WHITE PAPER

Decarbonising chemicals: the emissions map and the levers available today

Where the sector's emissions come from, why they are hard to abate, and the strategies available to companies now.

Author: François Briens, PhD (The Climate Tech Observatory)
Reviewer: Julien Armijo, PhD (The Climate Tech Observatory)



Produced by Greenly • The climate intelligence platform for industry

ABOUT GREENLY

Greenly, the number one in carbon accounting for businesses

Greenly was founded with a simple mission: to make carbon accounting simple, precise, and intuitive for every company. Today, Greenly is a top-rated, industry-leading solution for carbon accounting and sustainability management, trusted by over 4,000 companies worldwide. Our platform is the highest-rated in its category, with a 4.8/5 satisfaction score on G2, Trustpilot, and Capterra.

We combine a powerful, AI-driven technology platform with the deep knowledge of over 60+ in-house climate experts to deliver an unparalleled service. Our comprehensive suite provides 360-degree coverage for every climate need, including GHG & Decarbonization Management, Life Cycle Assessment (LCA), and ESG Reporting.

At Greenly, we are not just building a compliance tool; we are building a new category of Carbon Intelligence to turn historical data into a management system for the future. We are dedicated to democratizing climate intelligence and making sustainability accessible, so every organization can take part in building the Net Zero economy.

Discover Greenly



Table of contents

Key take-aways 04

Intro 06

The chemicals industry's scope 07

Primary products 07

Key industrial processes 09

Where do chemical industry emissions come from? 11

Full global value chain emissions 12

Scope 1 & 2 emissions 16

A fossil fuel-intensive sector 16

Process and energy-related emissions 18

Why are chemical industry emissions hard to abate? 25

Decarbonisation strategies for the chemical sector 27

Policy landscape for chemical sector decarbonisation in the EU 28

Demand reduction and circular economy 31

Energy efficiency 32

Low-carbon energy procurement 33

Process heat electrification and thermal storage 35

Low-carbon electrolytic hydrogen 42

Alternative carbon feedstocks 43

Carbon capture and storage 45

Conclusion 46

Sources 47

KEY TAKE-AWAYS

Seven things to know

1 The chemical industry is a major building block of the modern economy, with more than 95% of manufactured products using chemicals globally - most of which deriving from a limited number of basic chemicals.

2 Considering the full value chain, the chemical sector accounts for about 5% (3.2 $GtCO_2e$) of global GHG emissions. About two-thirds of the sector's emissions are Scope 3 emissions that occur upstream – in particular along fossil fuel extraction and transport to supply energy and feedstocks for chemical processes – or downstream, during the use, degradation and end-of-life of chemical products (e.g. ammonia based-fertilizers and plastics). These scope 3 emissions involve multiple actors beyond the chemical industry which makes emissions challenging to trace accurately and address. Scope 1&2 emissions derive mostly from the combustion of fossil fuels to generate heat for chemical processes. Three-quarters of the sector's final energy demand is in the form of heat, more than half of it at high temperatures (>500°C), for which few alternatives to fossil fuels are commercially mature and cost-competitive. Process emissions, released by the chemical transformation of feedstock into final products, constitute another source of emissions, also hard to abate without costly process transformations.

3 The regulatory landscape governing the sector's decarbonization is evolving rapidly, particularly in the EU, where chemical companies face binding emissions-reduction targets, operate under market-based mechanisms such as the Emissions Trading System (ETS) and the Carbon Border Adjustment Mechanism (CBAM), and must comply with transparency requirements under the Corporate Sustainability Reporting Directive (CSRD). Assessing, reporting, and reducing full-value-chain GHG emissions is increasingly important for chemical companies, not only to avoid regulatory penalties, but also to mitigate commercial risk as investors, customers, and downstream brand owners apply growing scrutiny through audits and sustainability scorecards. In this context, proactively strengthening GHG disclosure practices is a strategic lever to demonstrate leadership, anticipate evolving regulatory expectations and maintain investors confidence.

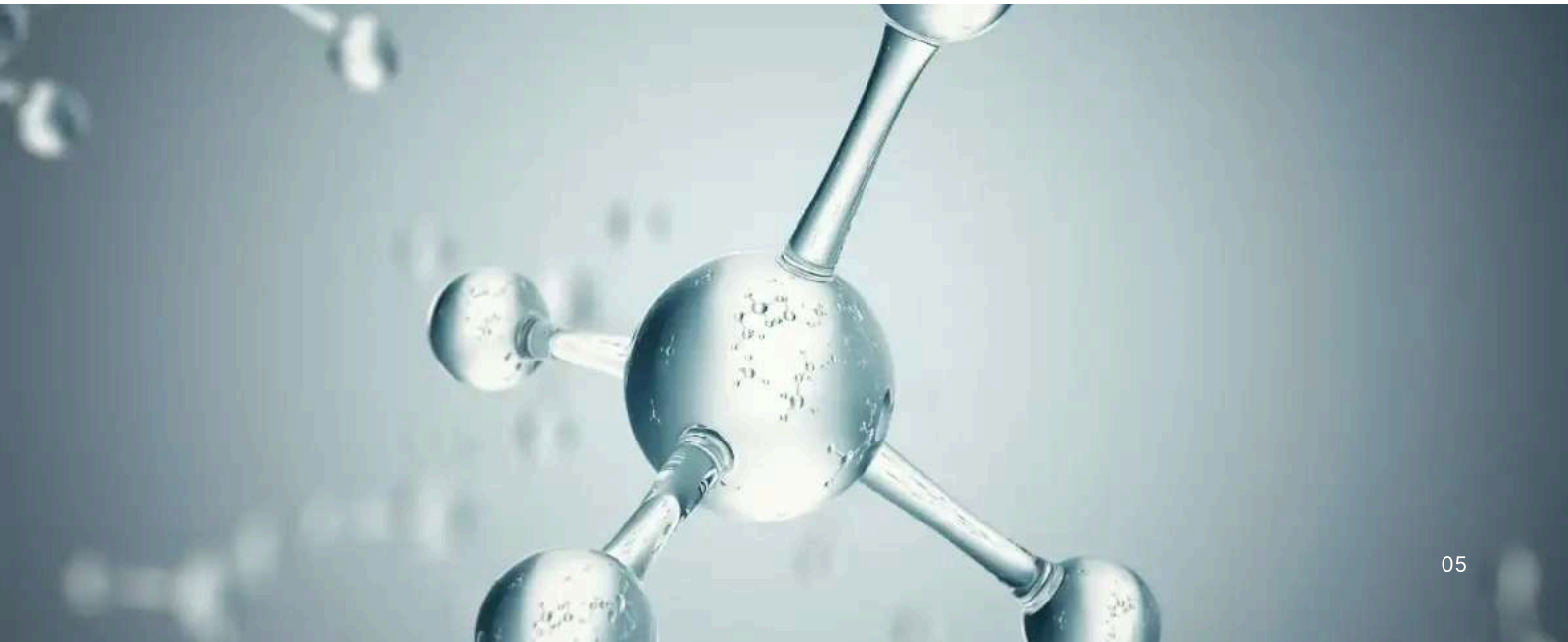
4 The complexity of the chemical sector and the diversity of processes and products imply that there is no silver bullet to reduce the chemical industry's GHG emissions. Levers can be articulated along 3 key complementary strategies: reducing chemical product demand; reducing fossil fuels use in processes by improving energy efficiency and substituting them with low-carbon energy; and enhancing carbon circularity along chemical value chains.

5 Reducing demand for chemical products is the most direct and cost-effective lever for cutting emissions, requiring neither large capital investment nor reliance on uncertain, costly technology development. Sufficiency-oriented strategies, material efficiency, and coordination among product designers, consumers, and other downstream stakeholders around circular economy initiatives: all depend on a supportive policy environment to scale.

KEY TAKE-AWAYS

6 To reduce fossil fuel consumption, chemical manufacturing companies can draw on commercially available technologies to improve energy efficiency – for instance by recovering waste heat – and to switch to renewable energy procurement, through direct investment or low-carbon heat and power purchase agreements. They can also electrify thermal processes – in particular low-temperature ones, where commercially available heat pumps can operate efficiently – and deploy thermal energy storage to hedge against increasing electricity price volatility and facilitate the integration of variable renewable energy.

7 Ambitious emission reductions will however require more structural changes for chemical value chains. These involve technology pathways that still have limited commercial maturity, such as switching to renewable-based hydrogen and alternative carbon feedstocks, including from carbon capture, and electrifying high temperature processes, for instance with electric steam crackers. Yet, technology deployment for these pathways is currently at an early stage and still needs to mature commercially and overcome economic challenges.



INTRODUCTION

Intro

The chemicals industry is a major building block of the modern economy and of global supply chain networks. It transforms raw materials into basic chemicals and thousands of derivatives that have become central to a variety of products and services across all sectors, from agriculture, food and healthcare to construction, manufacturing, and consumer goods. More than 95% of manufactured products use chemicals in one way or another (SBTi, 2025). However, this central role comes with a substantial environmental footprint, in particular from a climate perspective. The chemicals sector is among the largest industrial sources of greenhouse gas (GHG), accounting for almost 5% (3.2 $GtCO_2e$) of total GHG emissions globally (Gunawan et al., 2026). These emissions are generated throughout the value chain, including from fossil fuel combustion to provide heat or power, process emissions from chemical reactions, and the use of carbon-intensive feedstocks.

This white paper presents the chemical industry's contribution to global emissions, and explores the challenges and potential strategies and opportunities for companies to reduce the climate footprint of chemical products.

Share of total global GHG emissions from the chemicals sector — 3.2 $GtCO_2e$

~5%

Share of manufactured products using chemicals in one way or another

>95%

Chemical industry market size in 2024, roughly 4% of global GDP

€5 tn

Primary chemicals produced in 2022

720 Mt



THE CHEMICALS INDUSTRY'S SCOPE

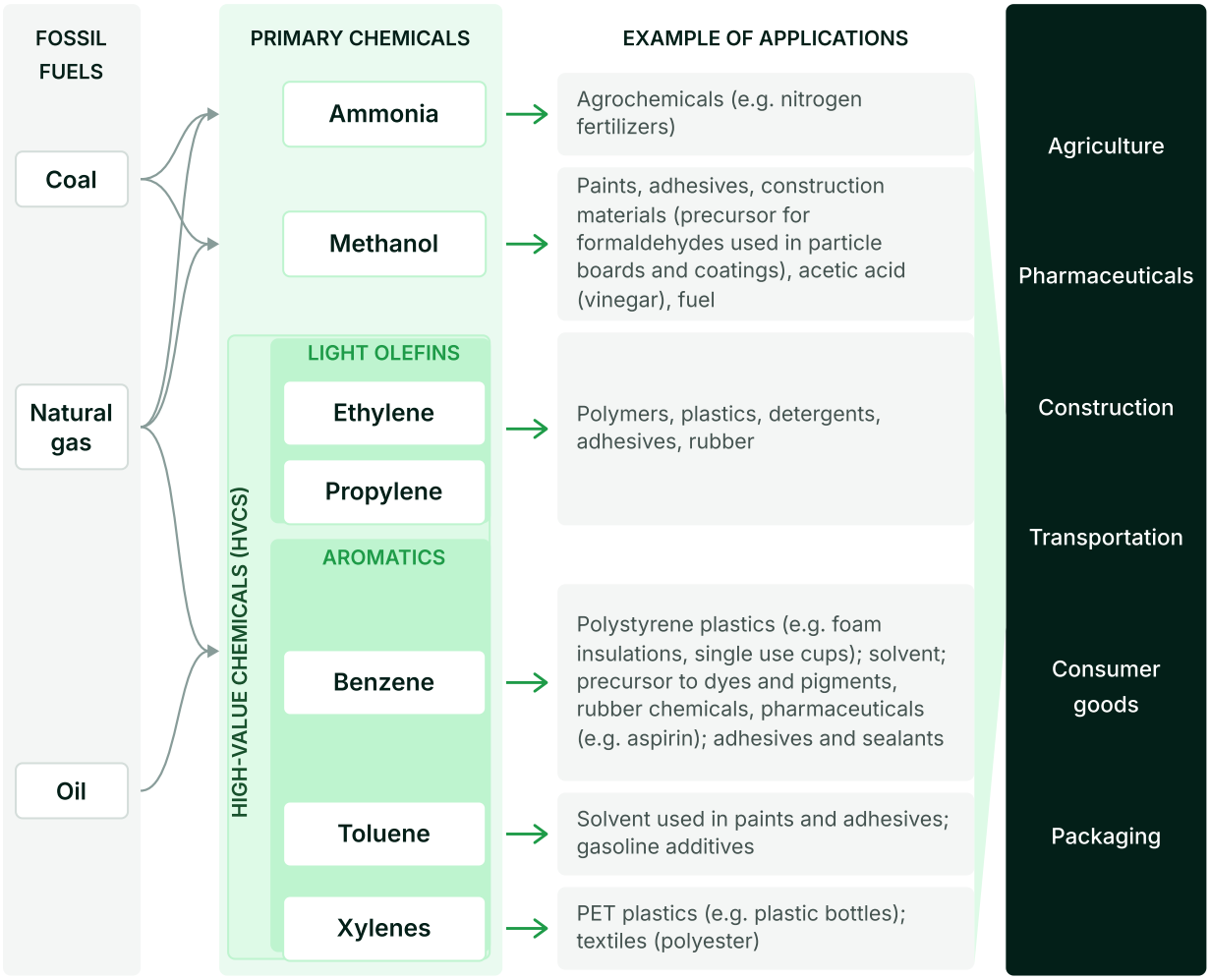
Primary products

In 2024, the chemicals industry represented an estimated € 5 trillion market – more than doubling from 2010 – representing roughly 4% of global GDP (Cefic, 2025). The sector's production covers thousands of different chemicals with applications across many other sectors, but most of them derive from a limited number of primary chemicals[1]: ammonia (NH_3), methanol (CH_3OH), olefins – in particular ethylene (C_2H_4) and propylene (C_3H_6) – and aromatics – in particular benzene (C_6H_6), toluene (C_7H_8) and xylenes (C_8H_{10}), generally referred to as BTX aromatics[2]. The production of these primary chemicals represented about 720 Mt in 2022, and approximately two-thirds of the chemical and petrochemical sector's[3] energy consumption (IEA, 2023a).

1. The term “primary chemicals” has no strict, universally agreed scientific definition. It generally refers to chemical products located upstream in value chains and used as intermediates in the production of other chemicals. These products are typically manufactured in large volumes through relatively standardized processes and supplied in competitive markets at comparatively low prices. For energy and emissions analysis, the IEA uses the term more specifically for large-volume, energy- and emissions-intensive chemicals, namely ammonia, methanol and high-value chemicals (ethylene, propylene, benzene, toluene and mixed xylenes). This scope excludes, for example, sulfuric acid (H_2SO_4), despite its being the world’s highest-volume manufactured chemical (>250 Mt/year), as its production is not particularly energy-intensive and generates relatively low direct GHG emissions. This report uses “primary chemicals” with the same scope.
2. Aromatics are cyclic organic compounds that are particularly stable due to the way their internal bonds are arranged.
3. “Chemical and petrochemical sector” is the terminology used in official statistics, reflecting the classification adopted by the IEA and aligned with the UN's International Standard Industrial Classification (ISIC). Within this sector, “petrochemicals” refer to organic industrial chemicals built from oil- and gas-derived hydrocarbon feedstocks, as distinct from inorganic chemicals.

FIGURE 1

Primary chemicals and their main current applications

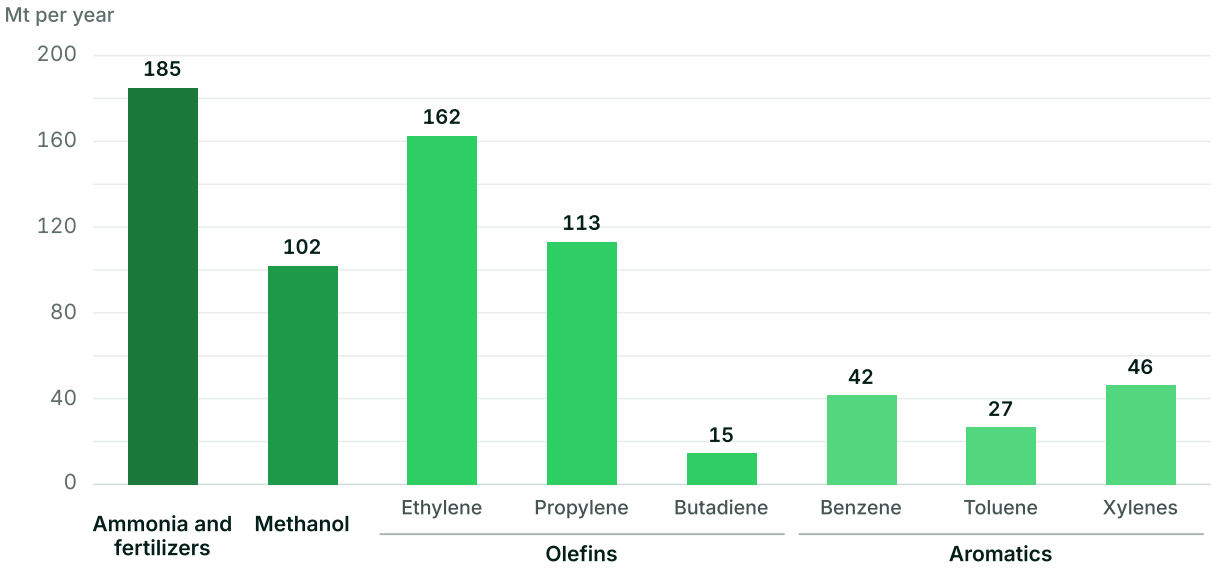


Source: figure based on (IEA, 2018; Meng et al., 2023).

Ammonia and fertilizers account for more than a quarter of primary chemicals demand on a volume basis, olefins for about 40%, and methanol and aromatics represent roughly 15% each (SYSTEMIQ, & Center for Global Commons, University of Tokyo, 2022).

FIGURE 2

Global demand in primary chemicals, 2020



Source: data from (SYSTEMIQ, & Center for Global Commons, University of Tokyo, 2022).

Demand for chemical products has increased sharply over the past fifty years, with demand for plastics in particular rising faster (x10 between 1970 and 2015) than for any other group of bulk materials (IEA, 2018).

THE CHEMICALS INDUSTRY'S SCOPE

Key industrial processes

Primary chemical molecules are mainly composed of carbon (except for ammonia) and hydrogen atoms. Today, these elements are largely sourced from fossil hydrocarbons – oil, natural gas, and coal – and assembled into different chemical molecules through a range of chemical processes.

Ammonia and methanol are mainly produced from natural gas through a process called steam methane reforming ($CH_4 + 2H_2O \rightarrow 4H_2 + CO_2$), which produces a gas rich in hydrogen and carbon monoxide, called synthesis gas (or syngas), used as the main building block for both chemicals. To make ammonia, this gas is combined with nitrogen from the air, purified from unwanted byproducts – with CO_2 captured along the way, and typically piped directly to a co-located urea plant –, and then converted into ammonia through the Haber-Bosch process ($N_2 + 3H_2 \rightarrow 2NH_3$)[4]. To make methanol, the gas mixture is instead adjusted to the right balance of hydrogen and carbon monoxide, then converted into methanol through a separate chemical process ($CO_2 + 3H_2 \rightarrow CH_3OH + H_2O$). Other feedstocks, such as coal, can also be used to produce the required hydrogen-rich gas through gasification ($3C + O_2 + 4H_2O \rightarrow 4H_2 + 3CO_2$) – a route used mainly in China, and significantly (~20-25%) more energy-intensive than natural gas-based production.

Other primary high-value chemicals, including ethylene, propylene and BTX aromatics, are produced through a mix of integrated chemical processes and refinery operations. Steam crackers, which break ("crack") hydrocarbon molecules into smaller molecules using high temperature (800–900°C) heat, are the main source for ethylene production and also co-produce propylene and BTX aromatics. BTX aromatics, however, are primarily sourced from refineries (fluid catalytic cracking or continuous catalytic reforming), which also supply large quantities of propylene obtained as a by-product of fuel production. Propylene can also be produced in dedicated processes such as propane dehydrogenation, while methanol-to-olefins technology provides an alternative production route in China, where low-cost coal makes methanol production more economical.

The chemical sector is therefore strongly integrated with the refining sector, especially for the production of olefins and aromatics.

Steam methane reforming

Generates a hydrogen-rich gas from natural gas, the main building block for both ammonia and methanol. Coal gasification is an alternative route, used mainly in China, and significantly more energy-intensive.

Haber–Bosch synthesis

Converts nitrogen - sourced from the atmosphere - and hydrogen into ammonia. About half of global ammonia production goes into urea fertilizers.

Steam cracking

Breaks hydrocarbon molecules into smaller ones using 800–900°C heat. The main source of ethylene, co-producing propylene and BTX aromatics.

Refinery operations

Fluid catalytic cracking and continuous catalytic reforming are the primary source of BTX aromatics, and supply propylene as a by-product of fuel production.

4. About 55% of the ammonia (NH_3) produced is immediately transformed into urea (H_2NCONH_2) using carbon captured along the production process. Of the roughly 250 $MtCO_2$ generated directly from the use of fossil fuels to produce NH_3, around 130 $MtCO_2$ are captured and used directly to produce urea. However, this CO_2 is only temporarily sequestered in the urea products before being rereleased downstream in the agricultural sector (IEA, 2021).

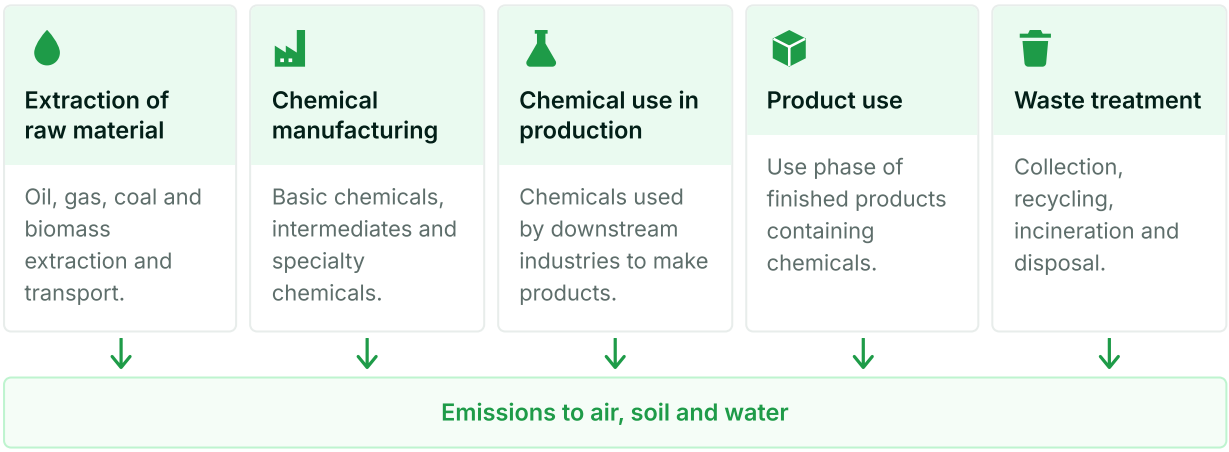
WHERE EMISSIONS COME FROM

Where do chemical industry emissions come from?

The chemical industry is one of the most greenhouse gas-intensive industrial sectors: emissions occur all along complex value chains, owing primarily to the sector's strong reliance on fossil hydrocarbons for both feedstock and process energy, and to the non-circularity of these value chains.

FIGURE 3

Emissions along the chemical value chain



Under the GHG Protocol, emissions are classified into three categories:

Scope 1	Direct emissions from sources owned or controlled by a company. For chemicals manufacturers, these include process emissions from chemical reactions, fugitive emissions, and those from fuel combustion used to generate heat and power and drive processes.
Scope 2	Indirect emissions associated with the purchase of electricity, steam and heat from a third party.
Scope 3	All other indirect emissions occurring across the value chain and not included in scope 1 or 2 — notably, for chemical manufacturing, those related to the upstream procurement of feedstocks, transportation, and the downstream use and end-of-life treatment of chemical products.

Data on chemical process and energy-related GHG emissions used to calculate the sector's scope 1 and 2 emissions are reported or estimated by international institutions, and partly available publicly – albeit with statistical frameworks, definitions and perimeters that differ from one source to another[5]. However, scope 3 emissions for the overall chemical sector are very challenging to estimate due to limited traceability for upstream (feedstocks) and downstream (end-of-life) emissions, and data is scarce.

SCOPE 1-3

Full global value chain emissions

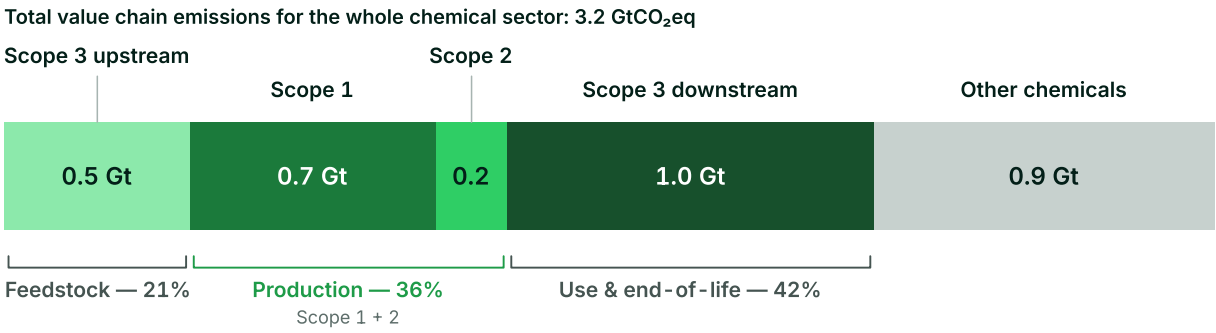
There are very few assessments of the full global value chain emissions (scope 1, 2 and 3) for chemicals, owing to the complexity and large uncertainties on scope 3 emissions. These scope 3 emissions include upstream emissions associated with feedstock supply, and downstream emissions from product use and end-of-life treatment and waste management (e.g. incineration of plastics, N_2O emitted from soils after fertilizer application, leakage of HFC refrigerants during equipment operation and disposal).

One of the most recent and comprehensive studies estimates scope 1, 2 & 3 emissions for the production of primary chemicals at 2.3 $GtCO_2eq$ for the year 2020[6], representing 72% of all chemical system emissions (3.2 $GtCO_2eq$) (Meng et al., 2023; SYSTEMIQ, & Center for Global Commons, University of Tokyo, 2022), and almost 5% of total global GHG emissions excluding land-use (Crippa et al., 2025). For primary chemicals, scope 3 represents almost two-thirds of emissions (1.5 $GtCO_2eq$), due to the chemical system's dependence on fossil inputs and the lack of circularity in value chains. About 85% of the sector's energy product demand, and more than 98% of carbon feedstock in the industry comes from fossil sources (SYSTEMIQ, & Center for Global Commons, University of Tokyo, 2022), leading to high upstream emissions from oil and gas extraction and transport (0.5 $GtCO_2eq$)[7]. Downstream, the degradation of fertilizers (e.g. urea) and the end-of-life treatment of carbon-dense products such as plastics release even larger downstream emissions (1.0 $GtCO_2eq$).

5. For instance, the Emission Database for Global Atmospheric Research (EDGAR) developed by the European Joint Research Center provides independent emission estimates using international statistics of activity data, technologies and emission factors. It uses the IPCC methodology, with process-/technology-based categories, of which "2.B-Chemical industry" covers process emissions for different GHG gases and chemical processes, while fuel combustion emissions are allocated to another manufacturing industry-wide sector category (1.A.2). In comparison, Air Emissions Accounts from Eurostat and the OECD use the NACE (Rev.2) economic activity classification, with chemicals manufacturing emissions covered under "C20 — Manufacture of chemicals and chemical products" (and C21 if pharmaceutical products are included), and including process emissions, emissions from fuel combustion and other direct emissions. The IEA's estimates cover essentially CO_2 from both process emissions and chemical production energy, with a focus on primary chemicals and petrochemicals. Due to different accounting perimeters, definitions and methodologies, it is not possible to directly map data from one source to another.
6. The authors underscore that potential underestimation of upstream fugitive methane emissions and uncertainty over downstream waste management mean that total system emissions could be almost 50% higher than their estimate.
7. For instance, the IEA estimates global fugitive emissions from all coal, oil and gas operations at around 8% of total energy-related GHG emissions for 2023 (IEA, 2025a).

FIGURE 4

Scope 1, 2 and 3 global GHG emissions for the production of primary chemicals, 2020

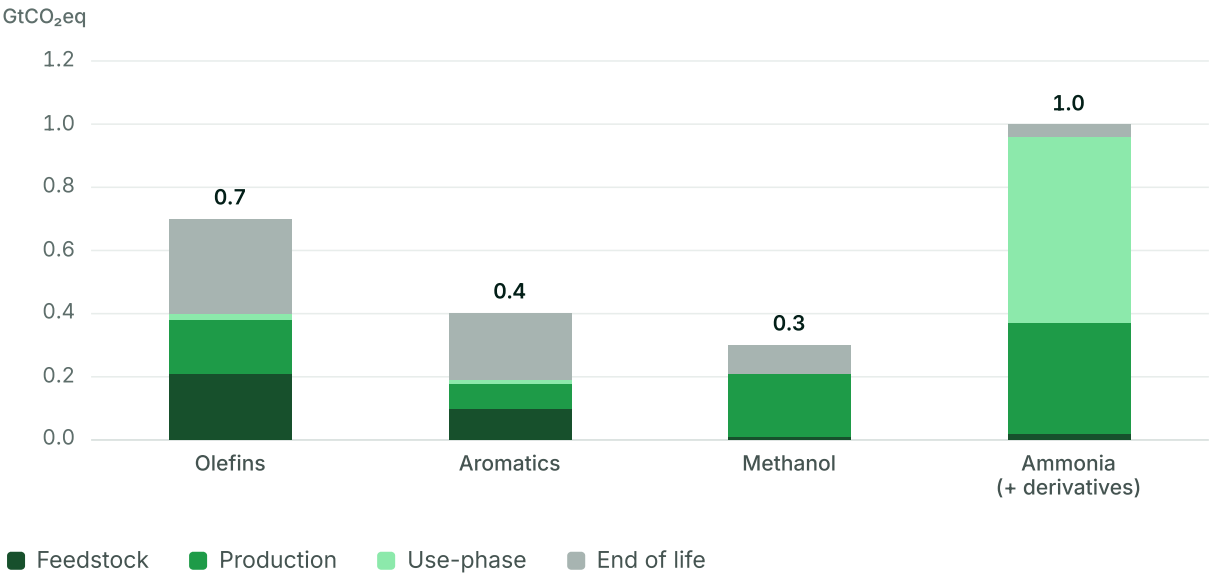


Note: For 2020, total value chain emissions for the chemical sector represented an estimated 3.2 $GtCO_2eq$, of which 2.3 $GtCO_2eq$ were from primary chemicals and about 0.9 $GtCO_2$ from other chemicals. Source: data from (SYSTEMIQ, & Center for Global Commons, University of Tokyo, 2022).

Yet, the life-cycle emission profile differs across product categories. For instance, most emissions associated with methanol occur during the production phase, while the release of N_2O – and CO_2 from urea decomposition – associated with the use phase of fertilizers dominates ammonia emissions, and end-of-life management is the largest source for olefins and aromatics.

FIGURE 5

Annual GHG emissions at different life-cycle stages for selected categories of chemicals, 2020



Source: (Meng et al., 2023).

Olefins

End-of-life management is the largest single source — plastics carry a high embedded carbon content.

Aromatics

Feedstock supply and end-of-life dominate; production is comparatively small.

Methanol

Most emissions occur during the production phase itself.

Ammonia (+ derivatives)

The use phase dominates: N_2O and CO_2 released from urea decomposition after fertilizer application.

Company-level emissions breakdown

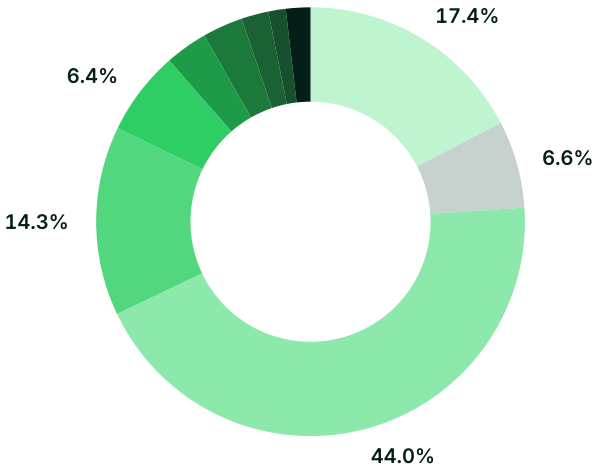
At the company level, emissions accounting works differently from sector-wide accounting. Alongside their own direct emissions, companies also report emissions linked to their suppliers and customers, to capture their impact across the value chain. This means the same tonne of CO_2 can appear in several companies' reports at once – for instance, once as a supplier's direct emissions (in its Scope 1 or 2), and again as a customer's indirect emissions (in its Scope 3) – which is why company-level figures generally shouldn't be added together (risk of double-counting). As many companies purchase intermediate chemical products from others, this often leads to Scope 3 emissions representing a high share of their reported emissions.

At the company level, many chemical companies report that Scope 3 emissions are several times larger than their combined Scope 1 and Scope 2 emissions. In a survey from CDP (2025), scope 3 emissions represent on average about three-quarters of a chemical industry company's[8] footprint, with the categories "purchased goods and services", "use of sold products" and "end-of-life treatment of sold products" representing together about two-thirds of the total scope 1-3 emissions.

8. In this survey, “chemical industry companies” covers producers of agricultural chemicals, basic plastics, biofuels, base chemicals, specialty chemicals, fertilizers, personal care and household products. A more detailed description of this category can be found in the CDP Activity Classification System.

FIGURE 6

Breakdown of GHG emissions by scope and category for chemical industry companies surveyed in 2021



- Scope 1 — 17.4%
- Scope 2 — 6.6%
- Purchased goods and services — 44.0%
- Use of sold products — 14.3%
- End of life treatment of sold products — 6.4%
- Upstream transportation and distribution — 3.2%
- Processing of sold products — 3.0%
- Fuel- and energy-related activities not in scope 1-2 — 2.1%
- Investments — 1.3%
- Other upstream and downstream categories — 1.9%

Source: (CDP, 2025) — 146 chemical companies responded to the survey.

of a chemical company's footprint sits in scope 3 on average, across the 146 companies surveyed by CDP — the categories purchased goods and services, use of sold products and end-of-life treatment alone make up about two-thirds of the total.

~75%

SCOPE 1 & 2

Scope 1 & 2 emissions

A fossil fuel-intensive sector

The chemical sector is very energy intensive: on average, manufacturing one tonne of primary chemicals requires 70 GJ of energy products[9] – a number that has remained stable over the past 10 years. Energy product demand for chemical production doubled globally since 1990, along with production expansion, to exceed 50 EJ in 2024 – equivalent to almost 30% of industrial final energy consumption and 8% of global final energy consumption (IEA, 2018, 2023c, 2026b). The chemical sector accounts for about 14% and 9% of total primary demand for oil and gas respectively, and the share of hydrocarbons in the overall sector's energy product consumption is very high, at 85% (IEA, 2020).

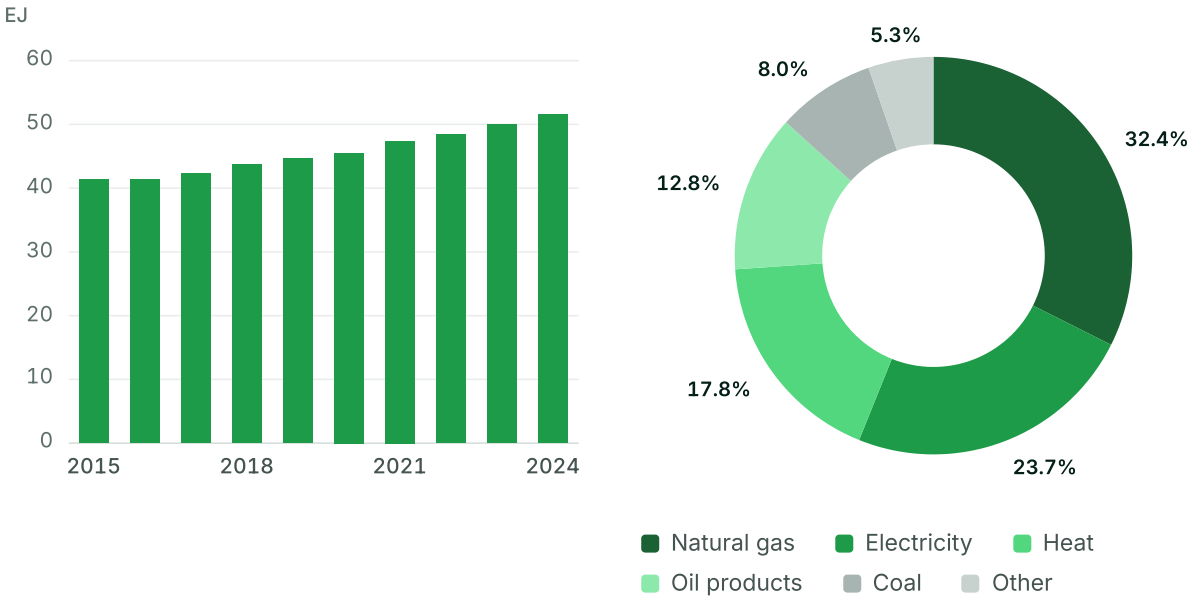
Just over half of the sector's energy product demand is in fact used as feedstock, that is as raw materials incorporated into or transformed into chemical products rather than being burned for energy to drive processes (IEA, 2018). Currently, this feedstock input is essentially (>98%) in the form of fossil fuels: oil is the dominant feedstock for high-value chemicals, whereas natural gas and coal are used for ammonia and methanol. This large use of fossil inputs as feedstock explains why the chemical sector ranks third in terms of direct industrial CO_2 emissions globally (16% of the total)[10], behind the iron and steel and cement sectors, despite consuming more energy products than each of these industries.

9. In comparison, the average energy intensity of steelmaking was 21GJ/ton globally in 2024 (worldsteel, 2025), that of cement is around 4 GJ/ton (Mokhtar & Nasooti, 2020), and that of primary aluminium production was 186 GJ/ton in 2019.
10. The chemical sector's share in industrial CO_2 emissions is generally higher in developed countries than in emerging economies, where iron and steel and cement often dominate emissions.

Excluding the fraction used as feedstock, more than half of the sector's energy consumption consists in the combustion of fossil fuels to drive large thermal processes like steam cracking, refining operations, and conventional ammonia and methanol synthesis routes (IEA, 2023c). Natural gas supplied 32% of the chemical sector's non-feedstock energy use in 2021. Electricity is the second largest energy source (24%), used in particular for the chloralkali process (electrolysis of sodium chloride to produce chlorine and caustic soda), as well as for electric motors and mechanical drives (e.g. pumps, compressors, fans), and refrigeration. The remainder was supplied by oil (13%), coal (8% – its use is particularly prevalent in China), and commercial heat[11] (18%) – the majority of which is generated from fossil fuels globally. Direct use of renewables – mostly bioenergy – accounted for only 0.2% of the sector's global final process energy consumption.

FIGURE 7

Global energy demand for the production of chemicals, including feedstock, 2015–2024 (left); and share of energy sources in final energy consumption for chemicals and petrochemicals, excluding feedstock, world, 2021 (right)



Source: data from (IEA, 2023c, 2026b).

The heavy reliance of the chemical sector on fossil fuel combustion to generate heat and power and drive processes results in large Scope 1 & 2 emissions.

11. Commercial heat is the term used in energy balances for heat that a plant sells to a separate buyer – most often a district heating network or an industrial site – as distinct from heat that a facility generates and consumes itself.

SCOPE 1 & 2

Process and energy-related emissions

The IEA estimates that chemical manufacturing CO_2 emissions – combining both process and energy-related emissions, and belonging to scope 1 & 2 – totalled 1.4 $GtCO_2$ in 2024 (IEA, 2025d). The bulk (60%) of these emissions comes from primary chemicals production, in particular ammonia and methanol which represented respectively 45% and 28% of primary chemicals manufacturing emissions in 2022 (IEA, 2023b). Chemical industry's manufacturing emissions increased 10% during 2015–24, mostly due to expanding methanol production, while average CO_2 intensity of production has remained stable around 1.3 tCO_2 per tonne of primary chemicals (IEA, 2023b).

> **Considering Scope 1 & 2, the chemical sector is the third largest industrial CO_2 emitter globally, after the iron and steel and the cement industries.**
>
> IEA, 2023b

According to IEA (2017), 85% (1.2 $GtCO_2$) of chemical manufacturing emissions are energy-related, i.e. released when fuel is combusted to generate heat, used directly or for the production of steam on-site, while the rest (0.2 $GtCO_2$) is from process emissions, calculated as the difference in carbon content between the feedstock and the product. The majority of these process CO_2 emissions is generated as a by-product of hydrogen production through steam methane reforming ($CH_4 + 2H_2O \rightarrow 4H_2 + CO_2$) or coal gasification ($3C + O_2 + 4H_2O \rightarrow 4H_2 + 3CO_2$).

of chemical manufacturing CO_2 emissions are energy-related — 1.2 $GtCO_2$ released when fuel is combusted for heat and steam

85%

tCO_2 per tonne of primary chemicals — the average CO_2 intensity of production, stable over the past decade

1.3

Non-CO_2 process emissions

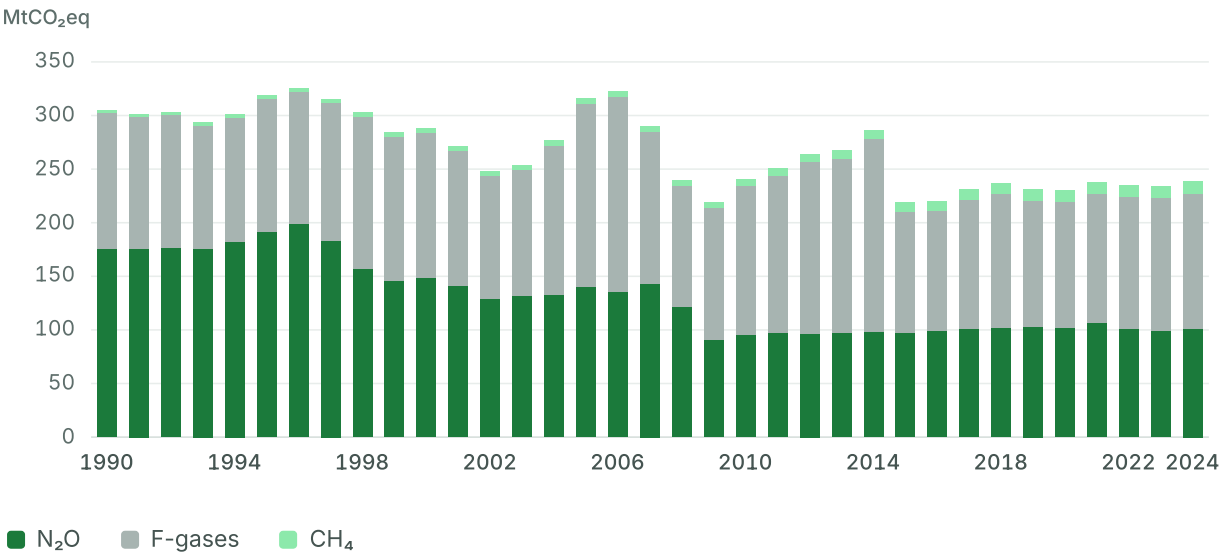
According to the EDGAR database[12], most non-CO_2 process emissions are in the form of fluorinated gases (F-gases – mostly HFCs) – used as refrigerants, aerosols and foams – and nitrous oxide (N_2O) – essentially from the production of adipic acid ($C_6H_{10}O_4$), used as precursor for polymers such as nylon and for food additives among others, and nitric acid (HNO_3), used for fertilizers.

N_2O emissions from the chemical sector have declined by 70% since 1990, essentially thanks to the progressive adoption of catalysts in the production processes of adipic acid from the 1980s, and nitric acid from the 2000s[13]. N_2O abatement from adipic and nitric acid production is one of the most notable and well-documented successes in industrial greenhouse gas mitigation. This was made possible by a combination of mature and effective technology, low abatement costs, early voluntary action from main manufacturers, followed by strong economic incentives under the Kyoto protocol's Clean Development Mechanism (CDM), and subsequent environmental regulation, particularly in Europe[14].

In CO_2-equivalent, direct F-gases emissions have stabilized in recent years at a level similar to that of 1990, with stricter regulations and efforts to phase down HFCs under the Kigali Amendment to the Montreal Protocol[15].

FIGURE 8

Non-CO_2 GHG process emissions from the chemical industry by gas, world, 1990–2024



Note: GHG emissions are expressed in CO_2eq using the 100-year Global Warming Potential values of the Fifth Assessment Report of the IPCC (Myhre et al., 2013): 28 for methane, 265 for N_2O, and specific values for each individual F-gas molecule (e.g., SF_6 = 23,500; HFC-134a = 1,300). Source: GHG data from Emissions Database for Global Atmospheric Research (EDGAR).

NOTES

12. This corresponds to IPCC (2006) category 2B, which covers industrial processes in which greenhouse gases are released as a result of chemical reactions, rather than primarily from fuel combustion. There is a large discrepancy with the IEA estimate for CO_2 process emissions (about 0.6 $GtCO_2$ more in EDGAR than in IEA estimates) that could possibly and partly be related to a gross/net difference in accounting for process CO_2 emissions that are sequestrated and used at a later stage within methanol and urea production processes. However, we were unable to obtain confirmation of this explanation at the time of writing.
13. Catalytic decomposition technologies destroy N_2O by converting it into nitrogen and oxygen, typically achieving 90–99% removal effectiveness with relatively modest capital costs, relative to their abatement potential in carbon-equivalent – N_2O being 273 times more potent than CO_2 for global warming on a 100-year time horizon.
14. Adoption of catalytic decomposition technologies for N_2O in nitric acid occurred later than for adipic acid, due to a higher number of plants and greater diversity of plant designs, and the need for significant modifications to incorporate the technology. Carbon credit incentives and regulations played a key role in driving adoption.
15. The Montreal Protocol on Substances that Deplete the Ozone Layer aimed at regulating the production and consumption of 100 synthetic chemicals identified as ozone-depleting substances. The treaty has evolved over time to adjust to scientific, technical and economic developments. The Kigali amendment, enforced in 2019, commits signatories to a gradual phase-down of HFCs emissions by 80–85 per cent by the late 2040s, starting with developed countries.



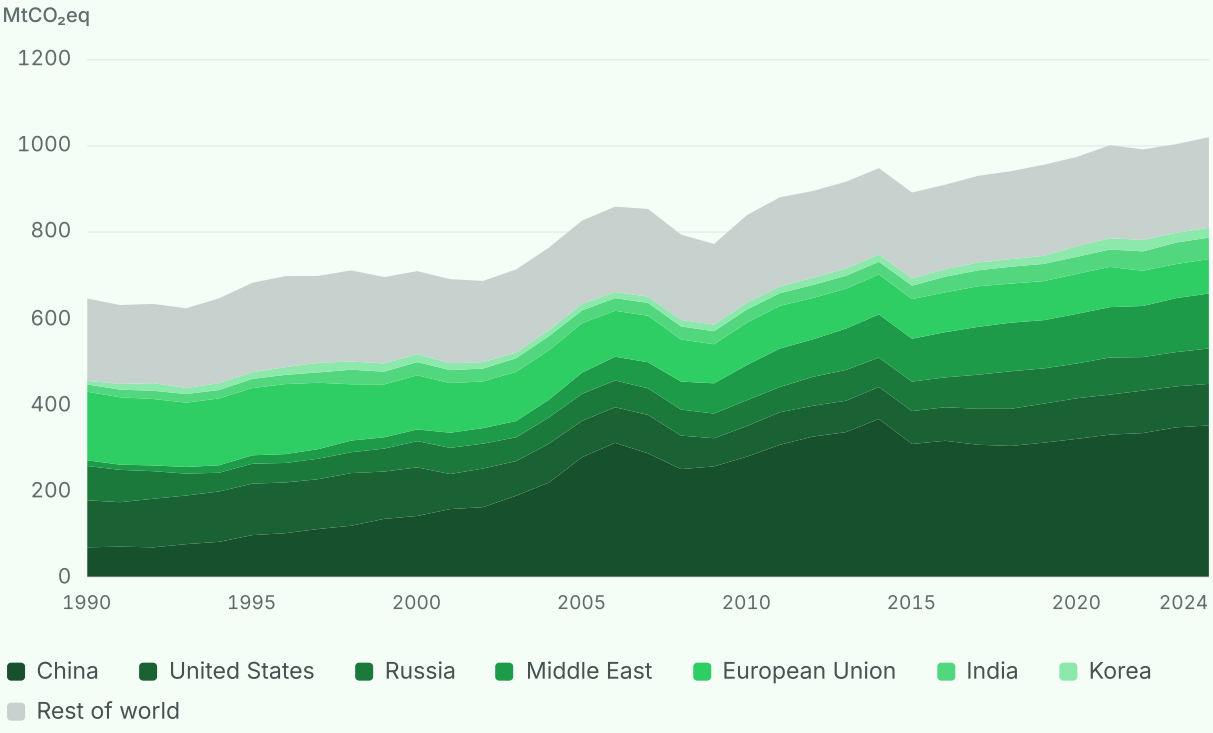
REGIONAL CONTEXTS

Regional contexts and production-phase emissions

Limited regional level data exist on the chemical sector's scope 2 and 3 emissions. Considering process emissions only – that is, excluding energy-related emissions – China, the world's largest producer and consumer of chemical products with about 1.3 Gt (40%) of global chemical output by weight (Chen et al., 2026), is the largest process emissions contributor globally, accounting for one-third of the global total, followed by the United States and Russia. The European Union is responsible for 8% of the industry's process emissions, with Germany, the Netherlands, Belgium and France together accounting for more than half of it (Crippa et al., 2025).

FIGURE 9

Chemical process GHG emissions, world, 1990–2024



Note: Middle East includes Saudi Arabia, Iran, Qatar, Oman, United Arab Emirates, Kuwait and Bahrain. In 2023, Saudi Arabia accounted for half of the region's sectoral emissions and Iran for one-fifth. Emissions correspond to IPCC 2006 Category 2.B, cover essentially process emissions, and exclude emissions from fuel combustion.
Source: GHG data from Emissions Database for Global Atmospheric Research (EDGAR) (Crippa et al., 2025).

REGIONAL CONTEXTS

China, the United States and the European Union

China — 1.3 billion tonnes produced in 2024

China's chemical industry is distinguished by its large scale, high degree of integration, and a particularly high reliance on coal as both an energy source and chemical feedstock. This coal-based production structure makes the Chinese chemical industry substantially more carbon-intensive than its counterparts in Europe or North America, where natural gas dominates. In China, the chemical industry accounts for about 13% of national CO_2 emissions and around 20% of national industrial emissions (Li et al., 2022). A recent study estimates Scope 1 & 2 emissions for the Chinese petrochemical sector at around 800 $MtCO_2$ (+/-25%) for 2021 (Chen et al., 2026). The industry's emissions have increased rapidly over the past three decades alongside China's industrial expansion. In recent years, the Chinese chemical industry continued to expand and modernize, focusing on integrated petrochemical complexes, electrification, low-carbon hydrogen, carbon capture and utilization, and recycling of plastics and chemical feedstocks. However, continued growth in coal-to-chemicals has partly offset these improvements.

United States — 250 Mt of chemicals produced in 2024

The United States' chemical sector is dominated by large-scale petrochemicals and bulk chemicals, with major production clusters located along the Gulf Coast. In 2023, reported scope 1 emissions from the chemical sector totalled 185 $MtCO_2eq$, of which 36% were from petrochemical production, 24% from hydrogen production and 19% from ammonia manufacturing (EPA, 2025). This corresponds to 2.9% of total U.S. GHG inventory, and reflects an 11% growth from 2011, driven by new ammonia and petrochemical production capacities and expanding hydrogen production, for fuel refining in particular. More than 90% of scope 1 emissions originated from Texas and Louisiana. The U.S. chemical sector saw important changes in the last decades. The shale gas boom in the 2010s provided abundant low-cost natural gas, enabling a rapid expansion of ethylene and derivatives production, offsetting the impact of fuel switching from more carbon-intensive fossil fuels and that of gradual efficiency gains.



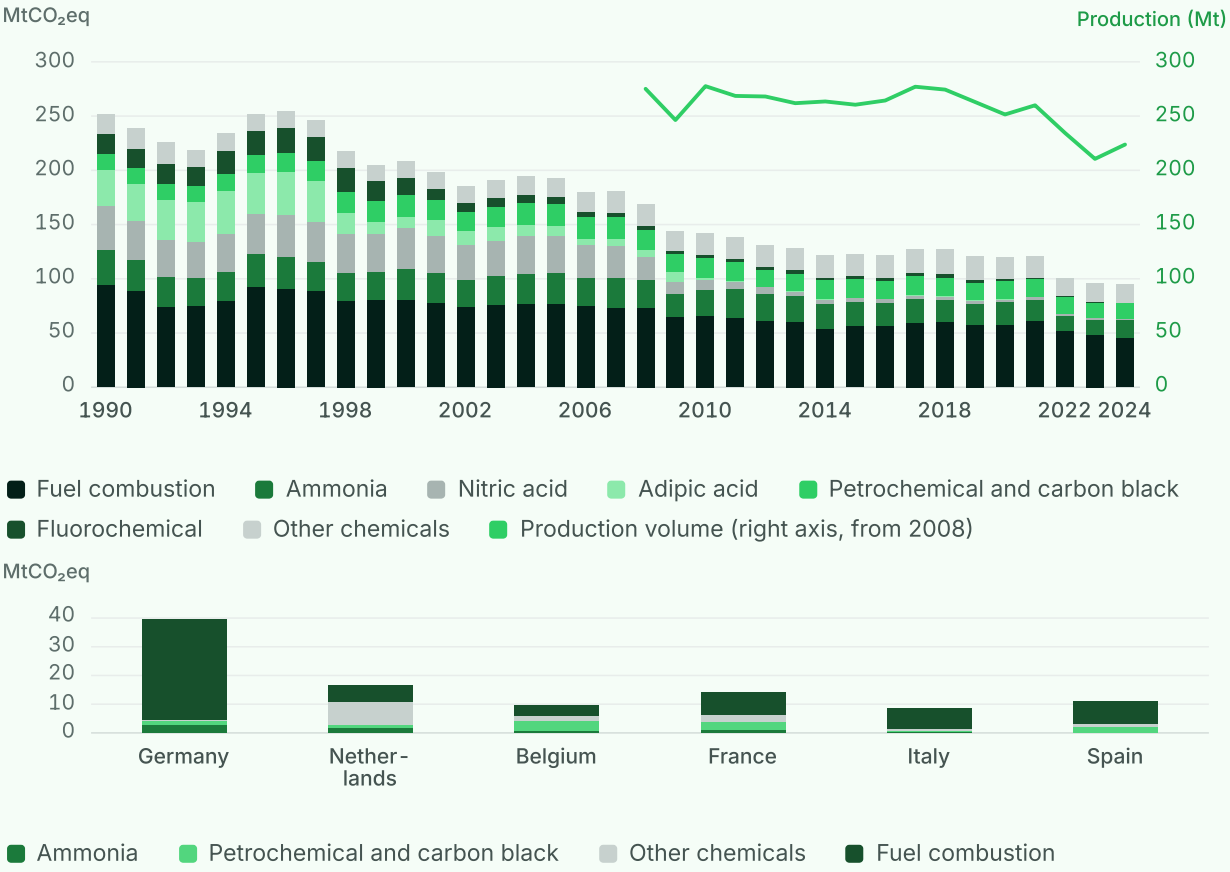
REGIONAL CONTEXTS

European Union — 224 Mt of chemicals produced in 2024

Scope 1 emissions from the chemical sector totalled 96 $MtCO_2eq$ in 2024, equivalent to 3.2% of the region's GHG emissions excluding land use, after declining by 62% since 1990. Almost half of this decline comes from the progressive implementation of catalysts to decompose N_2O process emissions from nitric and adipic acid production until 2010. A combination of improved leak prevention, recovery and destruction of fluorinated gases, and substitution with lower-global-warming-potential alternatives in the fluorochemical subsector also played a key role during this period, together with energy efficiency improvements to reduce fuel combustion emissions. However, in recent years, emission reductions also resulted from lower production volumes: the EU produced 224 Mt of chemicals in 2024, 19% less than in 2017, with a marked decline in 2022 and 2023 due to high energy costs and weaker demand.

FIGURE 10

Chemical industry direct GHG emissions and production volume, EU27, 1990–2024 (top), and Scope 1 energy-related and process emissions for selected EU countries, 2023 (bottom)



Note: emissions are direct emissions occurring at chemical-producing units, including their own fuel combustion. Emissions related to the consumption of purchased electricity and heat (Scope 2) are not included, as the database methodology allocates them to another energy branch. Fuel combustion emissions for Germany were not available in (Eurostat, 2025), and are estimated based on (Erlach et al., 2024) and (KEI, 2025). Source: data from (European Environment Agency (EEA), 2026; Eurostat, 2025).



A FOSSIL-CARBON INDUSTRY

More than 98% of the carbon feedstock used by the chemical industry comes from fossil sources. The sector absorbs around 14% of global oil and 9% of global gas primary demand.

THE ABATEMENT CHALLENGE

Why are chemical industry emissions hard to abate?

The chemical sector is largely regarded as one of the hardest-to-abate sectors, for various reasons.

Most emissions occur upstream and downstream with responsibilities shared across many actors

About two-thirds of the sector's emissions are Scope 3 emissions that occur upstream – in particular along fossil fuel extraction and transport to supply energy and feedstocks for chemical processes – or downstream, during the use, degradation and end-of-life of chemical products, reflecting the linearity of most chemical value chains. For instance, for fertilizers, CO_2 is emitted when urea decomposes (hydrolysis), and more than half of the nitrogen is not taken up by crops, runs off into the environment and generates N_2O emissions[16]. Less than 15% of plastic ever created has been recycled, with about one-third of plastic waste ending incinerated or burnt, releasing their high embedded carbon content (~80%) in the atmosphere, while mismanagement of the rest has a range of other adverse environmental impacts (SYSTEMIQ, & Center for Global Commons, 2022).

These scope 3 emissions fall outside of companies' control, spread across many actors, are difficult to trace accurately, and while GHG disclosure is growing in the industry, they remain under-reported compared to Scopes 1 and 2. Abating these emissions requires coordinating a wide range of actors within and beyond the chemical industry, in order to enhance value chain circularity.

> HOW GREENLY HELPS
>
> Greenly addresses this scope 3 traceability gap directly through automated supplier engagement — configurable per material category, with scoring, evidence capture and audit trails — moving Scope 3.1 data from spend-based estimates (80-90% uncertainty) toward primary supplier data (~25% uncertainty).

16. In the days following application, urea is broken down by hydrolysis into CO_2 and ammonium (NH_4^+). Only a fraction of this nitrogen (typically 40-50%) is taken up by crops; the rest is lost to the environment – either volatilizing as ammonia gas (NH_3), or being converted by soil bacteria into nitrate (NO_3^-). This nitrate can denitrify directly if the soil becomes saturated, releasing N_2O on-site; or, with rainfall or irrigation, it can leach down through the soil profile faster than roots can intercept it, with a smaller fraction later denitrifying in groundwater or rivers downstream. The rest of leached nitrate contributes to water pollution (eutrophication).

Almost half of final energy consumption is for high temperature process heat with few alternatives to fossil fuels

Moreover, decarbonizing energy inputs also faces technical challenges: around three-quarters of the chemical sector's final energy consumption is used for process heat, more than half – 60% in the EU – of which at high-temperature (>500°C) (Naegler et al., 2015). For instance, a steam cracker, used to produce ethylene, propylene and BTX aromatics, operates above 800°C. Many renewables-based alternatives are not compatible with such high operating temperatures. For instance, concentrated solar thermal collectors typically generate heat up to 350-400°C, geothermal heat is rarely available at more than 350°C, and industrial heat pumps (which harness ambient heat and can run on renewable-based electricity) operate efficiently only up to 160-180°C, unless they can harness waste heat sources. And while sustainable biomass can meet thermal requirements, its availability limits its application in the sector.

Fossil fuels are also used as material inputs

Fossil fuels are not only used to supply process heat, but also to provide the carbon and hydrogen atoms required to build most primary chemicals. Substituting these fossil inputs requires developing alternative renewable sources for the carbon and hydrogen required for feedstock. Technologies that offer such alternatives are still at a pre-commercial (e.g. carbon capture) or early deployment stage (e.g. electrolytic hydrogen) in the chemical sector, and scaling them rapidly represents an enormous challenge.

Main process emissions are difficult to abate without shifting to alternative production routes

In addition, a significant part of scope 1&2 GHG emissions originates from chemical reactions. For CO_2 emissions, for instance, these process emissions reflect the difference in carbon content between the chemical product and the feedstock, and represent about 15% of the chemical sector's direct CO_2 emissions according to (IEA, 2017). For example, when producing ammonia, CO_2 is produced as a by-product after steam reforming of natural gas or coal gasification, and only a fraction of this carbon is reused and temporarily sequestered in subsequent products (for instance, about a third of CO_2 process emissions for ammonia is reused directly to produce urea (Zakkour & Cook, 2010) - but will still be released when urea fertilizers decompose), while the rest is generally vented. These emissions are thus inherent to existing processes, and avoiding them requires substantial process modifications – i.e. alternative production routes or the integration of emissions capture and storage.

Production infrastructure is costly and assets have a long lifetime

Large chemical production units like steam crackers are very expensive – a single unit can cost up to USD 4 billion – and have a typical economic lifetime of around 30 years. Decommissioning or replacing such units before the end of their economic lifetime is possible, but can entail large cost penalties for companies, and an additional risk when replacement technologies are not mature.

Overall, there is no silver bullet: abating the chemical value chain emissions requires implementing a complex range of technologies in a diversity of subsectors, applications and processes. In a sector exposed to international markets and high cost-competitiveness pressures, where long asset lifetimes entail slow infrastructure turnover, long-term investment planning and coordination along the value chain will be essential for this transition.

DECARBONISATION STRATEGIES

Decarbonisation strategies for the chemical sector

Deep reduction of the chemical sector's emissions is challenging, but different complementary strategies can be planned and implemented to mitigate scope 1, 2 and 3 GHG emissions. These consist in reducing demand, shifting from fossil fuel inputs to renewable or low-carbon inputs for both feedstock and process energy, and enhancing circularity along the value chains. They include in particular the actions listed below, discussed in the rest of this section.

Strategy	Readiness and deployment[17]	Scopes and main actors
Demand reduction through sufficiency and circular economy approaches: reduction, substitution, reuse and recycling	Currently available; further innovation needed to scale substitution and recycling	Scope 1, 2, 3 up- and downstream. Product designers, consumers, waste management stakeholders
Energy efficiency and waste heat recovery for thermal processes	Currently available; further potential remains for process integration	Scope 1, 2, 3 upstream. Chemical manufacturers
Renewable and low-carbon energy procurement	Currently available	Scope 1, 2. Chemical manufacturers
Process heat electrification and thermal storage	Commercial for low-temperature heat electrification (e.g. e-boilers and heat pumps); demonstration for high-temperature heat (e.g. e-crackers) and integration with thermal storage	Scope 1, 2. Chemical manufacturers
Low-carbon electrolytic hydrogen	Commercial stage; early deployment at scale in chemicals	Scope 1, (2), 3 upstream. Chemical manufacturers
Alternative carbon feedstocks (biomass, recycled and captured carbon (CCU))	Mixed maturity: established for conventional biomass and mechanical recycling, and for CCU in ammonia and methanol production; demonstration or early commercial for advanced biomass conversion, chemical recycling and CCU in other subsectors	Scope (1, 2), 3 up- and downstream. Chemical manufacturers, waste management stakeholders
Carbon capture and storage (CCS)	Commercial stage for concentrated sources of CO_2; less mature for diluted sources	Scope 1, 3. Chemical manufacturers, upstream and downstream stakeholders

17. See (IEA, 2020), p. 192-198 for a more detailed discussion on technology readiness, in particular for electrolytic hydrogen, carbon capture, utilisation and storage, and alternative carbon feedstock solutions in the chemical sector.

While some actions can already be implemented today with existing technologies, others rely on advanced technologies that currently entail important cost premiums and still need to mature commercially.

POLICY LANDSCAPE

Policy landscape for chemical sector decarbonisation in the EU

As one of the major industrial contributors to GHG emissions, the chemical industry is under increasing regulatory and stakeholder pressure to decarbonize and align with the Paris Agreement objectives. In the European Union, the regulatory environment shaping industrial decarbonisation is rapidly evolving, combining binding EU-wide and national targets, market-based mechanisms, and voluntary frameworks.

The EU first endorsed the objective to reach climate neutrality by 2050 in its 2019 European Green Deal, before making it legally binding in 2021 with the European Climate Law. The latter also includes an intermediate 2030 target of 55% lower net GHG emissions relative to 1990, and was amended in March 2026 to add a legally binding headline emission reduction target of 90% by 2040 relative to 1990. In 2021, the EU launched its Fit-for-55 package, with the aim to operationalize this intermediate target through a set of legislative revisions, including an update of the emissions trading system (EU ETS) and a carbon border adjustment mechanism (CBAM).

2019	European Green Deal endorses climate neutrality by 2050.
2021	European Climate Law makes it binding, with a 55% cut target by 2030 relative to 1990.
2021	Fit-for-55 package operationalizes the target — EU ETS revision and CBAM.
2023	CSRD enforced; ETS2 created for buildings, road transport and small industry.
2026	CBAM becomes operational. Climate Law amended in March to add a binding 90% cut target by 2040.
2028	ETS2 expected to start fully, after monitoring and reporting began in 2025.

18. Every year, entities covered by the ETS have to buy allowances corresponding to their GHG emissions. For each year, a cap is set on how many allowances are put on the market, and that cap decreases with every passing year — since 2023, with a reduction factor increased to -4.3% per year until 2027 and -4.4% per year from 2028. This system puts a price on carbon and creates financial incentives for companies to cut emissions. In 2023, an additional and separate emissions trading system (ETS2) was created under the revision of the ETS Directive, covering buildings, road transport and small industries not covered under the existing EU ETS. Monitoring and reporting of emissions began in 2025 and the scheme is expected to start fully in 2028 (European Commission, 2026). However, the ETS2 only has a secondary, more indirect impact on the chemical sector, which is mostly covered under the old EU ETS.

TABLE 1

European Union's key industrial decarbonisation policy tools

EU ETS

IMPLEMENTED 2005

The EU's main tool to address industrial GHG emissions: a carbon market based on a system of cap-and-trade of emission allowances for energy intensive industries and the power generation sector[15]. The system currently covers approximately 10,000 companies and 40% of EU emissions (European Commission, 2026). A large fraction of the chemical sector — in particular large installations such as steam crackers, ammonia, methanol and hydrogen production, acids and bulk organic chemicals — is concerned by this scheme. While many chemical producers have historically benefited from free allocations to protect their international competitiveness and avoid carbon leakage, this protection is being gradually reduced in parallel with the EU's CBAM introduction.

CBAM

ADOPTED 2023 · OPERATIONAL 2026

The CBAM complements the EU ETS. It aims to foster decarbonisation in non-EU countries and preserve the international competitiveness of EU industries, by equalizing the carbon cost between domestic production and imports. Importers are requested to purchase certificates reflecting the EU ETS carbon price corresponding to the emissions embedded in their products. The initial CBAM scope only covers a limited set of carbon intensive products, among which fertilizers and hydrogen. While most organic and specialty chemicals are not concerned yet, the scope is expected to expand — so companies outside it should anticipate future inclusion, as early visibility into embedded-carbon intensity per product line can inform sourcing decisions ahead of mandatory compliance.

CSRD

ENFORCED 2023

The Corporate Sustainability Reporting Directive reinforces corporate transparency and accountability for large companies, by expanding mandatory disclosure requirements on climate risks, emissions, and transition plans among other sustainability aspects. For large chemical manufacturers, this represents a significant operational undertaking — requiring double materiality assessments and disclosure across multiple European Sustainability Reporting Standards (ESRS), for instance on climate, pollution and resource use, often demanding dedicated cross-functional resources beyond existing sustainability teams.

HOW GREENLY HELPS

Greenly has developed a specific **CBAM solution** which cuts compliance costs by automating emissions reporting, helping suppliers reduce CO_2, and finding low-carbon options. Its **CSRD Hero** module operationalizes reporting for chemical manufacturers — covering environmental ESRS E1 (climate), E2 (pollution) and E5 (resource use and circular economy) plus double materiality assessment, on the same platform used for Scope 1-3 measurement.

VOLUNTARY FRAMEWORKS

Beyond compliance: scorecards, targets and shared standards

While regulatory compliance is a pivotal driver for the sector's transparency and sustainability, chemical manufacturers also face another, often more immediate pressure: customer-facing scorecards and audits from downstream brand owners, such as EcoVadis, Carbon Disclosure Project (CDP) Supply Chain, or programmes run directly by large industrial customers. For many mid-market suppliers in particular, losing a scorecard-driven tender represents an even more concrete and immediate commercial risk than a regulatory penalty.

Besides, businesses that proactively strengthen their GHG disclosure practices — even beyond current regulatory requirements — can also demonstrate leadership, shape new standards, strengthen investor and customer confidence, and build a competitive position by anticipating evolving regulatory expectations.

Complementing regulatory drivers, voluntary initiatives such as the Science Based Targets initiative (SBTi), launched in 2015 by the United Nations Global Compact, the World Resources Institute and WWF, support companies in aligning their GHG reduction targets and strategies with the Paris Agreement. It provides a standardized validation process based on climate science through which companies commit to emission reduction pathways consistent with limiting global warming to 1.5°C.

companies worldwide had validated science-based climate targets through the SBTi as of mid-2026 — about half based in Europe, one-fifth with net zero targets

11,000+

chemical companies worldwide had committed to SBTi targets in line with 1.5°C in 2022 — the sector started from a very low base

11

For the chemical industry, in order to better reflect the specific emissions profiles of diverse chemical activities, SBTi has developed sector- and segment-specific guidance, providing methodology, metrics and actionable pathways to help chemical companies plan and realize emissions reductions – including both direct process emissions and significant Scope 3 value chain impacts (SBTi, 2025).

Another initiative is that of Together for Sustainability (TfS), founded in 2011 by chemical companies with the goal of assessing, auditing and improving the sustainability practices within their global supply chains. The programme has grown into a global organisation with regional representation in North and South America and Asia.

DEMAND

Demand reduction and circular economy

Demand reduction is the most direct and effective strategy to achieve deep and sustained reductions in GHG emissions from hard-to-abate sectors like chemicals. Applying material efficiency and sufficiency strategies across the economy – including reduced consumer purchases, reduced packaging, changes in diet and agricultural practices, food waste reduction – together with circular economy practices such as the reuse and repair of products to extend their lifetime, are crucial to help avoid demand for new chemicals. The substitution of plastics with bio-based materials (e.g. paper, PHA) as well as closed-loop plastic recycling — where post-consumer plastics are recycled into materials of equivalent quality that can substitute for virgin polymers — also have an important role to play to reduce the need for new petrochemical production. Scaling up closed-loop recycling will require improvements across the entire plastics value chain, including product design for recyclability, effective downstream collection and advanced sorting systems, and recycling technologies[19] capable of producing secondary materials that meet virgin-quality specifications[20].

A concrete illustration is the EU's Packaging and Packaging Waste Regulation (PPWR), adopted in December 2024, which directly targets demand reduction. It sets mandatory per-capita packaging waste reduction targets (-5% by 2030, -10% by 2035, -15% by 2040 vs. 2018 levels), makes packaging minimization a legal requirement, and introduces reuse targets — including a 40% reuse target for transport packaging by 2030. The regulation also bans specific single-use plastic formats (e.g., shrink wrap for multipacks, miniature toiletries) and mandates minimum recycled content in plastic packaging, combining demand reduction with support for closed-loop recycling. Another one is the EU's Right to Repair Directive (2024/1799), which requires manufacturers to repair certain products free of charge or at a reasonable price, even after the warranty expires. This helps reduce demand for the virgin chemical materials that would otherwise go into manufacturing replacements. However, as of September 2026, most member states had not yet implemented it nationally. Looking ahead, the EU's Circular Economy Act, currently in preparation and expected to be proposed in late 2026, aims to create a single market for secondary raw materials and double the EU's circular material use rate to 24% by 2030.

19. Mechanical recycling, which doesn't change the chemical structure of the material, remains the preferred option for clean, homogeneous waste streams due to its lower energy demand, while advanced chemical recycling technologies, such as depolymerisation or solvent-based recycling, can complement mechanical recycling for more complex plastic waste streams that cannot otherwise be returned to high-value applications.
20. On the private-sector side, for instance, the French biotech company Carbios has developed an enzymatic PET depolymerization technology, proven at demonstration scale since 2021, capable of producing virgin-equivalent, food-grade recycled PET. However, its first commercial-scale plant in France (Longlaville) has faced repeated financing delays and, as of mid-2026, has no confirmed start date, illustrating the capital-intensive and high-risk nature of scaling up novel closed-loop recycling technologies.

At national level, France's anti-ultra-fast-fashion law (2026) illustrates a direct attempt at purchase-side demand reduction, combining a per-item environmental penalty (up to €20 by 2030) with an advertising ban from 2027. However, by exempting mainstream fast-fashion retailers, it raises questions about its compatibility with EU law, and about the overall impact it can effectively have.

These demand reduction strategies help avoid upstream emissions throughout the entire value chain, from those associated with fossil feedstock extraction and transport, to chemical manufacturing, and end-of-life incineration or open-burning (for non-ammonia chemicals). It also reduces the reliance on new, uncertain and possibly costly technology developments, and lowers the investment needs for the sector's transition.

ENERGY EFFICIENCY

Energy efficiency

Opportunities for energy efficiency exist at multiple levels in the chemical industry, ranging from equipment upgrades — such as high-efficiency motors, compressors, pumps, and boilers — to process integration, heat recovery, advanced process control, and digital energy management systems. In many chemical plants, waste heat is generated in large amounts during high-temperature processes. About one-quarter of primary energy consumption in the EU chemical and petrochemical sector ends up as heat released in process exhausts and effluents and could, in principle, be recovered (Bianchi et al., 2019). Systematically recovering and reusing this heat through deeper process heat integration or cogeneration, or district heat integration can substantially reduce fuel consumption for process heat and associated Scope 1 emissions. Furthermore, waste-heat recovery projects in the chemical sector can offer relatively short payback periods, typically around 3–5 years for favourable high-temperature applications (Larrinaga et al., 2021).

A recent example is provided by Cerdia's chemical plant in Freiburg, Germany, where, since 2026, industrial process waste heat is recovered and supplied to the municipal district-heating network (~60 GWh of heat supplied annually).

ENERGY PROCUREMENT

Low-carbon energy procurement

Low-carbon energy procurement is an important lever for reducing Scope 2 emissions from purchased electricity and steam and, where feasible, Scope 1 emissions associated with fuel combustion.

Chemical companies can directly invest in renewable energy projects, such as wind farms, solar PV parks and biogas plants, with the option to create investment partnership and co-ownership structures with other actors. In addition, for electricity, one of the most widely adopted approaches is the use of renewable Power Purchase Agreements (PPAs), under which a company contracts directly with a renewable electricity producer to purchase electricity over a long-term period, often 10–20 years. Similarly, renewable gas agreements exist, and renewable Heat Purchase Agreements (HPAs) are increasingly developing between industrial consumers and renewable heat suppliers operating heat plants onsite, or supplying heat through district heat networks.

In the case of electricity, PPAs may be physical, where electricity is delivered through the grid, or virtual (financial), where the company continues to buy electricity from its utility but settles the difference between a fixed contract price and the market price with the renewable generator. Long-term PPAs and HPAs support decarbonisation objectives by providing developers with revenue certainty, facilitating the financing of new renewable generation – or the continued exploitation of old assets reaching the end of their initial policy support – while offering industrial consumers greater price predictability.

In addition to PPAs, companies can procure renewable electricity through utility "green" tariffs or by purchasing Guarantees of Origin (GOs), or equivalent Energy Attribute Certificates such as Renewable Energy Certificates in other regions, which certify that a corresponding amount of electricity has been generated from renewable sources[21].

21. However, while GOs are widely accepted under the GHG Protocol's market-based accounting approach and therefore enable companies to report lower Scope 2 emissions, they do not necessarily result in additional renewable generation unless they are linked to new projects or high-quality procurement strategies. Consequently, many organizations distinguish between contractual, market-based emissions reductions achieved through GOs and the extent to which those purchases really contribute to additional renewable energy deployment and real-world decarbonisation.

CASE EXAMPLE

Renewable electricity procurement by BASF

The German chemical company BASF[22] aims to achieve net-zero CO_2 emissions by 2050. As energy use represents around half of BASF's scope 1 and 2 emissions, the company aims at electrifying its processes with renewable power. The company developed a make-or-buy renewable energy procurement strategy, combining investment in its own assets with long-term PPAs and renewable energy certificates.

Over the past decade, BASF invested in a 24 MW solar park to supply the Schwarzheide production site, where battery materials are produced. BASF also co-invested in the 1.5 GW Hollandse Kust Zuid offshore wind farm in the Dutch North Sea, as well as in a 500 MW offshore wind farm in Zhanjiang in China. In addition, BASF has contracted long-term power purchase agreements for 186 MW of offshore wind capacity in the German North Sea with Ørsted, for 20.7 TWh of renewable electricity over a 25-year period with Engie, and for 48 MW of renewable power with X-Elios in the United States. It also contracted a 15-year agreement with BP Energy Retail Company in the U.S. to acquire Renewable Energy Certificates (REC) associated with 47 MW of wind capacity.

THE PORTFOLIO

Own asset	24 MW	Solar park supplying the Schwarzheide battery materials site
Co-investment	1.5 GW	Hollandse Kust Zuid offshore wind farm, Dutch North Sea
	500 MW	Offshore wind farm in Zhanjiang, China
PPA	186 MW	Offshore wind in the German North Sea, with Ørsted
	20.7 TWh	Renewable electricity over 25 years, with Engie
	48 MW	Renewable power in the U.S., with X-Elios
Renewable energy certificate	47 MW	Wind capacity certificates, BP Energy Retail Company (15 years)

22. BASF, the world largest chemical manufacturer with €60 billion of turnover in 2025, manufactures a broad range of basic chemicals, intermediates, plastics, coatings, and agricultural products for industrial and consumer markets. For the year 2025, BASF consumed over 35 TWh of natural gas as fuel for energy purposes worldwide (excluding feedstock), and reported Scope 1 & 2 emissions of 16.1 $MtCO_2eq$, and Scope 3 emissions of 94 $MtCO_2eq$.

PROCESS HEAT

Process heat electrification and thermal storage

About half of the chemical industry's scope 1 & 2 GHG emissions arises from fossil fuel combustion predominantly used to provide process heat.

More than 20% of the sector's heat demand is required at temperatures below 150°C (Naegler et al., 2015), for processes such as bioreactions, boiling, distillation, and thermoforming. In this temperature range, several renewable heat options are technically mature to meet industrial heat demand, including solar thermal, geothermal, sustainable bioenergy, and industrial electric boilers and heat pumps.

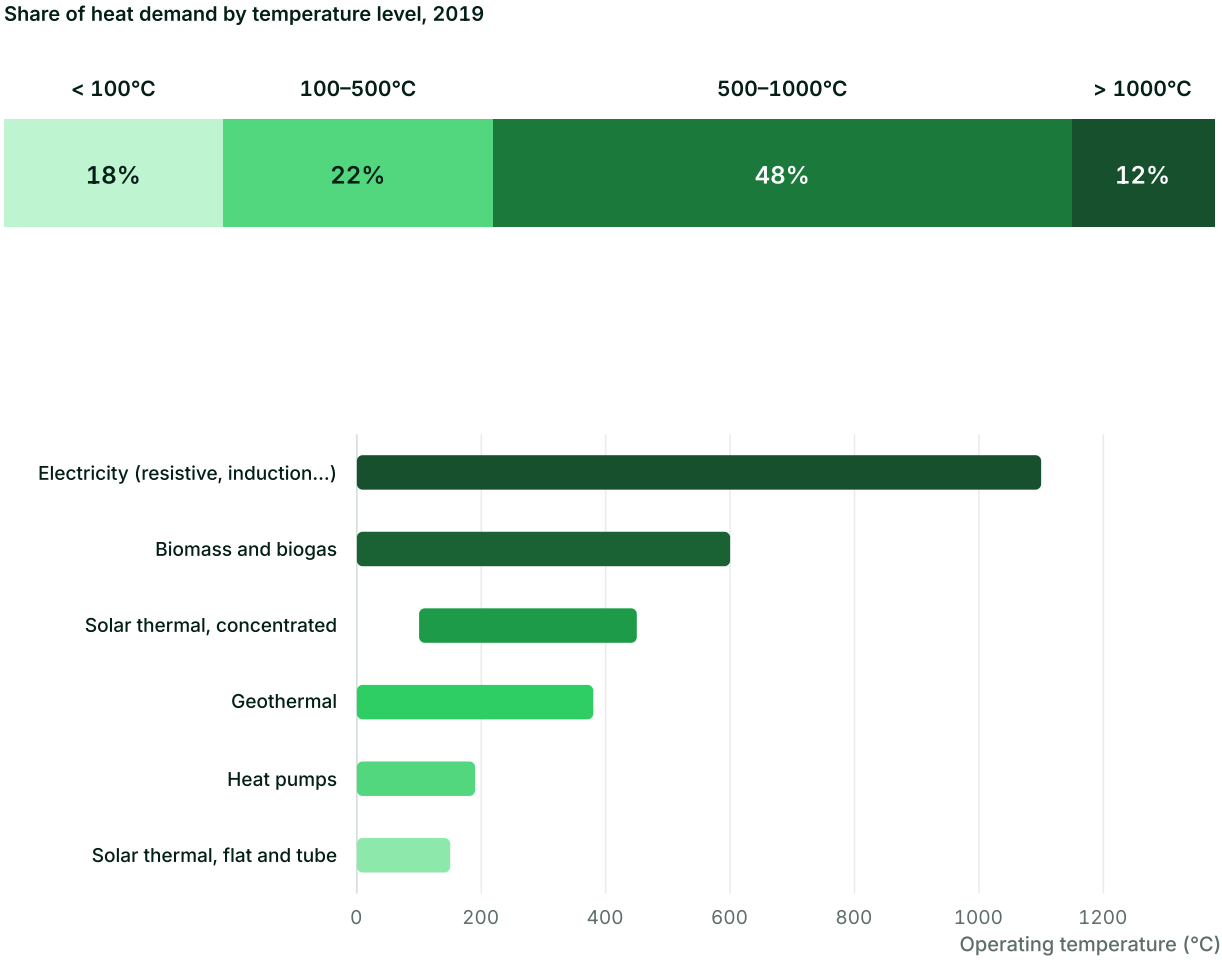
Heat pumps use electricity to transfer and upgrade ambient or waste heat, with heat output often 2–3 times greater than the amount of electric energy they consume. In some markets, this high efficiency can offset the cost gap between electricity and fossil fuels, making heat pumps cost-competitive (IEA, 2025c). Unlike other renewable heat sources such as solar or geothermal energy, their deployment is generally not constrained by local resource or space availability. Significant technological progress has been achieved in recent years, with commercially available industrial heat pumps now capable of delivering heat at temperatures exceeding 160–170°C while maintaining high efficiency. As a result, the market for high-temperature industrial heat pumps is expanding rapidly. For instance, BASF started constructing a 50 MW industrial heat pump at Ludwigshafen, scheduled for commissioning in 2027, that will use renewable electricity as well as waste heat recovered from a steam cracker to supply steam for formic acid production, with expected savings of 100 $ktCO_2$ per year.

At higher temperature levels, where most of the sector's heat demand is concentrated – steam crackers typically operate above 800°C – fewer low-carbon heat options are available. For high-temperature applications such as high-temperature steam or crackers, the use of low-carbon electricity offers a potential alternative to substitute fossil fuel combustion. For instance, in 2022, BASF, SABIC and Linde launched a demonstration project for **a 6MW electrically heated steam cracker**[23] at the BASF Ludwigshafen complex in Germany. According to project developers, using renewable electricity could cut direct CO_2 emissions by more than 95%, while also improving process performance and energy efficiency, and potentially allowing existing steam crackers to be retrofitted. Similarly, Shell and Dow have installed an experimental electric-heated steam cracker furnace unit at the Energy Transition Campus in Amsterdam.

23. This demonstration steam-cracker will process approximately 4 t/h of hydrocarbon feedstock, corresponding to around 5–10% of the throughput of a typical commercial-size steam cracker in Europe.

FIGURE 11

Breakdown of heat demand by temperature level in the European chemical industry (top) and operating temperature for renewable and electric heat technologies (bottom)



Source: temperature distribution of heat demand from PMC8972653; technology operating temperatures from (IEA, 2019).

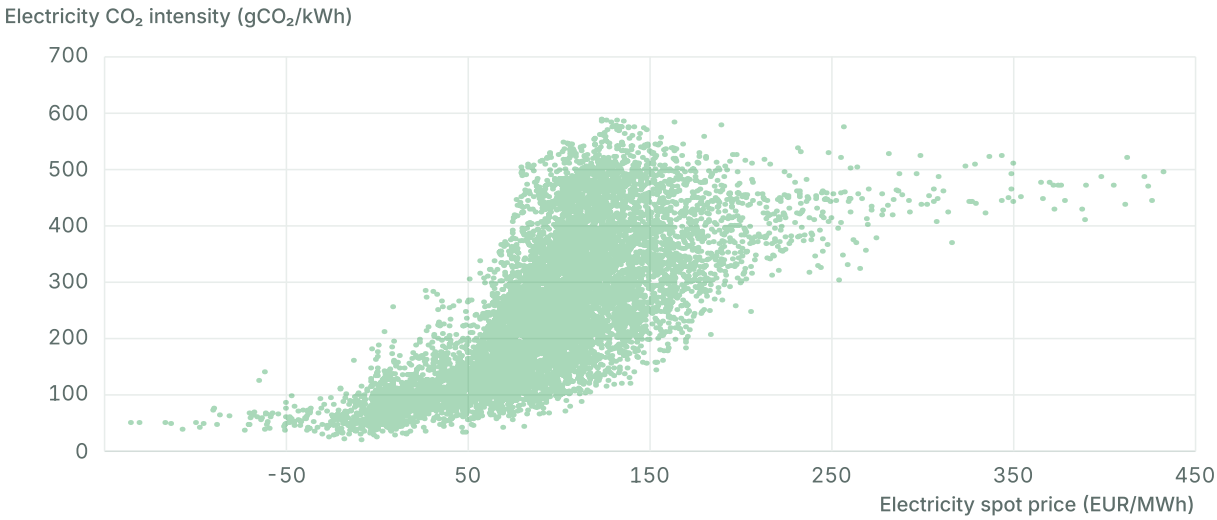


Electric heating[24] can also be combined with **thermal energy storage (TES)**, providing additional flexibility to industrial energy systems. Thermal storage can act as a buffer by decoupling heat generation from heat demand, allowing electricity consumption from the grid to be shifted from periods of high prices – and generally high CO_2 intensity – to periods when electricity is cheaper, typically when renewable energy is abundant and CO_2 intensity lower. As the share of variable renewable energy sources in the electricity mix increases, power markets show greater price fluctuations, strengthening the case for such demand-side flexibility solutions. TES can thus reduce both operating costs and scope 2 emissions, while supporting the integration of variable renewable electricity. Alternatively, TES can also be coupled with renewable electricity sources such as wind or solar PV, to turn variable electricity production into continuous heat supply.

Several TES technologies are commercially available for industrial applications, including steam accumulators[25] and solid-state thermal storage systems, which typically use inexpensive and widely available materials such as sand or refractory bricks. Compared with electrochemical batteries, these systems generally offer substantially lower storage investment cost per unit of energy (e.g. USD 10–15 per kWh_{th} (IEA, 2025c), versus more than USD 100 per kWh for lithium-ion battery packs in 2025 (BNEF, 2025) - and multiple times more for small industrial-size BESS projects). Commercial providers have emerged in recent years (e.g. Rondo Energy), demonstrating the growing maturity of these technologies.

FIGURE 12

Hourly electricity GHG intensity versus price, Germany, 2024



Note: each dot is one hour of 2024; 24 hours with prices above 450 EUR/MWh fall outside the axis. Source: data from ENTSO-E.

24. Electric heating encompasses technologies such as resistance heating, induction heating, electric arc heating and infrared/radiant heating, as well as indirect electrification technologies such as heat pumps and mechanical vapour recompression (IEA, 2017).
25. A steam accumulator is a pressurised vessel that stores thermal energy as hot, pressurised liquid water and releases steam on demand.

CASE EXAMPLE

Heat battery for high-temperature steam in the chemical industry

Covestro, a leading manufacturer of polymer materials, with €12.9 billion in sales, and 4.3 $MtCO_2eq$ of Scope 1 and 2 GHG emissions in 2025, is partnering with Rondo Energy to install a heat battery powered by renewable electricity that will supply 10% of the high-temperature steam needed at the Covestro site in Brunsbüttel. The project, supported by the Breakthrough Energy Catalyst foundation and the European Investment Bank (EIB), is expected to begin operation at the end of 2026, and to enable savings of 13 $ktCO_2$ per year. The heat battery converts electricity into heat, stored in bricks, to deliver continuous high-temperature steam on-site for production processes.



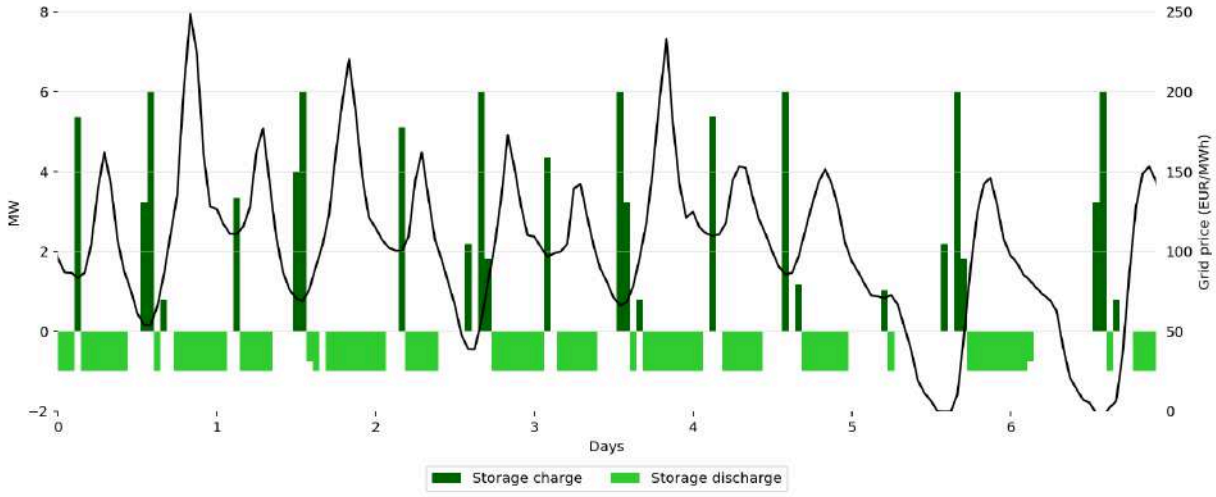
The Rondo Heat Battery at the Covestro site. © Rondo Energy

Quantifying the benefits of thermal energy storage

To quantify the benefits of TES, we developed an hourly optimization model representing a hypothetical industrial heat consumer with a steady heat demand, using electric heating powered by the grid coupled with TES, and optimizing its consumption pattern daily with the objective to minimize its energy bill based on day-ahead price information[26].

FIGURE 13

Example electricity prices and corresponding optimized thermal energy storage operation pattern, Germany, 2024 prices



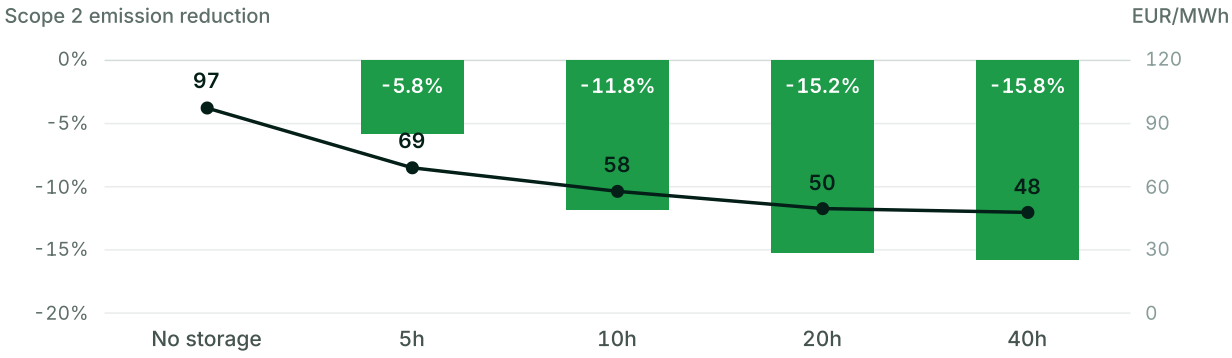
Note: the figure shows a week in June 2024; the storage charges when prices are low and discharges to take over grid consumption when prices are high, to meet the constant 1MW heat demand. When the storage doesn't charge nor discharge, electricity consumption corresponds to that needed to supply heat demand directly. Source: modelling based on ENTSO-E 2024 day-ahead prices for Germany.

Using historical 2024 market data, our modelling shows that for Germany, the demand flexibility provided by a storage capacity equivalent to 10h of heat demand makes it possible to reduce by 40% the annual average spot price of electricity purchases and by 12% the emissions associated with them, compared with a case without TES requiring continuous electricity purchases. Assuming the use of a heat pump operating with a coefficient of performance of 2.7[27], annual Scope 1 & 2 emissions would be more than 55% lower than with a gas boiler.

26. The author first developed this modelling for the IEA, with results published in (IEA, 2025c).
27. This value is typically achieved by heat pumps operating with a temperature lift of ~80K.

FIGURE 14

Scope 2 emission reductions and average spot price of electricity consumed for different capacities of thermal energy storage, Germany 2024 market data



Note: the modelling is based on ENTSO-E hourly spot price and electricity mix data for Germany for the year 2024, using direct emission factors from (Electricity Maps, 2024). The model minimises energy expenditures over each day of the year, based on day-ahead price information. The modelling assumes a constant heat demand of 1 MW_{th}, hourly storage loss of 0.08%, storage discharge efficiency of 98%, and a maximum charging rate of storage of 6 MW_{th}.

lower annual average spot price of electricity purchases with 10 hours of storage capacity, against a case without TES — Germany, 2024 market data

-40%

lower annual Scope 1 & 2 emissions than a gas boiler, assuming a heat pump with a coefficient of performance of 2.7 — Germany, 2024 market data

-55%

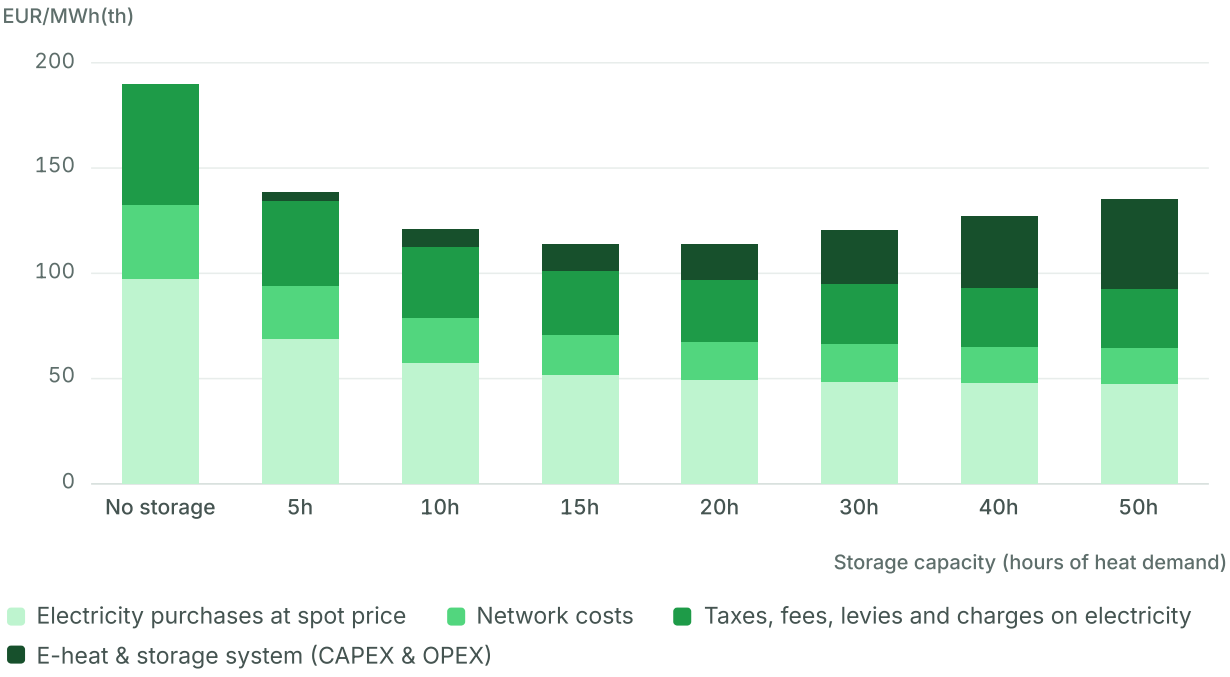


The marginal operating cost savings from additional storage capacity decrease as storage size increases, as the most valuable flexibility opportunities are captured first. Since larger storage systems also require greater investment, an economic trade-off emerges, leading to an optimal storage capacity for each application.

For instance, for a combined electric heating and storage system operating on the same principle as a Rondo Heat Battery, with an investment cost of EUR 70,000/MWh(th) and based on 2024 German electricity prices with simplified grid fee assumptions, the lowest levelized cost of heat is achieved at a storage capacity equivalent to approximately 18 hours of heat demand.

FIGURE 15

Levelized cost of heat for combined electric heating and storage systems of different capacities, Germany, 2024 electricity prices



Note: Modelling assumes an investment cost of EUR 70,000 per MWh(th) of storage capacity, annual maintenance costs of EUR 1,400 per MWh(th) of storage capacity, hourly storage losses of 0.08%, an 8% WACC, and a 30-year lifetime. Electricity prices are based on ENTSO-E hourly spot prices for Germany in 2024. Network costs account for 18.6%, and taxes, fees, levies and charges, for 30.1% of the electricity bill, based on Eurostat data for consumption Band IE (20–70 GWh/year) in Germany in 2024.

HYDROGEN

Low-carbon electrolytic hydrogen

The IEA estimates that global hydrogen production emitted 920 Mt CO_2 in 2023 (IEA, 2024), with about half of this production used for ammonia and methanol synthesis (IEA, 2026a). Decarbonizing hydrogen production will therefore be key to lower the chemical sector's carbon footprint.

Low-carbon electrolytic hydrogen, produced through water electrolysis with low-carbon electricity – such as renewables or nuclear – offers a promising decarbonisation pathway. It avoids upstream scope 3 emissions associated with natural gas extraction, as well as current scope 1 CO_2 emissions from methane reforming. Renewable-based hydrogen – or "green hydrogen" – enables the production of "green" ammonia and, when paired with non-fossil carbon feedstocks, that of "green" methanol, which in turn offers alternative low-carbon routes for the production of olefins and aromatics (methanol-to-X).

> One example is given by Envision Energy's Chifeng plant (Inner Mongolia, China), commissioned in 2025 as the world's first green ammonia facility operating at industrial scale: powered entirely off-grid by co-located wind, solar and battery storage, it currently produces 320 000 tonnes/year of green ammonia using 500 MW of electrolysis capacity, with plans to scale up to 1.5 million tonnes per year by 2028. Another case is AM Green's Kakinada plant in India — a brownfield urea plant conversion, expected to commission at the end of 2026, and targeting 1.5 million tonnes/year of green ammonia by 2030, backed by ~1,950 MW of electrolysis capacity and 7.5 GW of renewable capacity.

However, electrolytic hydrogen still entails relatively high production costs: average production costs for renewables-based hydrogen is around 8 €/kg, about four times higher than hydrogen from fossil fuels[28] (ACER, 2025). Electrolysers are capital intensive with limited cost-down potential anticipated in the medium term, and the process is energy intensive – approximately 50-60 kWh per kg of hydrogen, without factoring the energy for high pressure storage. Electrolyser deployment is still limited (global installed capacity dedicated to hydrogen production was around 4GW in 2025 – of which ~0.6 GW in the EU – and a further 2.5GW is expected to start operating in 2026 (IEA, 2026a; JRC, 2026)), and renewable-based hydrogen accounted for only 0.2% of total hydrogen production globally in 2025. However, the technology is developing rapidly, with global production of renewable-based hydrogen expanding 64% year on year in 2025 (IEA, 2026a). Scaling up production will require substantial investment in new electrolyser and renewable power capacities, as well as specific transport infrastructures.

28. However, some regions of China already achieve production costs below USD 4/kgH_2, and the IEA anticipates similar costs for India by 2030, and costs as low as USD 2/kgH_2 under optimal conditions in Northern China by then (IEA, 2026a).

CO_2 emitted by global hydrogen production in 2023

920 Mt

Renewables-based hydrogen production cost — four times fossil hydrogen

~8 €/kg

Share of renewable-based hydrogen in global production in 2025

0.2%

Year-on-year growth of renewable-based hydrogen production in 2025

+64%

FEEDSTOCKS

Alternative carbon feedstocks

Shifting from fossil carbon feedstocks to alternative and renewable carbon feedstocks is another pathway that can help mitigate the chemical industry's climate footprint by enhancing carbon circularity in chemical supply chains. Alternative carbon feedstocks can be of different types.

Biogenic carbon

Sourced from sustainably produced biomass, agricultural and forestry residues, organic waste and other biological by-products. Biomass can be converted directly into chemical intermediates — fermenting sugars or starches into bioethanol and then bio-ethylene — or processed through gasification or anaerobic digestion into biomethanol or biogas or biomethane. Biogenic CO_2 from fermentation or biogas upgrading can also be captured and combined with renewable hydrogen to produce e-methanol, albeit currently at multiple times the cost of fossil-based methanol (Sun et al., 2026). Bio-ethylene is already produced commercially, notably by Braskem in Brazil using sugar cane ethanol, but remains a very small share of global ethylene production. The Kassø facility in Denmark, producing e-methanol since 2025 from biogenic CO_2 and renewable hydrogen, illustrates the emerging integration of these technologies at commercial scale. Yet, scaling up these solutions requires overcoming challenges related to limited availability and sustainability of biomass and biogenic CO_2, competition with other uses, higher production costs, and the need for new dedicated infrastructure.

Recycled carbon

Waste recycling can feed carbon back into the chemical system: mechanical recycling returns carbon embedded in polymer feedstock (e.g. recycled PET, PE, PP) to converters and, in some cases, chemical producers; chemical recycling returns secondary feedstocks such as monomers, pyrolysis oils or syngas, which can enter conventional chemical production, to make new polymers or other chemicals. This option is currently limited by relatively low collection rates and material losses, challenges related to sorting and contamination, and higher procurement cost than fossil alternatives (OECD, 2022)[29].

Captured carbon

CO_2 captured from biogenic sources, process emissions, or fuel and waste combustion at concentrated industrial point sources can be combined with low-emissions hydrogen to produce methanol and other synthetic intermediates. Capture technologies at concentrated sources are relatively mature - they are used for ammonia production - but their application to more dilute industrial flue gases less so. The technology can be retrofitted to existing sites, however current capture costs hinder faster adoption. These costs of carbon capture range from around USD 15–25/tCO_2 for favourable concentrated streams to more than USD 120/tCO_2 for difficult sources (IEA, 2020). The Carbon2Chem demonstration project, launched in 2016 in Duisburg, captures carbon from steel production and combines it with electrolytic hydrogen to produce chemicals such as methanol.

These alternative carbon sourcing pathways can reduce scope 3 emissions by increasing carbon circularity in the chemical system. However, they are not yet widely deployed. Many technologies are still at the demonstration or early commercial stage – particularly for integrated CO_2 capture and utilization – the availability of sustainable biomass and waste feedstocks is limited, and their economic viability remains to be proven, in particular for production streams where the cost premium from using alternative carbon sources would add to that of using "green" hydrogen.

29. Current global plastic recycling rates remain around 9% of primary production (Walker et al., 2025), while recycled polymers typically cost 10-20% more than virgin resin due to feedstock scarcity, sorting costs and quality variability.

CARBON CAPTURE

Carbon capture and storage

Carbon capture and storage can be used to complement other strategies in reducing Scope 1 emissions by capturing CO_2 from unavoidable process emissions and fuel combustion. It can also help address Scope 3 emissions by capturing CO_2 from waste incineration at the end of a product's life, preventing these emissions from reaching the atmosphere. Captured CO_2 may then be stored durably, when not reused as a feedstock for chemical production, which helps reduce demand for fossil carbon.

However, while carbon capture for industrial point sources has reached commercialisation stage[30] and the technology can be retrofitted to existing sites, deployment is constrained by costs[31], the need for CO_2 transport and storage infrastructure, the difficulty of financing an integrated value chain with uncertain development perspectives, public acceptance, and regulatory and liability issues associated with long-term CO_2 storage.

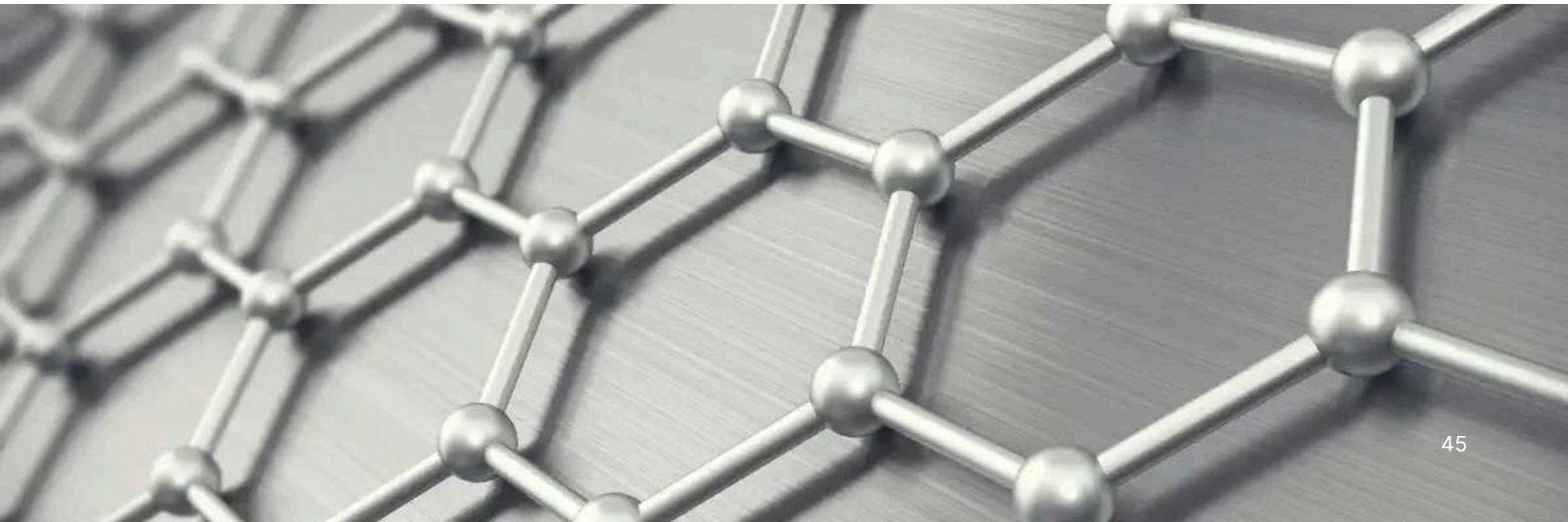
USD per tCO_2 to capture from favourable concentrated streams — rising to more than USD 120/tCO_2 for difficult, dilute sources (IEA, 2020)

15–25

more than unabated production, the estimated cost of CCUS-equipped ammonia and methanol output on 2020 technology and cost assumptions

20–40%

30. See for instance Yara's Sluiskil ammonia and fertilizer complex, in the Netherlands, where the company inaugurated Europe's largest industrial carbon capture facility in September 2026. It aims to capture and liquefy up to 800,000 tonnes of CO_2 annually for permanent offshore storage in Norway via the Northern Lights project.
31. For instance, in an IEA assessment based on 2020 technology and cost assumptions, CCUS-equipped ammonia and methanol production was estimated to cost around 20–40% more than unabated production (IEA, 2020). More recently, the World Economic Forum (2023) indicates a minimum 40% increase – underscoring the sensitivity of this figure to natural gas prices and project scale.



CONCLUSION

Towards a lower-carbon chemical value chain

Decarbonising chemicals is not a single technical fix. Emissions are spread across process chemistry, high-temperature heat, fossil feedstocks and the use and disposal of the products themselves — and the majority of them sit outside the plant fence.

The evidence in this paper points to a sequence rather than a choice. Demand reduction and circularity avoid emissions across the whole value chain at the lowest investment cost. Energy efficiency and low-carbon procurement address the scope 1 and 2 emissions that are already measurable today. Electrolytic hydrogen, renewable feedstocks and carbon capture address the residual process emissions, but remain constrained by cost and by the pace of infrastructure turnover.

What all of them share is a dependency on measurement. With 70–80% of a chemical company's footprint in scope 3, and long asset lifetimes locking in decisions for decades, the quality of the inventory determines the quality of the plan. Companies that can trace emissions to the process, the fuel and the feedstock are the ones able to price abatement, sequence capital, and meet the EU ETS, CBAM and CSRD requirements now taking effect.

About Greenly

This white paper was produced by Greenly, the climate intelligence platform that helps organisations measure, track and reduce their carbon emissions. Greenly's approach combines automated carbon accounting, analysis of both physical and monetary flows, a library of action plans, stakeholder engagement tools and annual performance tracking.



Sources

ACER. (2025). European hydrogen markets — 2025 Monitoring Report. European Union Agency for the Cooperation of Energy Regulators.

Arpagaus, C., Bless, F., Uhlmann, M., Schiffmann, J., & Bertsch, S. S. (2018). High temperature heat pumps: Market overview, state of the art, research status, refrigerants, and application potentials. Energy, 152, 985-1010.

Bianchi, G., Panayiotou, G. P., Aresti, L., et al. (2019). Estimating the waste heat recovery in the European Union Industry. Energy, Ecology and Environment, 4, 211–221.

BIP Europe. (2023). Insights into the current costs of biomethane production from real industry data | Executive Summary (Task Force 4.2).

BloombergNEF (2025). Lithium-Ion Battery Pack Prices Fall to $108 Per Kilowatt-Hour, Despite Rising Metal Prices. BNEF press release, 9 December 2025.

CDP. (2025). CDP Technical Note: Relevance of Scope 3 Categories by Sector — CDP corporate questionnaire, Version 3.0.

Cefic. (2025). 2025 Facts and Figures. Cefic.

Cefic. (2026). Landscape of the industry — Belgium [Cefic.org]. Cefic.

Chen, X., Lei, T., Zhao, W., Ma, S., Lai, C., & Guan, D. (2026). China's petrochemical plants' CO2 emissions and high-impact contributors for carbon-neutrality production. Science Advances, 12(12), eadx7784.

Citepa. (2026). Rapport SECTEN ed. 2026 — Données de gaz à effet de serre et données par secteur [dataset].

Crippa, M., Guizzardi, D., Pagani, F., Banja, M., Muntean, M., Schaaf, E., Monforti-Ferrario, F., Becker, W. E., Quadrelli, R., Risquez Martin, A., Taghavi-Moharamli, P., Köykkä, J., Grassi, G., Rossi, S., Melo, J., Oom, D., Branco, A., San-Miguel, J., Manca, G., … Pekar, F. (2025). GHG emissions of all world countries — 2025 Report — EDGAR GHG emissions database. Publications Office of the European Union.

EEA. (2023). Managing the systemic use of chemicals in Europe. European Environment Agency.

Electricity Maps. (2024). Electricity Maps emission factors methodology — Comparison and validation of the Electricity Maps emission factors dataset against the IEA Emission Factors (Appendix 1 and 6). Electricity Maps.

EPA. (2025). U.S. Environmental Protection Agency Office of Atmospheric Protection Greenhouse Gas Reporting Program (GHGRP) [dataset].

Erlach, B., Gierds, J., Fischedick, M., Matthies, E., Pittel, K., & Uwe Sauer, D. (2024). CO2 als Rohstoff — Baustein einer klimaneutralen Kohlenstoffwirtschaft.

European Commission. (2026). EU Emissions Trading System (EU ETS). European Commission.

European Commission, Joint Research Centre (2026). Water Electrolysis and Hydrogen in the European Union — 2025 Status Report, JRC144106.

European Environment Agency (EEA). (2026). Greenhouse gas emissions by source sector (EEA; Version 02/06/2026) [dataset].

Eurostat. (2025, December 16). EU chemical production: -15% over 10 years.

Gitnux. (2026). Belgium Industry Statistics 2026. Gitnux.

GTAI. (2026). Chemical Industry.

Gunawan, T. A., Luo, H., Greig, C., & Larson, E. D. (2026). Decarbonizing Basic Chemicals Production in North America, Europe, Middle East, and China: A Scenario Modeling Study. Environmental Science & Technology, 60(16), 11890-11900.

IEA (2017). Renewable Energy for Industry: From Green Energy to Green Materials and Fuels. International Energy Agency, Paris.

IEA. (2018). The Future of Petrochemicals.

IEA. (2019). Renewables 2019. IEA.

IEA. (2020). CCUS in Clean Energy Transitions — Analysis. IEA.

IEA (2021). Ammonia Technology Roadmap. IEA, Paris.

IEA. (2023a). Primary chemicals. IEA.

IEA. (2023b). Tracking chemicals. IEA.

IEA. (2023c). World Energy Balances [dataset].

IEA. (2024). Global hydrogen review 2024. IEA.

IEA. (2025a). Greenhouse Gas Emissions from Energy Data Explorer. IEA.

IEA. (2025b). Renewables 2025. IEA.

IEA. (2025c). Renewables for Industry. IEA.

IEA. (2025d). World Energy Outlook 2025. IEA.

IEA. (2026a). Global hydrogen review 2026. IEA.

IEA. (2026b). Tracking chemicals. IEA.

Jones et al. (2025). Annual greenhouse gas emissions including land use (with major processing by Our World in Data) [dataset].

KEI. (2025). Grundstoffchemische Industrie. Kompetenzzentrum Klimaschutz in energieintensiven Industrien.

Larrinaga, P., et al. (2021). Evaluation of the theoretical, technical and economic potential of industrial waste heat recovery in the Basque Country. Journal of Cleaner Production, 312, 127494.

Li, S., Wang, P., & Xue, Y. (2022). Transforming China's Chemical Industry — Pathways and outlook under the carbon neutrality goal. Rocky Mountain Institute.

Meng, F., Wagner, A., Kremer, A. B., Kanazawa, D., Leung, J. J., Goult, P., Guan, M., Herrmann, S., Speelman, E., Sauter, P., Lingeswaran, S., Stuchtey, M. M., Hansen, K., Masanet, E., Serrenho, A. C., Ishii, N., Kikuchi, Y., & Cullen, J. M. (2023). Planet-compatible pathways for transitioning the chemical industry. PNAS, 120(8), e2218294120.

Myhre, G. et al. (2013). Anthropogenic and Natural Radiative Forcing. In Climate Change 2013: The Physical Science Basis (IPCC AR5, Working Group I), Cambridge University Press, pp. 659–740.

Naegler, T., Simon, S., Klein, M., & Gils, H. C. (2015). Quantification of the European industrial heat demand by branch and temperature level. International Journal of Energy Research, 39(15), 2019-2030.

OECD (2022). Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options. OECD Publishing, Paris.

Office for National Statistics. (2026). Atmospheric emissions: Greenhouse gases by industry and gas [dataset].

SBTi. (2025). SBTi Chemical sector pathways and implementation criteria in brief.

SBTi. (2026). Target dashboard — Science Based Targets. Science Based Targets Initiative.

Sun, B., Mate, M., Li, T., Zhang, T., Fan, T., Fu, D., & Wang, K. (2026). Recent technology advances and commercialization on green methanol synthesis. Resources, Conservation and Recycling, 227, 108750.

SYSTEMIQ, & Center for Global Commons, University of Tokyo. (2022). Planet positive chemicals — Pathways for the chemical industry to enable a sustainable global economy. Systemiq, Center for Global Commons, The University of Tokyo.

Trading Economics. (2026). EU Natural Gas — Price — Chart — Historical Data — News.

VCI. (2025). The German Chemical Industry in Figures Online. VCI Online.

World Economic Forum (2023). Net-Zero Industry Tracker 2023. World Economic Forum, Geneva.

Zakkour & Cook (2010). CCS Roadmap for Industry: High-purity CO2 sources Sectoral Assessment. UNIDO.

Just like 4,000 companies, they have entrusted Greenly with their Carbon Footprint



To find out more or to meet a Greenly expert

Website: www.greenly.earth

Contact: contact@greenly.earth



Book a demo

greenly.earth