European Environment Agency

Zero-pollution, decarbonisation, and circular economy in energy-intensive industries

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This briefing presents key air pollutant trends and projections for energy-intensive industries in Europe. It also discusses greenhouse gas (GHG) emission trends over the past two decades. It outlines technology pathways and opportunities for industrial transformation related to zero pollution, decarbonisation and circularity in the context of the Clean Industrial Deal (CID).

Key messages

- Over the last 20 years, total GHG emissions from energy-intensive industries fell by 42%, SO_x by 63%, dioxins by 62%, nickel (Ni) by 64% and NO_x by 55%. Gross Value Added (GVA) remained relatively stable but declined after 2020.
- Progress in reducing emissions has stalled over the past decade. The external costs of these emissions are mainly health-related and remain high — at around EUR 73 billion annually.
- To achieve more reductions, environmental legislation needs to be fully implemented and emission-intensive processes require transformative change — while striving for the EU's sustainable competitiveness ambitions.
- Circularity and decarbonisation — in particular electrification — offer significant co-benefits for pollution prevention. A clear understanding of these co-benefits and risks should be used to guide investments and maximise environmental, health and competitiveness gains.

Challenges and opportunities for the energy-intensive industries in Europe

Energy-intensive industries are vital for the EU economy. They produce intermediate goods that are essential across numerous value chains — including those critical for the green transition, EU security and international trade. Together, these sectors account for 19.7% of GVA in EU manufacturing (Eurostat, 2025a). However, they also typically use high levels of energy, accounting for more than 60% of total energy consumption across all the manufacturing sectors (Eurostat, 2025b). This vulnerability has negatively impacted their competitiveness during the EU energy crisis, compounding existing challenges related to weak demand and global overcapacity in sectors such as steel. In the EU, electricity still costs two to four times as much as it does for the EU's main trading partners (EC, 2025a).

Given the strategic role of these sectors in strengthening the EU's independence in a volatile political climate, tailor-made action plans have been developed under the CID to strengthen their competitiveness. The CID also recognises the role of decarbonisation in driving sectoral growth.

As highlighted by this briefing, energy-intensive industries account for not only a significant share of GHG emissions but also other key air pollutants which have a substantial external cost to EU society. Supporting transformation in these sectors towards decarbonisation, pollution prevention and circularity would therefore offer multiple benefits for the environment and public health, while strengthening the EU's overall competitiveness by reducing societal costs.

This briefing presents the progress made over the past two decades, explains why further progress is needed and highlights the importance of considering the opportunities and risks of various transformation pathways.

For the purposes of this briefing, 'energy-intensive industries' refers to sectors classified under NACE codes 17, 20, 22, 23 and 24. They are:

- iron and steel;

- cement and lime;
- aluminium;
- pulp and paper;
- glass and clay;
- chemicals.

External cost of air pollution and GHG emissions

Despite progress in reducing emissions and EU frameworks to address externalities from industrial activities, the costs of industrial activity remain high[1].

The European Environment Agency (EEA), together with the European Topic Centre for Health and Environment, uses an impact pathway approach to estimate these costs. This approach[2] estimates 'marginal damage costs' per metric tonne for key pollutants[3]. These have been used to estimate the external costs of energy-intensive facilities using emissions data from the European Industrial Emissions Portal[4].

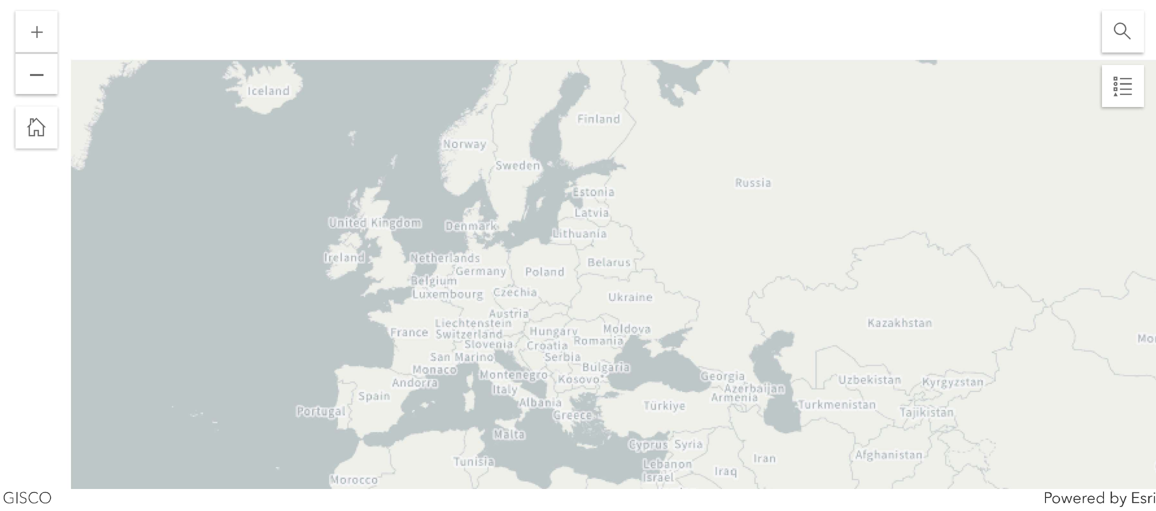
According to the EEA (2024a), external costs from energy-intensive industries fell by 23% from 2012 to 2021. Yet in 2021 they still amounted to over EUR 73 billion (see note on potential underestimation of this figure under Map 1). The majority of these costs are linked to impacts on human health. The non-metallic minerals sector (cement, lime, glass and ceramics) accounted for the largest share of external costs at 31% of the EUR 73 billion, followed by ferrous metals (24%) and chemicals (19%).

Across all the energy-intensive sectors, carbon dioxide (CO_2) was responsible for 58% of the external costs, NO_X 12% and sulphur dioxide (SO_2) 11%. These three substances are also responsible for the highest external costs in the non-metallic minerals sector.

The map below illustrates various high-cost hotspots across Europe. It highlights both the uneven burden of external costs associated with key air pollutants and the importance of region-specific policies and measures.

The hotspots can be found in Flanders, northern France, the Ruhr area and parts of Poland. There are other facilities with high external costs in northern Spain, southern Italy, southern France, the Netherlands and central Germany. Some countries, including Czechia and Slovakia, are missing from the analysis.

Map 1. External costs of air pollution and GHG emissions from energy-intensive facilities, 2021



GHG and air pollutant emissions from energy-intensive industries

Data on industrial emissions can help guide the design of targeted abatement policies and measures. Relevant knowledge includes the share of emissions for each pollutant from energy-intensive industries in comparison with other sources, as well as each sector's individual contribution to these pollutants.

Energy-intensive industries account for just under 27% of total industry GHG emissions (CO_2e), while they contribute over 63% of Pb, 56% of total PAHs, 35% of SO_X and 31% of NO_X[5] (Figure 1). Notably, the share of various pollutants emitted by energy-intensive industries — compared to total industry emissions — is often higher than their share of total GHG emissions.

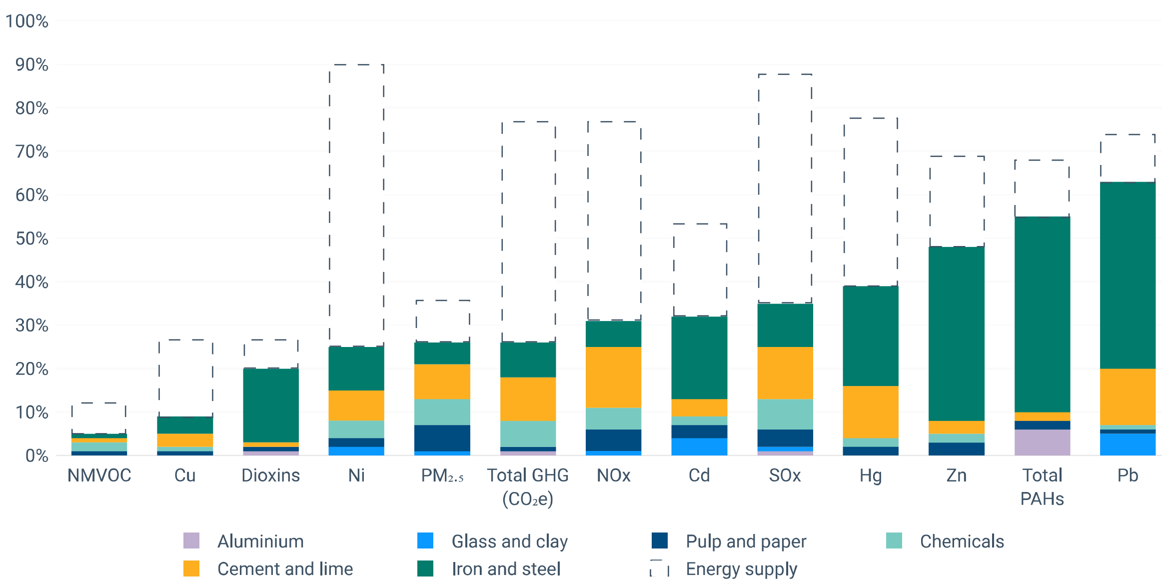
The iron and steel sector stands out as the largest source of several key pollutants in a sector-specific analysis. These pollutants include cadmium (Cd), copper (Cu), mercury (Hg), Ni, Pb, dioxins, total PAHs and zinc (Zn). For Pb, total PAHs and Zn, the sector contributes as much as 43%, 45% and 40% of the total emissions from all energy-intensive industries, respectively. Meanwhile, the chemicals sector — followed by pulp and paper — is the main contributor across the energy-intensive sectors of non-methane volatile organic compounds (NMVOCs). Cement production is the leading source of NO_X and SO_X (Figure 1).

These differing emissions profiles highlight the need for sector-specific measures to address the most critical sources of pollutants, whether they derive from combustion, feedstock impurities, the handling of raw materials or chemical processes within a plant.

Considering GHGs and air pollutants together also makes it possible to identify measures that can address multiple pollutants. For instance, clinker substitutes in the cement sector — depending on the material used — can mitigate emissions of CO_2, Hg, Pb, SO_X, and to some extent NO_X and fine particulate matter ($PM_{2.5}$) – all for which cement production is a key emitter. Similarly, electrifying the production of process heat — such as through electric furnaces in the steel sector — can reduce GHG emissions while also lowering emissions of relevant pollutants like SO_X at the stack level.

Figure 1 gives an overview of the sectoral shares of pollutants emissions from energy-intensive industries. The proportion of emissions from the power sector and refineries is included for comparison and is represented as a dotted line under 'Energy supply'.

Figure 1. CO_2e and other pollutant emissions by energy-intensive industries as a percentage of industry total for the EU-27, 2023



Significant progress in emissions reductions followed by recent stagnation

There has been substantial progress in reducing emissions from energy-intensive industries over the past two decades. Significant decreases have been observed in GHGs and all the assessed air pollutants, though there has been some stagnation and fluctuation in year-on-year emissions. Figure 2 shows the sectoral emissions trends for GHGs and key air pollutants between 2005 and 2023.

Air pollutants: The largest decreases can be seen in NO_X emissions (-1,056kt representing a 55% decrease), SO_X emissions (-1,010kt representing a 63% decrease), dioxins (-62%) and Ni (-64%). Despite these reductions, the relative share of emissions from energy-intensive industries compared to the industry total (which, in this briefing, includes the power sector) remains high for key pollutants.

In 2023, energy-intensive industries were responsible for between 5% and 63% of selected major air pollutant emissions from industry as a whole in the EU[6]. Emissions decreased at different speeds depending on the pollutant and sector. Of these, NMVOCs are notable for having decreased less than 10% since 2005 in the cement and lime, and pulp and paper sectors, whereas SO_X have decreased significantly across all energy-intensive sectors.

GHG emissions: According to inventory data, GHG emissions from energy-intensive industries fell by 42% between 2005 and 2023. Over the same period, these GHG emissions remained broadly stable as a share of the EU total, declining only slightly from 16% to 14%. The largest cuts in GHG emissions over this period came from the chemicals sector, followed by aluminium, and pulp and paper; these sectors each reduced their GHG emissions by about half.

When looking at the pace of progress over time, GHG emission reductions stagnated somewhat in several sectors from 2013 to 2021, compared to the period from 2005. It should be noted that this does not take into consideration the emissions associated with purchased electricity.

In the last two years there has been a more noticeable decrease in GHGs and most pollutants, especially in the aluminium, pulp and paper, and chemicals sectors. GHG emissions in those three sectors decreased by 49%, 45% and 51%, respectively, between 2005 and 2023. Combustion-related pollutants such as NO_X and SO_X have decreased similarly to GHGs in these sectors in the last two years.

Although it is difficult to attribute these reductions to specific drivers, one notable pattern is that the combined GVA of energy-intensive industries (Figure 2) remained broadly stable while emissions fell, indicating a positive decoupling from economic activity within the sectors. While GVA is not a direct measure of physical output, this divergence nonetheless reflects fuel and process-driven improvements. However, the post-2020 decline in GVA coincides with more pronounced emission reductions in most sectors, pointing to an increasing role of structural economic shifts.

Figure 2. Historical EU GHG and air emission trends in selected energy-intensive industries, 2005-2023

Policy developments and impacts for industrial transformation

The two policies with the most direct impact on the environmental performance of energy-intensive industries — the Industrial and Livestock Rearing Emissions Directive (IED) and EU Emissions Trading System (EU ETS) — were revised in 2024 and 2023, respectively.

A revised IED to strengthen industrial transformation

The objective of the revised IED (IED 2.0) is to prevent and reduce industrial emissions of pollutants to air, water and land, including NO_X, SO_2, $PM_{2.5}$ and NMVOCs. It further aims to improve resource efficiency and to promote the use of less hazardous substances, a circular economy and decarbonisation. The IED 2.0 sets a framework for issuing permits based on Best Available Techniques (BATs) and consistent environmental requirements for operators.

A key feature of the IED 2.0 is its additional flexibility in issuing permits; the aim of this is to stimulate the adoption of emerging techniques and achieve 'deep industrial transformation'[7] to contribute to a sustainable, clean, circular, resource-efficient and climate-neutral economy. The European Innovation Centre for Industrial Transformation and Emissions (INCITE) was established in 2024 to support this process by identifying and mapping emerging technologies.

In addition, sectoral reference documents — also known as BAT reference documents or BREFs — will be developed and updated in the coming years. Current versions include BAT-associated emission levels, except for greenhouse gas emissions which are regulated under the EU ETS. The documents are now expected to include 'environmental performance limit values'[8] and benchmarks for industrial installations. These will enable more comprehensive BAT conclusions to be drawn.

The Industrial Emissions Portal Regulation requires collection of data from industrial operators on their water, energy and raw material consumption from 2028. These data will complement information on industrial emissions to air and water, waste transfers and production volumes, thereby strengthening transparency and enabling more systematic assessment of industrial resource use and impacts.

Air pollutant emissions are expected to decrease significantly with strong policy implementation

According to a 2023 analysis (Logika Group and IIASA, 2023), full implementation of BAT measures in energy-intensive industries would result in significantly higher emissions reductions for SO_2 (over 74%) and NO_X (over 70%) by 2050 than a business-as-usual (BAU) scenario, using 2020 as a baseline year (Figure 3). For $PM_{2.5}$ and NMVOCs, less significant emissions reductions are expected — 55% and 35%, respectively. For these pollutants, additional measures are required and policy implementation needs to be strengthened to align with the EU's zero pollution vision for 2050.

The analysis also revealed that the decarbonisation of industrial and electricity sectors is expected to play a significant role in reducing air pollution during this period (Logika Group and IIASA, 2023). Although the electricity sector is outside the scope of this briefing, it is referenced here because its decarbonisation is an enabler of the green transformation of other industrial sectors. For instance, many industrial processes, especially those requiring low- to medium-temperature heat, can be electrified using technologies like heat pumps and electric boilers. These technologies are more energy efficient and can significantly reduce reliance on fossil fuels.

Figure 3. Potential impact of the IED 2.0 on future air pollutant emission trends from energy-intensive industries, 2020-2050

The EU ETS as the main driver of decarbonisation in energy-intensive industries

Implementing BATs may result in co-benefits for GHG emission reduction — though the potential contribution has not been quantified. Industrial installations covered by the IED 2.0 — relevant for more types of industrial activities than those considered energy intensive — account for 40% of all EU GHG emissions (EC, 2025c). However, the EU ETS remains the most significant policy for decarbonising energy-intensive industries in a cost-effective manner.

The EU ETS sets a price on emissions and implements a gradually decreasing cap on emissions from large industrial installations. Through this mechanism, it aims to encourage operators of energy-intensive industries to lower their GHG emissions. Improvements can be made through energy efficiency, the adoption of low-carbon energy sources and electrification. Energy-intensive industries have been exempted to a certain extent; they receive free allowances to enable the transition to take place gradually and to address the risk of carbon leakage. A less generous allocation of free allowances creates a stronger incentive to reduce emissions (Dechezleprêtre et al., 2023).

In October 2023, new rules were adopted requiring climate neutrality plans. Under these rules, the industrial operators of the 20% of installations which are least efficient must prepare a plan for how they will reduce their emissions. They will then be granted free allocation of emission allowances at the full benchmark level, which reflects the performance of the most efficient installations in the sector. Free allocation will be phased out entirely by 2034 for sectors covered by the Carbon Border Adjustment Mechanism, including steel, cement and aluminium[9].

Opportunities for strengthened regulatory support for circularity

Energy-intensive industries are not currently subject to quantitative targets for material recycling and recovery (beyond the EU-wide recycling targets for downstream products such as paper and cardboard, glass, aluminium, steel products from post-consumer waste and other product groups). This means that there is no strong regulatory signal for industry to invest in circular production routes and limited integration of circularity in industrial decarbonisation pathways.

Circular economy policies — including the upcoming Circular Economy Act, the Packaging and Packaging Waste Regulation and the revised End-of-Life Vehicles Directive — aim to improve supply and demand for secondary raw materials and to create better-functioning markets for these materials. In turn, this should increase the share of such materials being used as input materials for energy-intensive industries.

The Critical Raw Materials Act also includes ambitions to increase circularity, for example by introducing benchmarks for recycling capacity with the aim of increasing the share of strategic raw materials supplied through recycling.

The new-generation BATs, as defined in the IED 2.0, will aim for quantitative targets for resource efficiency at the sectoral level. They may also allow environmental performance limit values to be set; these would better incorporate circular economy principles and be reflected in permit conditions.

Synergies for industrial decarbonisation, zero pollution and circularity

The Clean Industrial Deal was launched in February 2025. It positions industrial decarbonisation — and to some extent circularity — as a strategic lever for competitiveness. A broad range of instruments in the CID aim to boost the production of EU-made cleantech, mobilise funds for industrial transformation and reduce energy costs, among other things.

The deal will enhance industry's access to clean energy and address affordability issues to incentivise electrification. These measures will contribute to the positive impact that fossil fuel phase-out has already had on preventing emissions and air pollutants.

The CID includes commitments to streamline and speed up permitting, helping to accelerate the deployment of cleaner fuels, electrification or cleaner production processes in energy-intensive industries. By embedding robust environmental safeguards within the mechanisms for procurement, funding and issuing permits, the deal can promote an integrated approach that aligns industrial transformation with pollution prevention and broader environmental goals.

The Clean Industrial Deal offers an opportunity to optimise industry's transition to strengthen the competitiveness and resilience of the EU economy; it also has positive implications for air pollutant co-benefits. Research consistently shows that the societal benefits of avoiding air pollution often outweigh the costs of pollution control measures (EEA, 2024a; CREA, 2023).

According to a recent study from the European Commission (EC) (EC et al., 2025), setting permit conditions at the strictest achievable levels under the IED 2.0 could deliver annual benefits of around EUR 27 billion. This far exceeds the benefits of applying less stringent emission limits or granting derogations that fall short of the IED 2.0's full potential.

Meanwhile, pollution control and prevention in the EU represents a major investment gap. Member States currently underspend on this by EUR 35 billion per year (EC, 2025b). Given that resources are limited, a cost-effective strategy would be to maximise synergies between climate mitigation, pollution prevention and circularity.

An approach like this would need to anticipate trade-offs and unintended impacts to mitigate resource conflicts or burden-shifting. Historical sector-level data show how these dynamics can be complex. For example, in the pulp and paper sector, emission intensity dropped by 70% for Ni and SO_X between 2000 and 2021, while increasing for dioxins and NMVOC's. This illustrates how technological shifts can present trade-offs between pollutants.

The table below summarises key technological pathways along with associated synergies and challenges, focusing on technological measures at the facility/production level. It does not take into consideration upstream or downstream solutions across the value chain for energy-intensive sectors, such as demand-side measures, sustainable design and circular business models. It is important to keep in mind that pathways and technological options have different feasibility and relevance depending on the specific sector.

Table 1. Selection of key technological pathways for greening energy-intensive industries

Pathway	Examples	Synergies	Risks/Challenges
Electrification	• Electrification of high-temperature heat (with electric arc furnaces, induction furnaces, electric calciners/kilns) • Electrification of low-and medium-temperature heat (with electric boilers, heat pumps and steam crackers) • Electrification of cross-cutting process equipment (pumps, compressors, chillers, auxiliary systems) • Green hydrogen direct reduced iron • Electrolysis of iron ore • Electrowinning in non-ferrous metallurgy	• Lower local levels of air pollutants (NO_X, SO_X, particulate matter) from fossil fuel combustion • Reduced CO_2 when electricity is green • Potential flexibility in terms of demand response • Enabling of recycling-friendly processes (e.g. electric arc furnaces for scrap steel) • Possible energy savings • Reduced water use in thermal systems	• High up-front investments for certain electrification technologies • A common requirement for significant changes in process and plant setups • Emission reduction benefits are dependent on the use of low-carbon electricity • Dependent on stability and capacity of electrical grid • Demand for renewable energy infrastructure, supply and storage • Increased indirect demand for rare minerals
Alternative fuels	• On-site renewable energy production • Biomass boilers • Hydrogen or biomass integration in cement kilns • Hydrogen oxy-fuel burners for glassmaking • Black liquor combustion and gasification (pulp and paper)	• Reduced fossil fuel dependence and associated emissions • Improved energy security • Reduced exposure to volatile fossil fuel commodity prices	• Higher costs • Feedstock limitations • Operational complexity • Land competition (for biomass, renewables) • Potential local increases in concentrations of pollutants such as NO_X and SO_2 (e.g. from waste-to-energy) • Risk of hydrogen leaks (an indirect GHG) and safety issues • High demand for water for electrolysis
System optimisation and efficiency	• Digitalisation • Heat recovery systems • Variable speed drives • High-efficiency motors • Efficient furnace design • Direct and indirect batch preheating • Superheated steam drying • Novel anode design and inert anodes in aluminium production • Energy-efficient material grinding	• Reduced use of energy, resources and water • Reduced emissions and waste across air, water and land • Reduced demand for cooling water	• Potential rebound effects such as additional consumption enabled by efficiency gains • Short life spans of digital technologies • Risk of prolonging lifetimes of fossil-based technologies via marginal improvements

Pathway	Examples	Synergies	Risks/Challenges
Alternative feedstock and materials	• Low-carbon iron ore (e.g. pellets) • Supplementary cementitious materials in cement • Use of sustainably sourced bio-based raw materials • PFAS alternatives • Sustainable sourcing of high-quality sand • Hydrogen as a reducing agent in steelmaking • Green hydrogen in ammonia (NH_3) production	• Lower process emissions • Potential for industrial symbiosis • Reduced ecosystem disruption (depending on the material)	• Supply chain complexity due to sourcing challenges, variable availability and the need for new processing or logistics infrastructure • Potential quality and safety trade-offs • Concerns about conflicting land use and biodiversity (for bio-based materials)
Circularity	• Use of secondary raw materials (e.g. glass cullet, scrap steel) • Use of by-products (e.g. blast furnace slag in cement production) • Closed-loop water circuits • Water recycling in cooling systems • Leakage control	• Reduced use of energy, material resources and water • Reduced impact from primary extraction • Reduced emissions and waste across air, water and land	• Potential quality and safety trade-offs • Increased use of recycled glass in glass furnaces can increase SO_X emissions • Potential accumulation of pollutants in closed-loop systems (higher operational costs for maintenance)
Carbon removals	• Amine-based capture at kilns • CO_2 capture in the production of NH_3 and ethylene oxide (relatively pure CO_2 streams) • CO_2 capture from the combustion of bioenergy at pulp and paper mills • Post-combustion capture (amine, calcium looping) • Cement recarbonation	• Use of CO_2 as a raw material • Can be combined with abatement technology (e.g. for SO_X) in some systems	• High additional energy requirements and associated pollutant emissions • Risk of increased NO_X • Risk of prolonging the use of fossil fuels and feedstocks • Risk of temporary as opposed to permanent carbon storage, depending on the use case • Emissions associated with amine slip • Possible groundwater contamination • Long-term CO_2 storage risks • Additional waste streams
Pollution management	• Scrubbers • Oxy-fuel burners • High-efficiency particulate air filters	• Improved local air quality • Protection of ecosystems and health	• Potentially hazardous solid and liquid waste • Energy use • Does not address CO_2 unless combined with carbon capture and storage

Sources: EU sectoral transition plans and strategies (see reference list)

Selected examples of synergies and risks associated with specific pathways are elaborated below to illustrate the context-specific dynamics.

Coal phase-out: Phasing out coal as a fuel has reduced and continues to reduce GHG emissions. Coal phase-out also leads to lower levels of air pollutants such as SO_2, NO_X and particulate matter (PM). However, coal is also used as a feedstock in industry. In fact, the steel industry's reliance on coking coal contributes indirectly to methane (CH_4) emissions, primarily through coal-mining activities. CH_4 is a potent GHG and a precursor of ground-level ozone, causing respiratory diseases and premature deaths. Reducing the use of coking coal, for example by switching to hydrogen-based steelmaking, has the potential to mitigate various negative health and environmental effects (EEA, 2025d).

Alternative fuels (biomass): Increased use of biomass can elevate $PM_{2.5}$, NO_X and ammonia (NH_3) levels (Zauli-Sajani et al., 2024; Wood E&IS GmbH, 2021). In fact, while it is projected that total emissions from sectors regulated by the IED 2.0 will decrease, the rapid increase in biomass combustion is expected to contribute to an overall increase in SO_2 and NO_X emissions in sectors such as cement, lime and glass production (Logika Group and IIASA, 2023). As such, while balanced biomass use can help to reduce GHG emissions it may still result in or even increase emissions of other pollutants. As highlighted by the EU's new bioeconomy strategy it may be better to promote high-value uses of biomass, such as bio-based materials, rather than its use for fuel.

Alternative feedstock/circularity: In order to achieve transformational decarbonisation of energy-intensive sectors, the energy supply and process-related emissions must both be addressed. For instance, 60% of GHG emissions from the cement sector are released in the chemical process of limestone calcination (JRC, 2023). Opportunities related to alternative production processes and materials — such as reducing the clinker-to-cement ratio — result in co-benefits beyond decarbonisation, like reduced limestone extraction, decreased air pollution from reduced kiln use and enhanced circularity of industrial by-products. One of the aims of circularity is to promote long-lived products, slowing material cycles and lowering demand for virgin resources, while cutting energy use and the associated emissions (EEA, 2024d).

Carbon capture: Carbon capture and storage (CCS) can offer certain air pollution co-benefits. However, it may also increase emissions of pollutants such as PM and NO_X due to the extra energy required by the process. In addition, emissions of NH_3 could increase by a factor of three or more as a result of the degradation of amine-based solvents used in CO_2 capture (EEA, 2020). Currently the most common and widely deployed CCS uses amine-based solvents.

However, newer solvent systems aim to reduce such emissions. Emissions could be abated through pre-combustion CCS or simultaneous investments in desulphurisation and denitrification technologies which could be taken into consideration in the total cost of the technology. While CCS is technically feasible and several pilot and commercial projects exist, its deployment in energy-intensive industries remains limited. Widespread adoption is still constrained by high costs, infrastructure requirements and regulatory hurdles.

Conclusions

While the EU advances parallel policies on reducing pollution, mitigating GHGs and enhancing circularity for energy-intensive industries, it is crucial that the impacts of various pathways towards these goals are fully understood and exploited to maximise synergies. The Clean Industrial Deal offers a strategic framework to support decarbonisation and circularity efforts; integrating pollution prevention more explicitly will maximise the societal benefits — with an estimated value of billions of euros annually — while also addressing significant investment gaps in pollution control.

Historical evidence demonstrates that technological shifts typically provide co-benefits but can also create trade-offs between pollutants, underscoring the need for careful, sector-specific approaches. Decarbonisation policies and project support should aim to identify solutions with the greatest potential to deliver co-benefits for pollution prevention and circularity. Such solutions and pathways will help to avoid missed opportunities to reduce emissions at the lowest possible cost. An integrated perspective could be further extended when determining funding criteria for projects, developing new frameworks for issuing permits, or setting sustainability standards and procurement criteria for products such as low-emission steel.

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Footnotes

1. Externalities are the unintended costs of an activity (e.g. relating to factory waste or emissions) that affect society but are not included in product prices.
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2. The approach and scope of impacts for air pollutants are described in Box 2 of the briefing 'The costs to health and the environment from industrial air pollution in Europe — 2024 update'.
↵
3. The main air pollutants are: NOX, sulphur dioxide (SO2), particulate matter (PM) and non-methane volatile organic compounds (NMVOCs); GHGs include: carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O); heavy metals include: arsenic (As), cadmium (Cd), hexavalent chromium (CrVI), mercury (Hg), Ni and Pb; the organic pollutants are: benzene, dioxins and furans.
↵
4. European Industrial Emissions Portal.
↵
5. This share takes 'energy supply' (power plants, refineries and solid-fuel manufacturers) as well as 'waste management' to be a part of 'total industry'. This alters the share of emissions that energy-intensive industries are responsible for compared to calculations which do not include 'energy supply'
↵
6. Energy-intensive industries' share of total EU industrial emissions for each pollutant in 2023: Pb (63%), total PAHs (56%), Zn (49%), Hg (39%), SOX (35%), Cd (32%), NOX (31%), PM2.5 (26%), Ni (24%), dioxins (20%), Cu (9%) and NMVOCs (5%). Energy-intensive industries' share of total EU industrial emissions for each pollutant in 2005: Pb (70%), total PAHs (68%), Zn (52%), Hg (39%), Cd (36%), PM2.5 (29%), NOX (27%), Cu (16%), Ni (14%), SOX (13%), dioxins (11%) and NMVOCs (5%).
↵
7. 'Deep industrial transformation' is defined in the IED 2.0 as the 'implementation by industrial operators of emerging techniques or BATs involving a major change in the design or technology of all or part of an installation or the replacement of an existing installation by a new installation, which allows an extremely substantial reduction of emissions in line with the objective of climate neutrality and optimises environmental co-benefits'.
↵
8. Environmental performance limit values are a new element of the IED and are quantitative permit-specific ranges or limits that cover a wider range of environmental performance aspects.
↵
9. This is potentially subject to change with the upcoming EU ETS review
↵
10. This category includes: 2.B.1 — Ammonia production; 2.B.2 — Nitric acid production; 2.B.3 — Adipic acid production; 2.B.4 — Caprolactam, glyoxal and glyoxylic acid production; 2.B.5 — Carbide production; 2.B.6 — Titanium dioxide production; 2.B.7 — Soda ash production; 2.B.8 — Petrochemical and carbon black production; 2.B.9 — Fluorochemical production; and 2.B.10 — Other chemical industry.
↵

Annex

Mapping and scope coverage for the activity categories used for the dataflows in this briefing

In all cases the geographic scope is the EU-27.

Contextual information in introductory paragraphs

Energy use data: taken from Eurostat, 2024, 'Final energy consumption in industry — detailed statistics' and based on the Eurostat data set: 'Simplified energy balances' (last updated 28 April 2024).

Final energy consumption data in this data set were extracted for the following: 'Chemical and petrochemical industry', 'Non-metallic minerals', 'Paper, pulp and printing' and 'Iron and steel'. The same Eurostat analysis points out that industry as a whole accounted for 25.1% of final energy consumption in the EU in 2022. This figure was used to calculate the percentage of energy use from energy-intensive industries in the total.

GVA data: taken from Eurostat data set: 'Gross value added and income by detailed industry (NACE Rev.2)' (last updated 25 November 2025).

NACE categories used:

- C16-18 — Manufacture of wood, paper, printing and reproduction;
- C20 — Manufacture of chemicals and chemical products;
- C22 — Manufacture of rubber and plastic products;
- C23 — Manufacture of other non-metallic mineral products;
- C24 — Manufacture of basic metals.

There are more granular NACE categories but GVA data are not available at that level of detail for all the NACE codes needed. For C20, the EU-27 figure is confidential. The total has been obtained by aggregating the national GVA for this NACE category for the 25 EU Member States where the data were available.

The reference year is 2023.

Map 1 External costs of air pollution and GHG emissions from energy-intensive facilities, 2021

External costs of air pollution and GHG emissions from energy-intensive facilities, 2021

The damage cost data are based on: EEA (2024a), 'The costs to health and the environment from industrial air pollution in Europe — 2024 update', EEA Briefing No 24/2023

Facility emissions are based on E-PRTR data, which are bottom-up and therefore include all emissions at the facility (combustion and process emissions). Conversely, indirect energy emissions (i.e. when using electricity from fossil fuel sources from the grid) are excluded as they are emitted by thermal power plants.

Table A1 E-PRTR Annex I activities included in the damage cost numbers for energy-intensive industries and Map 1

E-PRTR activity code	E-PRTR activity name
2(a)	Metal ore (including sulphide ore) roasting or sintering installations
2(b)	Installations for the production of pig iron or steel (primary or secondary melting) including continuous casting with a capacity of 2.5 tonnes or more per hour
2(e)	Installations for the production and/or smelting of non-ferrous metals
3(c)	Cement and lime
3(e)	Glass and glass fibre
3(f)	Installations for melting mineral substances, including the production of mineral fibres
3(g)	Installations for the manufacture of ceramic products by firing, in particular roofing tiles, bricks, refractory bricks, tiles, stoneware or porcelain
4(a)	Basic organic chemicals
4(b)	Basic inorganic chemicals
4(c)	Phosphorous-, nitrogen- or potassium-based fertilisers (simple or compound fertilisers)
4(d)	Basic plant health products and of biocides
6(a)	Industrial plants for the production of pulp from timber or similar fibrous materials

E-PRTR activity code	E-PRTR activity name
6(b)	Industrial plants for the production of paper and board and other primary wood products (such as chipboard, fibreboard and plywood)

Figure 1 CO_2e and other pollutant emissions by energy-intensive industries as a percentage of industry total for the EU-27, 2023

These data are based on the reported national emissions inventory data detailed below:

Air pollutant emissions: taken from EEA, 2025a, 'National Emission reductions Commitments (NEC) Directive emission inventory data, 1980-2023 ver 2.0' (accessed 6 July 2025). The reference year is 2023.

GHG emissions: taken from EEA, 2025b, 'EEA greenhouse gases — data viewer' (accessed 7 July 2025).

The graph shows the contribution to pollution from several pollutants and for all GHGs (expressed as CO_2e). This is compared to emissions from 'Energy supply' which are given as a dotted line for comparison. For energy-intensive industries, the mapping of Common Reporting Framework (CRF) vs Nomenclature for Reporting (NFR) categories is given below.

Table A2 Mapping of CRF categories vs categories used for the briefing

CRF reporting category (GHG inventory)	Categorisation in the briefing
1.A.2.a — Iron and steel (combustion)	Iron and steel
1.A.2.b — Non-ferrous metals (combustion)	Aluminium
1.A.2.c — Chemicals (combustion)	Chemicals
1.A.2.d — Pulp, paper and print (combustion)	Pulp and paper
1.A.2.f — Non-metallic minerals (combustion)	Cement and lime
2.A.1 — Cement production (process emissions)	Cement and lime
2.A.2 — Lime production (process emissions)	Cement and lime
2.A.3 — Glass production (process emissions)	Glass and clay
2.B — Chemicals industry (process emissions)[10]	Chemicals
2.C.1 — Iron and steel production (process emissions)	Iron and steel
2.C.3 — Aluminium production (process emissions)	Aluminium

Table A3 Mapping of NFR categories vs categories used in the briefing, including both auto-generation of energy (on site) and process emissions, and excluding transport and handling

NFR	Sector name	Categorisation in the briefing
1A2a	Stationary combustion in manufacturing industries and construction: iron and steel	Iron and steel
1A2c	Stationary combustion in manufacturing industries and construction: chemicals	Chemicals
1A2d	Stationary combustion in manufacturing industries and construction: pulp, paper and print	Pulp and paper
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	Cement and lime
2A1	Cement production	Cement and lime
2A2	Lime production	Cement and lime
2A3	Glass production	Glass and clay
2B1	Ammonia production	Chemicals
2B2	Nitric acid production	Chemicals
2B3	Adipic acid production	Chemicals
2B5	Carbide production	Chemicals
2B6	Titanium dioxide production	Chemicals
2B7	Soda ash production	Chemicals
2B10a	Chemical industry: other	Chemicals
2C1	Iron and steel production	Iron and steel
2C2	Ferroalloys production	Iron and steel
2C3	Aluminium production	Aluminium
2H1	Pulp and paper industry	Pulp and paper

Tables A4a and A4b The NFR and CRF categories used under 'Energy supply'

NFR	Sector name	Categorisation in the briefing (Figure 1 only)
1A1a	Public electricity and heat production	Energy supply
1A1b	Petroleum refining	Energy supply
1A1c	Manufacture of solid fuels and other energy industries	Energy supply

NFR	Sector name	Categorisation in the briefing (Figure 1 only)
1B1b	Fugitive emissions from solid fuels: solid fuel transformation	Energy supply
1B2aiv	Fugitive emissions oil: refining/storage	Energy supply
1B2av	Distribution of oil products	Energy supply
1B2d	Other fugitive emissions from energy production	Energy supply

CRF category	Categorisation in the briefing (Figure 3 only)
1.A.1.a — Public electricity and heat production	Energy supply
1.A.1.b — Petroleum refining	Energy supply
1.A.1.c — Manufacture of solid fuels and other energy industries	Energy supply
1.B.1 — Solid fuels	Energy supply
1.B.2 — Oil and natural gas and other emissions from energy production	Energy supply

Figure 2 Historical EU GHG and air emission trends in selected energy-intensive industries, 2005-2023

Air pollutant emissions: The data are based on: EEA, 2025a, 'National Emission reductions Commitments (NEC) Directive emission inventory data, 1980-2023 ver 2.0' (accessed 6 July 2025). See mapping of reporting categories as for Figure 1 above.

GHG emissions: taken from EEA, 2025b, 'EEA greenhouse gases — data viewer' (accessed 7 July 2025). See mapping of reporting categories as for Figure 1 above.

GVA data: taken from Eurostat data set: 'Gross value added and income by detailed industry (NACE Rev.2)' (last updated: 25 November 2025).

NACE categories used:

- C16-18 — Manufacture of wood, paper, printing and reproduction;
- C20 — Manufacture of chemicals and chemical products;
- C22 — Manufacture of rubber and plastic products;
- C23 — Manufacture of other non-metallic mineral products;
- C24 — Manufacture of basic metals.

There are more granular NACE categories but GVA data are not available at that level of detail for all the NACE codes needed. For C20, the EU-27 figure is confidential. The total has been obtained from aggregating the national GVA for this NACE category for the 25 EU Member States where the data were available.

The reference year is 2023 and the trends are given for the 2005-2023 period.

Figure 3 Potential impact of the IED 2.0 on future air pollutant emission trends from energy-intensive industries, 2020-2050

Potential impact of the IED 2.0 on future air pollutant emission trends from energy-intensive industries, 2020-2050: This figure is derived from EEA data analysis based on Logika Group and IIASA (2023).

The work from Logika Group and IIASA was based on different scenarios of the GAINS model. Under these scenarios, emissions up to 2015 were based on NEC submissions whereas emissions from 2020 to 2050 were projected. In order to adapt the results of these scenarios to the latest NEC inventory data, the graphs were built using the following:

2020: EEA, 2025a, 'National Emission reductions Commitments (NEC) Directive emission inventory data, 1980-2023 ver 2.0' (for the year 2020).

2025 onwards: projected emissions based on Logika Group and IIASA, 2023, Analysis of air pollutant emission trends for EU energy intensive industry sectors (accessed 4 December 2025)For 2020, the NFR categories selected to represent energy-intensive industries are the same as for Figure 1 above. For the projected data (2025-2050), emission reductions were calculated as a relative decrease as modelled by Logika Group and IIASA (2023). For that project, a less granular sectoral classification was used. Therefore, the relative sector reductions in selected energy-intensive industries were obtained from these wider groups. Since the graphs show emissions from these industries as a whole, this approach did not need to account for uncertainties derived from a more aggregated sectoral classification in the projections.

Table A5 Mapping of energy-intensive industries and sector classification in projected data Figure 3

Categorisation in the briefing	Categorisation in Logika Group and IIASA (2023)
Iron and steel	2 Metals production
Non-ferrous metals or aluminium	2 Metals production
Cement and lime	3 Mineral industries
Chemicals	4 Chemical industries
Glass	3 Mineral industries
Ceramics	3 Mineral industries
Pulp and paper	6 Other activities

As noted above, emissions from energy generated on site were considered in the scope as well as process emissions; transport and handling (downstream) were excluded.