicals used as building blocks for the chemical industry. The basic organic chemicals produced include ethylene, propylene, butadiene and the aromatic compounds benzene, toluene and xylene (together referred to as BTX). Steam crackers are currently responsible for around 30 Mt$CO_2$ annually, which represents approximately 20-25% of the European chemical sector's direct GHG emissions.[2] A structural rationalisation in naphtha-fed cracker capacity is currently taking place in Europe in the face of global overcapacity.[3] The investment decisions made now will be crucial to the future competitiveness of European production facilities.

Ninety percent of emissions from steam crackers relate to energy consumption for heat generation.[4] **Electrification of cracker furnaces** is therefore one possible route to reducing emissions from steam crackers. While fluctuating energy supply could create challenges, this could also be seen as an opportunity for flexibility in operations, enabling plants to respond to varying electricity prices that reflect the production of renewable energy production. While not yet deployed at scale, these electrified furnaces are nearing commercial reality; 2025 saw ground broken on a demonstration plant for large-scale electrically heated steam cracker furnaces at BASF Ludwigshafen, with a heat pump with thermal output of 50 MW and expected to reduce annual emissions by 100 kt$CO_2$.[5]

$CO_2$ can also be captured from conventional fossil furnaces. However, steam crackers typically rely on **multiple small furnaces which release flue gas with low $CO_2$ concentrations**. This means retrofitting capture technology is technically challenging and capture costs are expected to be high. Recent estimates for industrial CCS in Germany estimated total costs in the range of €150-300/t$CO_2$.[6] Given the challenges discussed above, steam crackers are likely to be at the higher end of this range.

[1] EEA, 2024, Total greenhouse gas emissions in the chemical industry (Indicator)
[2] Borealis Group, 2021, Accelerating electrification with the "Cracker of the Future" Consortium
[3] Chemicals United B.V., 2025, European Overview of Steam Crackers and Solvent-related Upstreams
[4] BASF, 2024, BASF, SABIC, and Linde celebrate the start-up of the world's first large-scale electrically heated steam cracking furnace
[5] BASF, 2025, Groundbreaking ceremony at BASF's Ludwigshafen site: next project phase for one of the most powerful heat pumps for CO2-free steam generation
[6] Agora Industrie, Öko-Institut, 2026, Carbon Capture and Storage (CCS) in der Energiewende zur Klimaneutralität

In their 2025 roadmap "The Carbon Managers", CEFIC still foresee a need to retrofit carbon capture technologies to steam crackers up to 2050 in their base case scenario. This is due to constraining total electricity supply to 300 TWh/year as a result of an assumed electricity price of 109 $€_{2019}$/MWh.[7] CEFIC's scenario shows that only around two thirds of steam cracker capacity is at least partially electrified, with less than a quarter fully electrified (Figure 1).

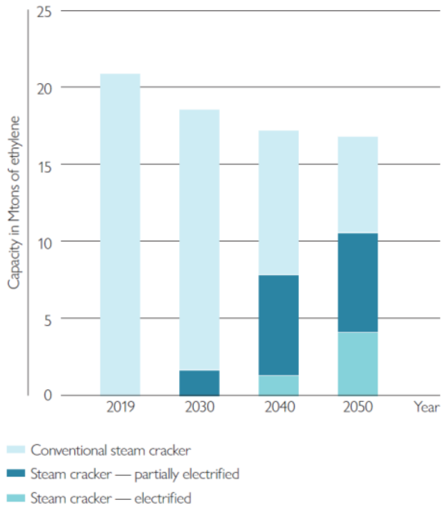



*Figure 1. Projected electrification of steam crackers, according to CEFIC's iC2050 base case scenario [7]*

As noted by Accenture's 2022 assessment for CEFIC,[8] the energy demand created by replacing all of European crackers' fossil fuel-based furnaces with electric furnaces would only amount to an additional 200 TWh/year. Yet even in CEFIC's "High Electrification" scenario, in which 1000 TWh is available to the sector at a price of just 57 $€_{2019}$/MWh, only 79% of the total steam cracking capacity is electrified in 2050. This suggests **electrification potential may be being underestimated in scenario design choices**. In reality, electric furnaces will be competitive with CCS, increasingly so as the electricity grid decarbonises. Recent studies suggest, when renewable electricity is used, electric steam crackers will be marginally cheaper in comparison to crackers fitted with CCS.[9]

## Hydrogen production

**Steam methane reforming** (SMR) produces a mixture of hydrogen and carbon monoxide, known as synthesis gas or 'syngas'. Hydrogen is separated and used primarily as a feedstock for ammonia production. Like steam cracking discussed previously, high-temperature steam is also required for this process. However, unlike steam cracking, a concentrated, high-purity $CO_2$ stream is generated as an intrinsic by-product of the process, making SMR one of the few large-scale chemical production routes where carbon capture is relatively technically straightforward. As a result, SMR is often cited as a priority candidate for deployment of carbon capture in the chemicals sector, particularly in the absence of near-term alternatives such as large-scale availability of renewable hydrogen. Some carbon capture projects are already beginning operation, most notably Yara's Sluiskil plant in the Netherlands.

**Carbon capture projects at European hydrogen and ammonia plants**

**Yara's** CCS project at its **Sluiskil plant in the Netherlands** is being inaugurated in 2026. The project is set to liquefy and transport 800,000 tons of $CO_2$ per year by ship to Norway and stored under the North Sea floor in the Northern Lights storage site.

[7] CEFIC, 2025, The Carbon Managers
[8] Accenture, 2022, The chemical industry's road to net zero: Costs and opportunities of the EU Green Deal
[9] W. Shin et al., 2025, Decarbonization approaches for ethylene production: comparative techno-economic and life-cycle analysis, *Green Chemistry* 27.14, 3655-3675.

The **Kairos@C** project at **BASF** and **Air Liquide**'s Antwerp facilities is currently postponed.[10] $CO_2$ would be captured from hydrogen, ammonia and ethylene oxide production installations. The investment amounts to more than a billion euros, including a €500 million subsidy from Europe, spread over a 13-year period. The project is also based on €10 million of co-financing from Flanders.

However, while technically feasible, the dual-stream capture method required for SMR is relatively costly and inefficient. Autothermal Reforming (ATR) is a method which combines partial oxidation and catalytic steam reforming in a single reactor, enabling higher capture rates and lower overall life cycle emissions.[11] Although green hydrogen produced from electrolysis is expected to be affordable and dominate hydrogen supply by 2050, if cost reductions and scale-up of green hydrogen does not take place as expected in Europe, **ATR+CCS may become an attractive option, especially in locations with higher electricity prices**.

If these fossil-based production routes are to persist, it is essential that their full lifecycle emissions are accounted for in EU legislation. In particular, **it is imperative that upstream methane leakage during fossil fuel extraction is properly accounted for**. The EU's methane regulation will require mandatory measurement, reporting and verification (MRV) requirements for emissions at the source level, including for non-operated assets. However, some key features of this regulation are not yet in force, and several detailed guidelines and standards are still to be confirmed and there are concerns that upstream emissions will not be fully accounted for. For example, the Low-Carbon Fuels Delegated Act assumes a methane leakage rate of around 1.2%, significantly lower than the global average leakage rate, estimated to be between 2.8 - 3.2%.[12] It is essential that these emissions are properly considered to enable green hydrogen to compete on a level playing field.

## Other chemicals production

Beyond steam cracking and SMR, the chemicals sector is highly heterogeneous in terms of products and processes, with emissions scattered across the value chain, which means high capture rates are generally economically unfeasible. **The total amount captured across the sector has been projected to be in the range of 30-40 Mt in 2040 and 2050 in the European Commission's 2040 Impact Assessment modelling**, across all scenarios consistent with the EU's climate targets. CEFIC also estimate 35 Mt of $CO_2$ will be captured in 2050 in their Base Case scenario. For context, the total lifecycle emissions from the sector currently amount to 328 $MtCO_2eq$ with production of hydrogen alone currently accounting for 70-100 $MtCO_2eq$ in the EU.[13]

[10] Flows, 2025, BASF Antwerp shelves billion-dollar investment in CCS
[11] A. O. Oni et al. "Comparative assessment of blue hydrogen from steam methane reforming, autothermal reforming, and natural gas decomposition technologies for natural gas-producing regions." Energy Conversion and Management 254 (2022): 115245.
[12] T&E, 2025, Blue threat: can EU hydrogen policy stay green?
[13] European Commission, 2020, A hydrogen strategy for a climate-neutral Europe. COM(2020) 301 final.

## End-of-life emissions: Focus on prevention in absence of silver bullets

Emissions associated with the production of chemicals are only around a third of the total lifecycle emissions of chemical-based products.[14] The vast majority of the remaining emissions arise at the end-of-life stage, most notably from plastics which are becoming increasingly entrenched in modern society. Addressing emissions at the point of production is therefore necessary but insufficient; **reducing emissions from the chemicals sector requires confronting emissions embedded in products and released when they are discarded, incinerated or otherwise treated**.

Part of the solution is a move towards greater circularity, which would have the added benefit of reducing feedstock demand. In the Commission's 2040 Impact Assessment, the LIFE scenario shows clear benefits from higher levels of circularity in industry, with investment needs reduced by 19% compared with S3 scenario.[15] However, it is important to remember that **not all circularity measures deliver equivalent climate benefits.** Circularity does not come for free in both an economic and energetic sense, and efforts to increase circularity face both physical and thermodynamic limits.

A 'waste hierarchy' is theoretically in place in Europe (see Figure 2**Error! Reference source not found.**), but this is not being enacted as strongly as is needed, particularly higher up the hierarchy. In practice, policy attention and investment remain skewed towards downstream treatment rather than upstream prevention of waste creation. As well as limiting the problem of how to deal with the waste, there would be added benefits in upstream action. Demand-side actions could lead to an optimisation of production of chemicals, with savings of up to around 28% of olefins and ammonia in 2040 (vs 2019).[15] Introduction of additional measures, as modelled in the Commission's LIFE scenario, such as a ban of single use water bottles and strong reduction of plastic-packaging are also projected to save approximately 15% of primary input material in 2050. These are **'easy wins' which must be implemented as a first priority**.

Additionally, the waste hierarchy lacks nuance. For example, there exist different methods of recycling which have intrinsic differences and should not be equally incentivised:

**Mechanical recycling** is the term used for processing plastics waste into secondary raw materials or products without significantly changing the material's chemical structure. This is less energy-intensive than other recycling methods. However, there are limits to the number of times plastics can be mechanically


*Figure 2. Waste hierarchy, as set out in the Waste Framework Directive*

[14] Agora, 2023, Chemicals in Transition
[15] European Commission, 2024, Commission Staff Working Document Impact Assessment Report Part 1 Accompanying the document 'Securing our future Europe's 2040 climate target and path to climate neutrality by 2050 building a sustainable, just and prosperous society'

recycled, with materials losing their properties with each cycle, resulting in so-called "downcycling". There are additional issues as well, including concerns around the chemical safety of recyclates through carryover of contaminants or material degradation. However, there are undoubtedly benefits to keeping plastics in circulation for as long as possible. Stronger design-for-recycling incentives are needed to reduce these contaminants and make products easier to recycle.

**Chemical recycling** is the process of breaking chemical bonds to transform polymers back into monomers or oligomers through depolymerisation, chemolysis or solvolysis techniques. The process is most applicable to condensate polymers such as polyethylene terephthalate (PET), the formation of which are reversible. The term 'chemical recycling' is also often misleadingly used to refer to **thermal decomposition** methods, in particular pyrolysis or gasification. These processes should more accurately be considered a form of 'chemical recovery' as polymers are transformed into a variety of basic feedstock rather than specific monomers.[16] These thermal decomposition processes are highly energy consuming. Studies have shown that, under certain assumptions and system boundaries, chemical recovery can emit up to four times more greenhouse gases than plastic landfilling, while producing additional toxic by-products.[17]

In terms of the applicability of carbon capture to these processes, capturing $CO_2$ from pyrolysis is challenging due to small units and dilute flue gas concentrations whereas gasification routes allow a more efficient pre-combustion capture of concentrated syngas $CO_2$ streams. Even so, achieving circularity through these methods is expected to offer only moderate climate value for the sector by 2050, comparable to other end-of-life treatment options.[18]

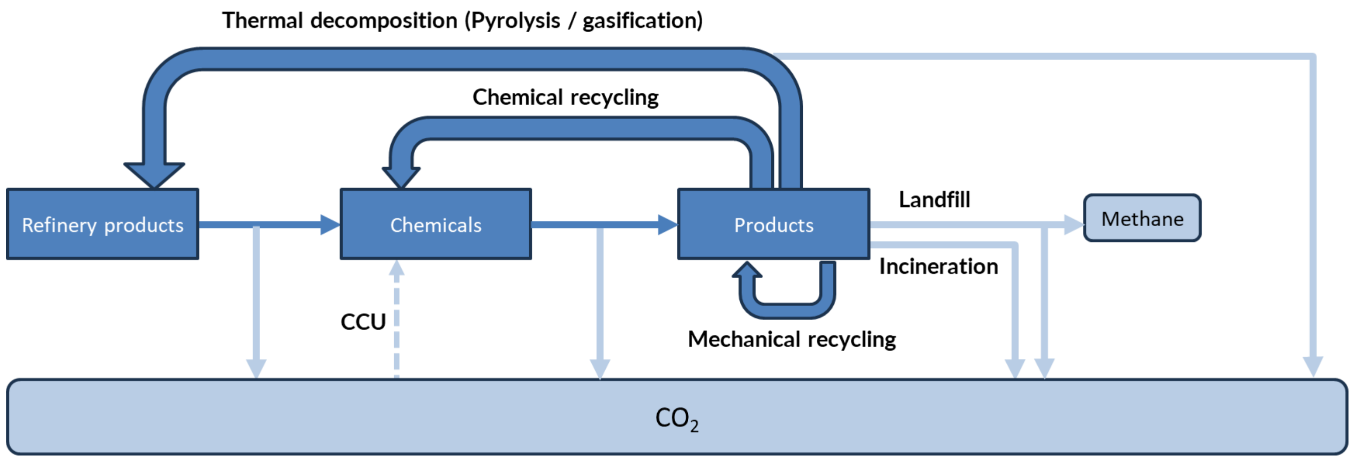



Figure 3. Simplified overview of select end-of-life processes in the chemical industry

Even with all recycling efforts operational at their potential, there is still a **significant hurdle in the way for a circular plastics value chain**. Maximum yields of 60% for mechanical recycling and 40% for chemical recovery via pyrolysis are

[16] Zero Waste Europe, ECOS, DUH, 2021, Chemical Recycling and Recovery – Recommendation to Categorise Thermal Decomposition of Plastic Waste to Molecular Level Feedstock as Chemical Recovery
[17] Environmental Health News, 2022, Chemical recycling grows — along with concerns about its environmental impacts
[18] E3G, Bellona, 2026, Capture and Storage Ladder: Assessing the Climate Value of CCS Applications in Europe

expected, so even if all plastic is produced through these routes, around half of plastic production will still be virgin polymer production.[19]

Prevention of waste should therefore be reinforced through stronger measures and incentives although it is inevitable that some mixed or contaminated waste streams will need to be dealt with. This mixed waste can be dealt with through landfilling or **municipal waste incineration (MWI).** Energy can be recovered from incineration, a process known as waste-to-energy (WtE). By avoiding methane from landfills and displacing fossil energy, waste incineration with energy recovery can lower net emissions compared with traditional waste disposal. However, this process produces significant quantities of hazardous and non-hazardous residues, much of which must still be landfilled.[20] It is notable that in CEFIC's arbitration, CCS on waste incineration does not take place as "the CCS potential is fully dedicated to direct emissions of chemical operations". The logic behind this is questionable given the availability of other options to reduce upstream emissions. Furthermore, a number of full-scale demonstration projects are already in operation.[21]

While waste prevention should be prioritised, some MWI will need to be tolerated, and the likely inclusion of MWI in the ETS will necessitate the reduction of emissions from these installations. **Capturing $CO_2$ produced by these facilities presents several challenges**, including the small size and inland location of many incinerator facilities. Post-combustion capture units require substantial additional space for absorbers, compressors and $CO_2$ handling infrastructure. Preliminary assessments suggest that only a minority of European facilities have sufficient available footprint for full-scale retrofits without major site reconfiguration. In view of these constraints, it is clearly preferable to maximise efforts to avoid creation of waste in the first place.

Considering all the options together, it is clear **a life-cycle approach must be taken to tackling end-of-life emissions** to ensure attempts to increase circularity do not increase emissions. The challenge of tackling end-of-life emissions is made more difficult by the fact that, as we reduce primary production emissions, the incentives to improve circularity also reduce. Strong circularity interventions related to product design and waste reduction will therefore be needed to further guide the chemical industry toward a more sustainable future. The Commission is making steps in this regard. The Packaging and Packaging Waste Regulation (PPWR) introduced in 2025 sets binding recycled content targets to all packaging placed on the EU market. The Commission also recently presented its Circular Plastics Package, a first step towards the Circular Economy Act , which is due later in 2026. The initial package included an implementing act to create EU-wide end-of-waste criteria for plastics under the Waste Framework Directive. The Circular Economy Act itself is expected to include several relevant measures, including the creation of a single market for waste. **It is imperative that such a framework incentivises reuse and repair of materials and resource efficiency as well as recycling, so as to minimise energy consumption**, with low carbon energy a scarce resource in the coming years.

[19] Bellona, 2024, Decarbonising Plastics
[20] Zero Waste Europe, 2022, Incineration and residues in the EU: quantities and fates
[21] IEA Bioenergy, 2025, Full-scale Waste-to-Energy CCS in Norway Oslo CCS Hafslund Celsio, WP2 Case Study

## CCU: A niche complement rather than a pillar of emission abatement

**The prospect of repurposing captured greenhouse gas into a feedstock is undoubtedly appealing**, especially when the availability of non-fossil feedstocks is expected to be limited. In the Industrial Carbon Management Strategy of 2024, the European Commission set out an intention to promote the use and 'recycling' of captured $CO_2$ as a resource to replace fossil fuels when producing fuels, chemicals and materials.

Some direct use pathways for captured $CO_2$ already exist, for example in the food sector for soft drink carbonation or reacting with ammonia to produce urea through the Bosch-Meiser process. However, fundamental energetic and economic constraints exist and are expected to persist for the foreseeable future, limiting the potential of CCU. **$CO_2$ has high thermodynamic stability, which means that significant amounts of energy are required to convert it into fuels or chemicals**. In order to produce hydrocarbons, hydrogen is needed to react with $CO_2$. In the future this will need to be green hydrogen, the production of which also requires significant amounts of low carbon electricity. These factors mean the energy required to produce chemicals from captured $CO_2$ is often higher than the energy contained in the molecule itself raising fundamental questions about efficiency, scalability and cost.

Some chemicals are energetically easier to produce from $CO_2$ than others. For example, the reduction of $CO_2$ to produce **formic acid** is a two-electron process, and is therefore emerging as a contender to conventional fossil-based production of this chemical.

$$CO_2 + 2H^+ + 2e^- \rightarrow HCOOH$$

By contrast, let us consider a higher volume industrial chemical, **methanol**, which is primarily used as a feedstock to produce formaldehyde, acetic acid, and various plastics, resins, and adhesives. Reduction of $CO_2$ to methanol is a six-electron process, thus requiring substantially more hydrogen and energy input.

$$CO_2 + 6H^+ + 6e^- \rightarrow CH_3OH + H_2O$$

If methanol is then used as an intermediate to produce olefins via the methanol-to-olefins (MTO) route, the overall energetic demand increases further due to additional conversion steps and associated losses. Overall, we estimate that **converting $CO_2$ to olefins of monomer purity via the MTO process would require 27 MWh of electricity per tonne of ethylene** (see Figure 4). For comparison, this energy use is significantly higher than an electrified steam cracker which is estimated to require **only 1.75 MWh per t of ethylene.**[22]

[22] S. G. Naraghi et al, 2025, Multi-objective Optimization of Steam Cracking Microgrid for Clean Olefins Production, Systems and Control Transactions, 4, 837-843
Note the 1.75 MWh does not include upstream energy use associated with production of naphtha feedstock

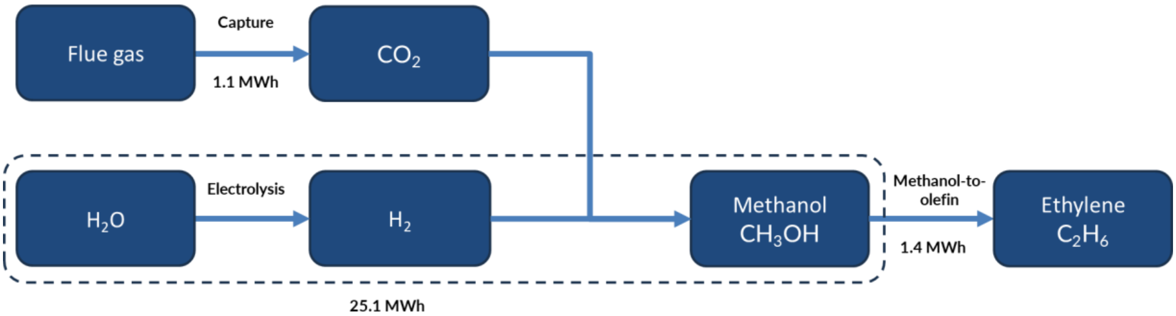



Figure 4. Overview of energy consumed in CCU pathway to ethylene production (see Appendix 1)

Even in countries with low-carbon electricity grids, scaling up **CCU would require significant amounts of additional low-carbon electricity generation.**[23] It has been estimated that the domestic production of CCU fuels and chemicals for the transport and industry sectors will require up to 1,187 TWh of low-carbon electricity in 2050[24], almost equivalent to the total electricity produced by renewables in 2025 (1,331 TWh).[25] It has been estimated that scenarios which rely on higher levels of CCU could increase industrial electricity consumption by a factor of four.[26] In the near term, and in view of the expected constraints in supply of low carbon electricity, the benefits of using this electricity for what amounts to a temporary delay of emissions rather than using it to prevent primary emissions (by displacing fossil heating for instance) must be considered. As noted by Bellona in their 2024 analysis, "*CCU can only make a meaningful contribution if the entire life cycle is compatible with the goals of climate neutrality and ecological sustainability*".[27]

Studies have shown that **storing $CO_2$ captured from waste incineration reduces more than twice the emissions of utilising it**, even when 100% renewable electricity is used in the utilisation process (Figure 5).[28] This is also not considering the potential for "induced emissions" associated with renewable electricity use at times of marginal fossil power generation.[29] If fossil electricity is used, lifecycle emissions increase substantially relative to incineration without carbon capture. Achieving a decarbonised grid capable of supporting industrial electrification will require accelerated renewable deployment, expanded transmission and distribution networks, faster permitting of grid connections, and significant system flexibility investments. In this context, industrial pathways that maximise emissions reductions per unit of scarce clean electricity should be prioritised in order to minimise additional strain on network infrastructure. The merit of CCU pathways must be viewed in comparison to more efficient direct electrification routes.

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[23] P. Gabrielli, et al, 2023, Net-zero emissions chemical industry in a world of limited resources, One Earth, 682-704,
[24] $CO_2$ Value Europe, 2024, $CO_2$ Value Europe's 2050 CCU Roadmap
[25] Ember, 2026, European Electricity Review 2026
[26] Material Economics, 2024, Industrial transformation 2050: Pathways to net-zero emissions from EU heavy industry
[27] Bellona Deutschland, GermanWatch, 2025, Carbon Capture and Utilisation: Opportunities, Risks and Guiding Principles
[28] H. Croezen et al, 2018. Screening LCA for CCU routes connected to CO 2-Smart Grid, C E Delft
[29] Sandbag, 2025, Getting Electrification Right: The broader challenge of induced emissions

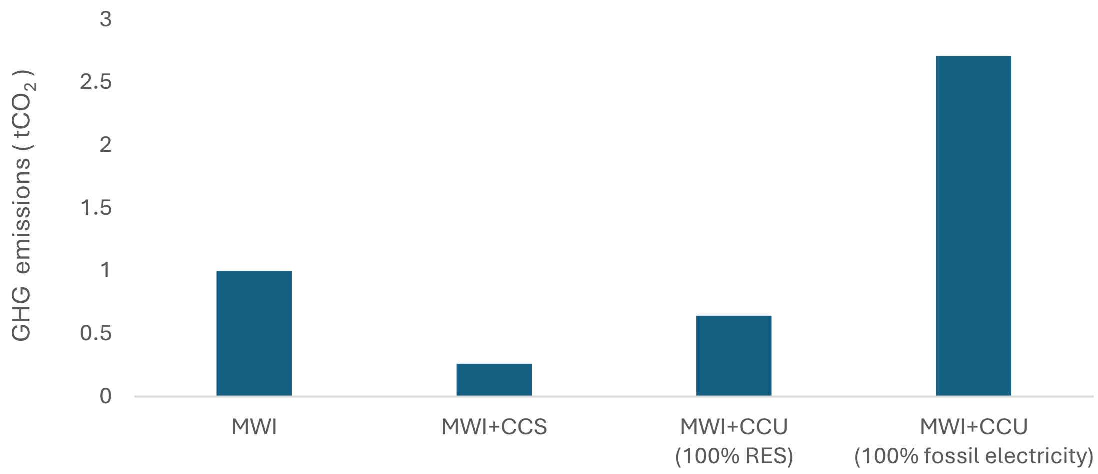


Figure 5. Comparison of GHG emissions of municipal waste incineration (MWI) without mitigation, combined with CCS and combined with CCU for methanol production, under different electricity assumptions (Source: Croezen et al[28])

Following a 2023 amendment to the EU ETS Directive, GHG are now considered emitted once released from an ETS installation unless it is stored permanently geologically (CCS) or in products (permanent CCU),[30] This means the ETS currently does not provide incentives for non-permanent CCU, something the Commission is looking to address in 2026. However, accounting for this non-permanent CCU presents additional challenges and risks creating loopholes that could allow emissions to go unabated.

**Non-permanent CCU: Caution needed in the absence of easy accounting solutions**

The European Commission has been mandated as part of the 2026 revision of the EU ETS, to assess how to account for fossil $CO_2$ that is captured and used to produce products in which the carbon is non-permanently bound.

There is currently an **inconsistency in how captured fossil $CO_2$ is treated across end-use applications**. Until 2040 if fossil $CO_2$ from industrial point sources is used to produce aviation or maritime fuels, the release of $CO_2$ upon the combustion of these fuels is treated as zero emissions under the RFNBO accounting rules. The original cost of producing the $CO_2$ is passed on through the short value chain, and is only paid once.

However, **this is not the case if the fossil $CO_2$ is used to produce products like plastics**. The expected inclusion of downstream municipal waste incineration (MWI) in the ETS would effectively lead to double counting of the release of this $CO_2$, first at the original capturing installation and then at the MWI installation. If the $CO_2$ from the MWI installation is then captured and utilised again, the effect is compounded. Unlike with fuels, the cost cannot be simply passed down the chemicals, plastics and waste value chain due to its complexity.

[30] European Commission, 2023, Commission Delegated Regulation (EU) 2023/1185 supplementing Directive (EU) 2018/2001 of the European Parliament and of the Council

However, **there are no easy solutions to this problem which do not pose serious risks**. As identified by Concito and Clean Air Task Force (CATF),[31] there are effectively two options for accounting for non-permanent CCU, either maintaining the 'capture installation pays approach' or pushing the accounting downstream at the point of emission.

**Shifting carbon accounting downstream** would involve transferring the obligation to surrender allowances from the capture installation to the final emitter. This approach would require significant changes to monitoring, verifying (MRV) in the chemicals and plastics sectors and could open the door to widespread underreporting of emissions and risks turning the EU ETS into a subsidy for a temporary delay in emissions. We consider that in practice, it is neither credible nor enforceable to implement robust MRV across all end uses of carbon, particularly for short-lived products like plastics or chemicals.

If an **upstream approach is maintained**, double pricing could be avoided by allowing guarantees of origin (GoOs) to pass on costs to MWI installations. However, as with the downstream accounting approach there is still the possibility for overestimation of the captured $CO_2$ that is embedded in products ending up in landfill and a risk of disproportionately incentivising fossil CCU as an upstream abatement option relative to biogenic CCU and CCS which ultimately achieve greater GHG emission reductions. A conservative correction factor would need to be applied to account for these risks, downrating GoOs to represent significantly less than an ETS allowance.

The benefits of introducing an accounting mechanism to incentivise non-permanent fossil CCU appear extremely limited in the face of these risks, especially when some demand for captured fossil $CO_2$ already exists from the aviation and maritime sectors and in permanent products. If such a mechanism is to be introduced, we recommend a **conservative approach, with care taken not to give non-permanent CCU an advantage** over CCS or other value chain decarbonisation options.

**The upstream 'capture installation pays' approach should be maintained**. If GoOs are introduced to allow the carbon cost to be passed down the value chain, both downrating of GoOs to correct for leakage of CCU products from the system and additional obligations on plastic producers should be considered.

**The extent to which non-permanent CCU should be incentivised must also be considered in line with its forecasted cost, ability to scale and potential to reduce emissions**. Fossil-based CCU for chemicals production will be at most a niche solution for the foreseeable future and attempts to incentivise CCU could risk doing more harm than good from a lifecycle emission standpoint. Feedstock switching is one of the key abatement levers for the chemical sector, but CCU is unlikely to be cost-competitive with alternatives in the coming years. For example, e-methanol is expected to be around twice as expensive as biomethanol at least until 2034.[32]

[31] Concito and Clean Air Task Force, 2025, Pricing it Right
[32] Methanol Institute, 2024, Economic value of methanol for shipping under FuelEU maritime and EU ETS

The Oxford Institute for Energy Studies notes that "*the overall impact (of CCU) on the CCUS market is expected to be minimal from a volumetric standpoint*"[33] while CEFIC's modelling also suggests a relatively limited role for CCU in transitioning the sector, with **captured $CO_2$ contributing only around 2% of total carbon feedstock by 2050**. Similarly, Plastics Europe's roadmap for production indicates that plastics based on CCU would only begin to scale after 2040, rising to 3.2 Mt (5% of plastics used by converters) by 2050.[34]

**We do not consider there is a strong rationale to further incentivise the utilisation of $CO_2$ for chemicals production in the near future given the points discussed above**. Offtake demand already exists for captured fossil $CO_2$ as it can be used in the production of e-fuels to meet sustainable aviation fuel (SAF) mandates until 2039. While the production of e-fuels is similarly energy-intensive and costly as e-chemicals production, the aviation sector represents a more logical destination for captured $CO_2$ in the near future as decarbonisation options are more limited as electrification of long-haul aircraft is not feasible. Creating competition for $CO_2$ from the chemicals sector makes little sense given the availability of other (more cost- and energy-efficient) abatement levers to the sector.

[33] Oxford Institute for Energy Studies, 2025, Putting the U in CCUS: Overview of Emerging Pathways in Carbon Utilisation
[34] Plastic Europe, 2024, The Plastics Transition

## Conclusions: Lifecycle approach needed to cut chemical sector emissions

**The European chemical industry is facing several concurrent challenges**; the need to reduce emissions from production processes, while transitioning away from fossil feedstock and reducing end-of-life emissions in the face of increasing demand. All this while attempting to remain competitive in the face of global overcapacity. It is therefore essential that a policy framework is in place which incentivises cost-effective, energy-efficient and future-proof emission reductions in the sector.

### Carbon capture at production and end-of-life stages

We find that, despite the European chemical industry positioning itself as "*the carbon managers*", current evidence suggests **capture potential is structurally concentrated in specific processes rather than broadly applicable across the sector**. Inherent techno-economic limitations and the emergence of alternative emission reduction measures mean the application of carbon capture in the chemical industry is set to be limited to certain cases in production and end-of-life applications. CEFIC's own estimates, which are based on conservative electrification assumptions and therefore not likely to be underestimates, foresee limited potential, with 35 Mt captured in 2050 (less than 8% of the total amount projected to be captured in the EU[35] and 9% of current lifecycle emissions of the sector) and just 5 Mt utilised (of which only 1 Mt is expected to come from the chemical industry).

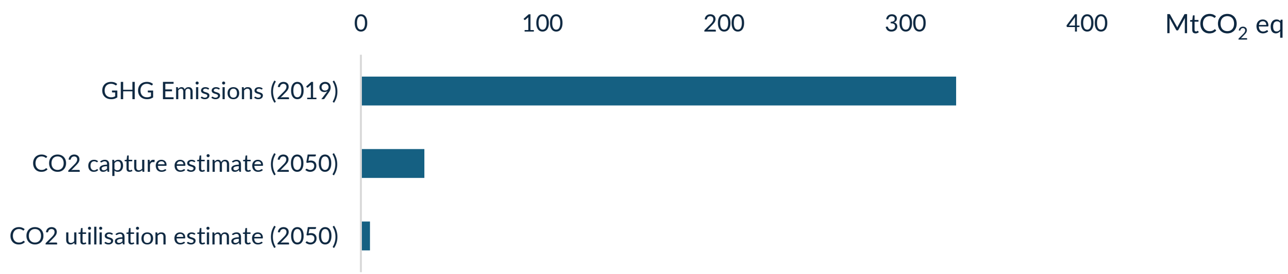


Figure 6. Overview of projected capture and utilisation of $CO_2$ compared to current sector emissions (Source: CEFIC)

At the **production** stage, the majority of emissions arise from fuel combustion for heat generation, particularly in processes such as steam cracking and steam reforming. For these emissions, electrification especially holds the potential to achieve deeper, future-proof decarbonisation. Carbon capture may make economic sense as a bridging solution in a limited number of cases, most notably where facilities which produce concentrated $CO_2$ streams are located close to emerging $CO_2$ transport and storage infrastructure. However, for diffuse and low-concentration flue gases, capture costs are high and alternatives are increasingly available. Any public support for carbon capture projects in the chemical sector should therefore be reserved for cases only where avoidance options are demonstrably unavailable.

[35] European Commission, 2024, Industrial Carbon Management Strategy

For **end-of-life** emissions reductions, a range of solutions must be adopted. However, as a priority **the Commission must enact policies which reduce the amount of waste being created** by incentivising reuse and repair, and design-for-recycling. Energy-intensive processes like pyrolysis, gasification and waste incineration should be treated as last resort options, and capturing $CO_2$ emitted from these processes is not straightforward. Circularity policies must be assessed through a life-cycle emissions lens and practices which increase energy demand or lock in fossil feedstock use, most notably thermal decomposition processes, risk undermining climate objectives rather than supporting them.

## Utilising $CO_2$ as a chemical feedstock

While some niche applications will exist for utilising captured carbon, **the role of CCU in the chemicals sector is structurally constrained by high energy requirements**. In the coming years focus should firmly be placed on avoidance rather than delaying of emissions from industry through CCU. The Commission should thus take a cautious approach to accounting for 'non-permanent' CCU in the ETS as this risks creating a potential loophole for avoiding accounting of industrial emissions. If guarantees of origin (GoOs) are allowed to pass carbon cost down the value chain, they should be downrated to correct for leakage of CCU products from the system and additional obligations on plastic producers should be considered.

## The bigger picture

First and foremost, a **robust industrial policy framework including a strong and predictable carbon price and timely phase out of free allocation is essential** for future-proof solutions with the greatest climate benefit to be implemented. A timely inclusion of chemicals in the CBAM, as we advocated for in our recent policy brief, is an essential part of the picture. This is necessary to avoid imports of emission-intensive products undermining Europe's transition to less emissions-intensive production and greater circularity.

2026 is set to see several important developments for the European chemical sector including the ETS revision and creation of a "Critical Chemicals Alliance", whose remit set to include assisting Member States and Regions in setting up EU Critical Chemicals Sites, to facilitate investments, innovation, improve access to funding and assist the modernisation of critical production capacities. **Technological solutions which avoid $CO_2$ emissions should be considered a first priority** for funding, with CCS/U only receiving support where it makes economic and environmental sense to do so (i.e. where alternative abatement options are limited or where local storage sites or offtakers could be utilised).

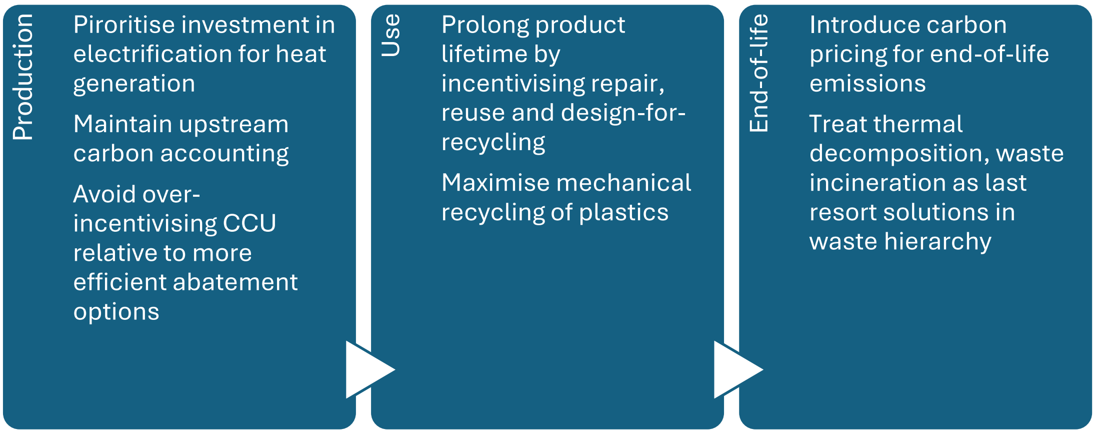


Figure 8. Overview of key principles for decarbonising chemicals sector in Europe

**The sector's move towards circularity should not entrench incumbent fossil-dependent production practices nor lead to skyrocketing energy demand for technologies which deliver minimal GHG savings**. A joined-up approach considering full lifecycle emissions is needed to create a truly 'circular' chemicals sector in Europe. Within this context, we expect carbon capture will likely be limited to a few applications, in particular waste treatment and some production facilities in the medium term.

# Appendix 1: CCU calculation

*Table 1. Overview of assumptions used in CCU example calculation*

| Process step | Energy used | Assumptions | Source |
|---|---|---|---|
| **$CO_2$ capture** | 1.1 MWh | 0.35 MWh/t $CO_2$<br><br>1.373 $tCO_2$, / t methanol<br><br>2.28 t methanol / t ethylene<br><br>1.373 x 0.35 x 2.28 = 1.1 MWh | Ingvarsdóttir[36]<br><br>Chiou et al[37]<br><br>Materials Economics[38] |
| **Methanol synthesis** | 25.1 MWh | ~11 MWh/t methanol × 2.28 t methanol<br>= 25.1 MWh<br>(includes hydrogen electrolysis) | Materials Economics |
| **MTO conversion** | 1.4 MWh | 1.4 MWh/t olefins | Materials Economics |
| **TOTAL** | **27.6 MWh/ t ethylene** | | |

[36] A. Ingvarsdóttir, 2020, Comparison of direct air capture technology to point source CO2 capture in Iceland
[37] H-H Chiou, et al, Evaluation of alternative processes of methanol production from CO2: Design, optimization, control, techno-economic, and environmental analysis, Fuel, 343, 2023, 127856
[38] Material Economics, 2024, *Industrial transformation 2050: Pathways to net-zero emissions from EU heavy industry*. Material Economics.

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