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SCIENCE FOR POLICY BRIEF

Mapping the transition of the EU glass manufacturing industry to carbon neutrality

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HIGHLIGHTS

- The EU glass industry is very diverse. Its decarbonisation trajectory is built to a different extent on key levers: electrification, fuel switching, circularity, and potentially Carbon Capture Utilisation and Storage (CCUS).
- Electric melting is critical for deep decarbonisation. While feasible for small furnaces (<200 tonnes/day), for electrification in large furnaces (average of 700 tonnes/day for flat glass), other production steps, and certain glass compositions, further innovation and demonstration are needed.
- Timely deployment is critical: furnace lifespans (10-20 years) mean investments made this decade, including in R&D and infrastructure, will define emissions until 2050.
- The long-term decarbonisation of the EU glass industry is technically feasible, but achieving it remains highly challenging due to significant technological, economic and other exogenous barriers that currently exist.

THE CHALLENGE

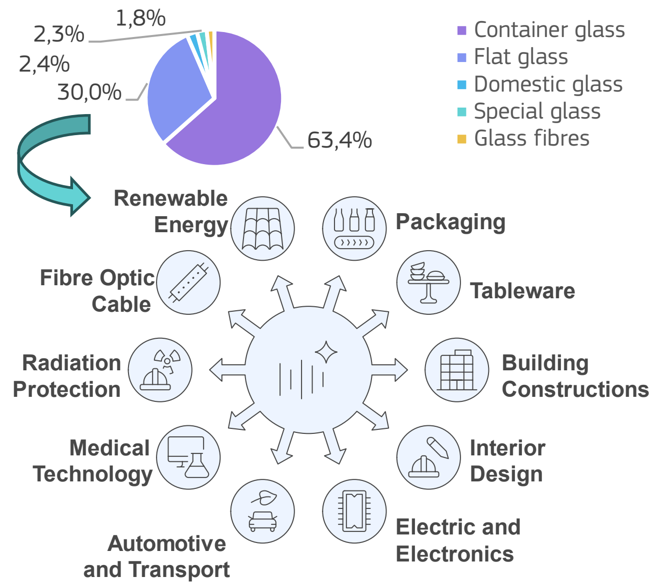
Introduction

The European Union (EU) ranks among the top global producers of glass and glass related products, alongside China and North America. It accounts for about one third of total global production, making it the world's largest single producing region. Germany leads EU production, followed by Italy, France, Spain and Poland. In the EU, there are around 400 glass production installations, from SMEs to large companies.

As a key and innovative contributor to the EU economy, the European glass industry produced 36.1 million tonnes of glass in 2024 [1], with annual emissions of approximately 22 million tonnes of CO_2 equivalent [2][3]. In 2024, the EU glass market was estimated at EUR 70 - 80 billion [1]. However, the sector faced challenges such as high energy costs and rising non-EU competition, including unfair practices such as dumping and state subsidies. In 2024, compared to the previous year (2023), overall glass production decreased by 4%. Employment in the industry has been gradually declining since 2019, and in 2024 it fell by 1.1% compared to the previous year, down to 176,000 workers [1].

The glass industry is composed of six rather diverse subsectors. The main glass subsectors, mostly referred to in this factsheet, are container glass (used in food, beverages, cosmetics, perfumes and pharmaceuticals) and flat glass (used in construction, automotive, solar panels and electronics). The other subsectors are domestic glass, special glass, continuous filament glass fibres, and mineral glass and stone wool insulation. Figure 1 below shows the distribution of the glass production in the EU and overview of the key glass applications based on 2024 data [1].

Figure 1 – 2024 production volumes breakdown (%) by glass industry subsectors with an overview of key glass applications



Note: % of output in tonnage terms

Source: JRC, based on reference [1]

Glass is essential not only for everyday products, but also for the transition to a climate-neutral circular economy, contributing to building construction and renovation, renewable energy, energy efficiency in buildings, sustainable transport, eco-friendly packaging, defence, and digitalisation (Figure 1) [4] [5].

Glass can be recycled an unlimited number of times without losing its quality, which makes it a highly sustainable and circular material. Glass remains one of the most recycled packaging materials, with an 74.9% recycling rate in the EU in 2023 [6].

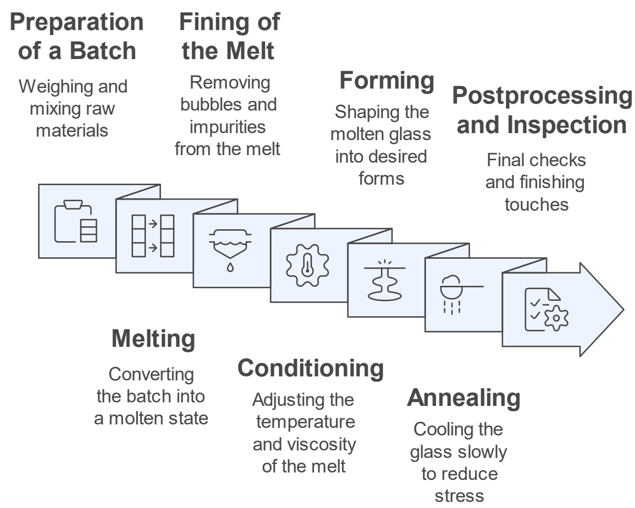
Each glass type can admit different amounts of recycled glass (cullet) in their manufacturing. For instance, mineral wool manufacturers use a high amount of recycled material, up to 60%, in the production of insulation materials [7].

Production process

Figure 2 shows an overview of the main steps of the glass manufacturing process. Industrial glass production is a highly energy-intensive process, comprising multiple stages that vary depending on the glass type, composition and application, as well as the scale of production [8].

Glass production relies on raw materials, such as silica sand, soda ash and limestone, with additives such as alumina and metal oxides to achieve desired properties[1]. These materials are categorised by their role in the glass structure and melting process, with silicon oxide (SiO_2) being the main network-forming constituent. Recycled glass (cullet) is a key source of silica. The batch is melted at 1000 – 1600°C to form molten glass, which then undergoes a series of process steps, such as refining/fining, conditioning, fiberizing, forming, annealing, curing, and cutting/finishing [8], depending on the glass sector and product type[2].

Figure 2 – Overview of the typical steps for the glass manufacturing process



Source: JRC, based on reference [8]

It is important to highlight that while these steps are typical for the production of most glass types, their relative importance in the complete process, and strategies and tools involved in the production process may differ greatly from one glass product do another (depending on the composition, product type and quantity). The theoretical minimum energy input required for glass melting is 2.6 GJ/tonne for soda-lime-silicate glasses [8]. Nevertheless, due to heat transfer limitations, the energy input is higher in real operations, ranging on average from 5.8 GJ/tonne for container glass to above 6.5 GJ/tonne for flat glass

[1] An exception is stone wool, which is mainly produced from volcanic materials and supplemented with limestone, dolomite, and significant shares of secondary raw materials including recycled stone wool briquettes and metallurgical slags

[2] Most of the industrially produced glasses are preparing using similar steps, as described. Nevertheless, depending on the glass type and the quantity produced, the processing and fabrication techniques employ may vary greatly from one glass type to another.

[8]. Natural gas supplies 75–85% of the sector's energy needs, followed by electricity (10–15%) and other fossil fuels (5–10%). Nevertheless, these levels may vary depending on the industry location. Electricity is mainly used by the compressors, used to provide air for the glass-forming process for container glass, and for electric boosting in the melting process, when applied [8] [9].

The melting process in container and flat glass accounts for 80–90% of total energy demand, mostly from natural gas burners. This may vary for other glass types, for instance, tableware and glass wool. Alternatives include heavy fuel oil, biogas, biomethane, electricity, and hydrogen (still under research). Furnaces using oxy-fuel combustion are present in certain glass sectors, and full electric furnaces are emerging as an option for some of them, although still limited by the furnace size and by glass compositions and colours.

Furnace type and fuel choice depend primarily on the availability of technologies, energy sources, and their associated costs. Heat recovery systems such as recuperators and regenerators are widely applied to improve efficiency. Glass melting furnaces typically last 10–20 years depending on the product. As only a maximum of 2-3 generations of furnaces can be updated by 2050, urgent innovation in furnace design and low-carbon melting technologies is critical [9]. Additionally, exogenous factors – such as the availability of carbon-neutral energy at competitive costs and supporting infrastructures – is essential for achieving decarbonisation goals.

Current CO_2 emissions

In 2022, the European glass industry emitted an estimated 22 million tonnes of CO_2 equivalent from direct sources [2][3]. The industry has already significantly reduced its CO_2 emissions per output by 43% between 1990 and 2020, mostly due to a fuel shift to natural gas, the increased use of secondary raw materials - recycled glass (cullet), and general efficiency improvements. It is estimated that 1 kg of glass in a natural-gas-fired furnace generates 0.4 to 0.6 kg of CO_2 in container and flat glass sectors. Around 75-80% of these emissions stem from fuel combustion in furnaces, while 20–25% arise from chemical reactions during melting, particularly from the decarbonation of raw materials [8] [10].

Policy targets and context

The flat glass sector is close to reducing emissions by at least 55% by 2030 compared to 1990 levels (43% was achieved in 2020), in line with the EU's "Fit-for-55" package under the European Green Deal. Recently, the European Commission has proposed an amendment to the EU Climate Law, setting a 2040 climate target of a 90% reduction in net greenhouse gases (GHG) emissions, compared to the 1990 levels.

Under the EU ETS, the glass industry is considered as being at risk of carbon leakage. Although it is not included in the first phase of the Carbon Border Adjustment Mechanism (CBAM) (policy mechanism that will replace the carbon leakage provision of the EU ETS), discussions are ongoing about its possible inclusion. Once/if that happens, the free allowances currently granted to the industry will be phased out gradually. Under the REPowerEU plan, the industry is encouraged to shift from natural gas towards less carbon-intensive energy sources such as renewable electricity (through electric or hybrid furnaces), renewable hydrogen, and biomethane. This transition supports EU objectives to reduce reliance on imported natural gas, cut emissions, and strengthen industrial sustainability.

The recent Clean Industrial Deal outlines concrete actions to turn decarbonisation into a driver of growth for European industries, focusing on energy intensive industries. Additionally, the EU Renovation Wave initiative is expected to boost demand for glass construction product. High-performance glazing can cut building energy use by up to 37%, making it a key solution for energy-efficient renovations [11]. Likewise, the Net Zero Industry Act is set to further increase demand for glass used in renewable energy technologies, such as solar panels and wind turbine components.

THE WAY FORWARD

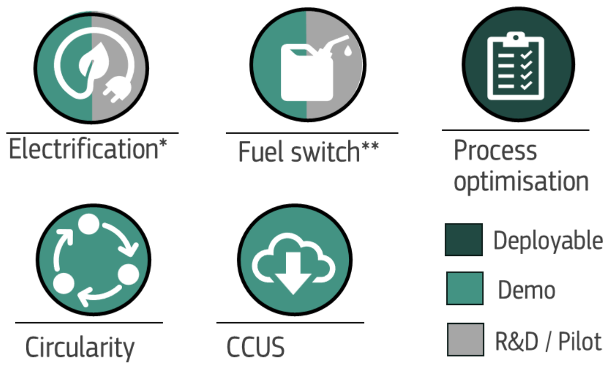
Decarbonisation trajectories[3]

The decarbonisation trajectories for the glass industry can be structured around five key technological and

[3] This factsheet avoids using the term 'pathways' to prevent confusion with the sector-specific decarbonisation pathways published by the European Commission in November 2025. Those sector-specific pathways are intended as a voluntary tool to support companies set their individual decarbonisation targets in line with the European Climate Law. See EC, Making finance flows consistent with climate goals – Climate Action, 2025

operational levers[4]. These levers represent the practical actions and innovations that, combined, define the strategic trajectories to achieving climate neutrality by 2050 (Figure 3). Table 1 shows the key strategies and associated challenges and considerations associated to these levers.

Figure 3 – Stage of lever deployment within the glass sector in the EU



Note: *Electrification - Demo: small electric furnaces, R&D/Pilot, large electric furnaces and specific glass composition (e.g. E-glass). **Fuel switch: Demo: biomethane, biogas, and hydrogen share in the gas mixture up to 20%, R&D/Pilot: hydrogen content in the gas mixture from 20% up to 100%.
Source: JRC, based on selected references [4] [10] [12]

For instance, Glass for Europe, the flat glass industrial association, estimates that implementing Best Available Techniques (BAT) could yield only an additional 7% reduction in direct emissions for the sector. To achieve higher cuts, the sector advocates for key decarbonisation strategies including electrification and fuel switching (potential for 75% reduction), circularity (6%), and CCUS (up to 85%; however, CCUS is considered an uncertain solution) [10].

Recently, a report on deep industrial decarbonisation for the glass industry recommended a chronological trajectory for decarbonising the sector [13]. Based on it, for the next 5 years (2025–2030), the sector must maximise the use of secondary raw materials/cullet (where quality allows) and deploy efficiency measures such as advanced process control and further digitalisation.

Energy efficiency measures should also be implemented depending on the price. According to this report, over the next 5-15 years (2030–2045) hybrid electric boosting will be scaled up and progressively electrify melters where low-carbon electricity is available and affordable. Where oxygen supply and CCUS infrastructure are planned, thermochemical heat recovery and oxy-fuel retrofits can be considered with carbon capture. Around 2040, the full transition of high-temperature heat to renewable hydrogen and/or near-100% renewable electricity for electric melting, where the grid/infrastructure supports it, is anticipated to become possible and expected to be fully implemented. For the remaining process emissions, carbon capture could in theory be deployed at sites in larger industrial clusters. Policy support (infrastructure, CO_2 pricing, investment incentives for electrification and CCUS) and coordinated value-chain action (collection, standardisation of cullet quality) are decisive to unlock the technical potential outlined above.

Decarbonisation technologies

Within the decarbonising levers highlighted for the glass sector, a non-exhaustive list of technologies/measures is presented in Table 2 with their associated Technology Readiness Level (TRL) and CO_2 abatement potential.

It should be noted that these CO_2 abatement potentials cannot be summed up and that some technologies exclude others. Regarding the technology costs, most of the technologies/measures linked to these decarbonisation levers are associated with significantly higher operating expenses (OPEX) compared to the conventional use of natural gas (EUR 50 per MWh).

For instance, for the flat glass industry, in 2023, the average electricity price was approximately EUR 150 per MWh. Fossil-based hydrogen was estimated at EUR 6 per kg (around EUR 180 per MWh), while renewable hydrogen were estimated at above 10 EUR per kg (EUR 300 per MWh) in the same year [14].

Additional Capital Expenditure (CAPEX) compared to traditional processes for container and flat glass electric furnaces are expected to decrease from EUR 111 per tonne of glass in 2020 to EUR 82 per tonne of glass in 2050 [16].

[4] The increase in the use of decarbonated raw material is also a potential lever for decarbonisation of the glass industry, however it was not considered as a key lever in this work.

Table 1 – Decarbonisation levers for the glass industry, key strategies and associated challenges and considerations

Levers	Key strategies	Challenges and considerations
Process optimisation	• Upgrade furnaces for higher efficiency • Use oxy-fuel combustion • Recovery of waste heat • Apply batch pelletisation • Preheat raw materials and cullet • Reformulate feedstock composition	• Requires capital and increasing OPEX investment • Suitability varies by product type and plant scale
Electrification	• Electric boosting in hybrid furnaces • Fully electric melting systems, where feasible • Prioritise carbon-neutral electricity (e.g. wind, solar, nuclear)	• Reliable, stable and continuous supply of energy • Limited capacity (>200 t/day not feasible) • High secondary raw material/cullet use is challenging • Dependent on grid stability, cost and emissions profile of electricity
Fuel switch	• Shift from natural gas to biogas, biomethane or hydrogen	• Biogas and biomethane supply is limited • Hydrogen infrastructure still developing • Costs related to switch to alternative energy sources • Need to define NOx emission levels in case of H_2 application in combustion processes • >20% hydrogen blends need furnace redesign
CCUS	• It is the only lever that can capture CO_2 emissions from released from raw materials (process emissions, 20–25% of total emissions)	• Needs large-scale CO_2 transport and storage infrastructure • High implementation cost • Probably oversized for typical glass production site
Circularity	• Increase secondary raw material/cullet use to reduce energy and emissions • Improve post-consumer glass collection • Promote pre-demolition audits and better collection, sorting and recovery in construction and demolition • Introduce material-specific collection targets	• Requires separate collection systems and sector coordination (e.g. automotive, construction) • Quality control essential to maximise recycled content use • Fragmented legislation and lack of harmonisation across the EU are key barriers for recycling potential to fully unfold

Source: JRC, based on references [8] [9] [15] [16] [17]

STATE OF DEVELOPMENT

Industrial pledges

Over the past years, the European glass industry has made significant progress in reducing GHG emissions. In 2021, Glass Alliance Europe (GAE), representing six glass segments, reported a 69% reduction in CO_2 emissions per tonne of melted glass over the last 50 years. GAE emphasises that further reductions will require disruptive technologies such as large-scale furnace electrification, the use of biofuels, high hydrogen content (>20%), expanded recycling infrastructure, and CCUS.

Glass for Europe, the flat glass industry association achieved the target of decreasing 43% of their GHG emissions per tonne of glass in 2020 compared to 1990 levels, but to keep decreasing their emissions, they in their 2024-2029 manifesto stated that further supported is required [18]. The European Container Glass Federation (FEVE) reported that by 2015 container glass emissions had decreased by 5% per tonne of glass compared to 2009 values. Nevertheless, no specific targets were given by the container glass industry. FEVE members continue to invest around EUR 610 million annually in research and innovation (e.g. focused on energy efficiency) and emerging technologies such as electric furnaces and CCUS [17].

Demonstrators

A non-exhaustive overview of 21 EU-funded demonstration sites for glass sector decarbonisation shows active work across key levers, with projects supported by programmes such as Horizon 2020, Horizon Europe, Innovation Fund (IF) and LIFE. Most projects – nine in total - were identified under the process optimisation lever. Examples are the PRIME (TRL 9), OPTIMELT (TRL 9), GreenPower (TRL 9), Smart Oxy-Boost (TRL 9), CleanOx (TRL 9) and SUGAR funded projects. For instance, SUGAR is currently developing a glass furnace aiming at total energy recovery by releasing exhaust gases at the lowest possible temperature. This recovered heat is reused within the production process, achieving over 15% energy savings and reducing CO_2 emissions. A key innovation is using this waste heat to power steam reforming, converting natural gas into hydrogen.

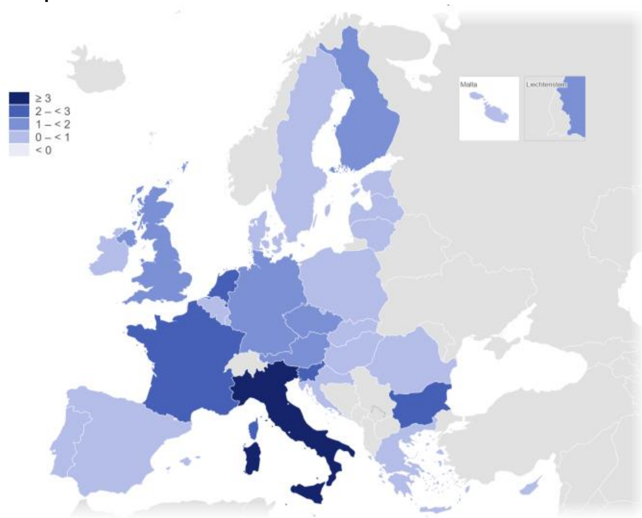
Table 2 – Non-exhaustive list of technologies/measures with their associated TRL and CO_2 abatement potential

Levers	Technologies	Current TRL	CO_2 abatement potential
Electrification	Electric melting in small furnaces	9	75 - 85 %
	Electric melting in large furnaces and for specific glass types	5	75 - 85 %
	Electric melting with continuous filament glass fibres	3	75 - 85 %
Fuel Switch	Biogas or biomethane	8	75 - 85 %
	Liquid biofuel	8	75 - 85 %
	Hydrogen - 20% content in the gas mixture	7	≤ 20 %
	Hydrogen - 100% content in the gas mixture	5	75- 85 %
Circularity	Increased use of cullet (container glass)	9	≤ 20 %
	Increased used of cullet (flat glass)	9	≤ 5 %
CCUS	Carbon Capture Utilisation and Storage	4	≤ 90 %
Process optimisation	Batch pelletisation	6 – 8	≤ 5 %
	Raw materials preheating	8	≤ 15 %
	Glass batch reformulation	4	≤ 20 %
	Oxy-fuel combustion	7 - 9	≤ 50 %
	Waste heat recovery	9	≤ 15 %

Source: JRC, based on reference [15]

Electrification is a key decarbonisation lever. Although electric melting has a high TRL for small furnaces (TRL 9), it still needs to upscale from TRLs 3-5 for large furnaces and specific glass types. For instance, the IF BEAR project (EUR 2.2 million) aims to achieve TRL 9 in in its plant based in Slovenia. It recently (2025) started running a first-of-a-kind (FOAK) end-fired regenerative furnace with an electrical melting share of more than 40% for the production of container glass for luxury goods. With an output capacity of 170 tonnes of glass per day, it aims to achieve a 50% reduction of natural gas consumption and up to 33% GHG emissions avoidance over the first 10 years of operation.

Figure 4 – Non-exhaustive map with number of glass demonstration sites in Europe aiming for TRL ≥ 6 when completed



Source: JRC, based on the CINEA and Innovation Fund dashboards and reference [19]

Additionally, the IF Volta Project (EUR 12 million), which also started operating in 2025, introduced a hybrid glass furnace combining 50% electric melting with oxy-fuel combustion at its flat-glass plant in the Czech Republic. The project also aims to replace up to 100% of virgin raw materials with recycled glass (cullet).

Fuel switching from natural gas to hydrogen is being tested by the H2GLASS project, in five different demonstrator sites in Europe: Slovenia, Italy (two sites), France and the UK. The project is co-funded by Horizon Europe with a total budget of EUR 31.8 million (70% funded by the EU). It aims to achieve TRL 7 by 2027, demonstrating the use of up to 100% hydrogen as fuel.

For CCUS, only one project was identified: GLASS2LIFE, under the LIFE programme (EUR 11.2 million), aims to reach TRL 8 by 2028. Its objective is to demonstrate in a container glass manufacturing plant a CO_2 capture process using hot potassium carbonate (HPC) and make it replicable in many other hard-to-abate industries. It aims to enable cost-effective sequestration of 80% of CO_2 from furnace flue-gases.

Only one project was identified for circularity in the glass industry, MC4 (EUR 7.5 million), which recently reached TRL 6 (2025), and is focused on a specific glass type (glass fibre).

Evaluation of progress and alignment with policy and industry targets

The EU glass industry demonstrates a strong decoupling between emissions and production. Since 1990, the average production has risen from 29 million to around 36 million tonnes in 2024. The glass industry projects an increasing output up to 43.5 million tonnes by 2050. Looking ahead, the sector needs to reduce emissions by 90% by 2040 and reach net-zero by 2050, to be in alignment with EU climate policy targets, including the Fit-for-55 package and climate neutrality objectives. For instance, the flat glass industry already reduced 43% of its GHG emissions from 1990 to 2020, making it approximately halfway to delivering the 90% decrease target for 2040.

Experts consider that improvements to the float process are likely to improve efficiency marginally, while being technology intensive. This indicates that deep decarbonisation is envisioned alongside continued industrial growth, highlighting the need for transformative technologies, affordable and carbon neutral energy supply, as well as substantial policy and investment support to enable emissions reductions without compromising output and quality.

CONCLUSIONS

The decarbonisation of EU glass production requires a strategic shift towards electrified melting processes, prioritising hybrid or fully electric systems. Where electricity alone is insufficient or not possible, hydrogen could serve as a complementary energy source. Additional measures include enhanced process control, furnace efficiency improvements, waste heat recovery, and, where supply is limited, thermochemical recuperation and cullet preheating.

Key barriers include technology availability, high costs (CAPEX and OPEX) and limited availability of carbon-neutral energy, alongside with existent infrastructure optimised for fossil fuels. Retrofitting requires significant investment, while renewable intermittency poses operational risks.

Regulatory uncertainty, non-EU competition, high energy prices, and weak financial incentives also hinder progress. Supply chain limitations, such as cullet scarcity, specialised equipment shortages, and limited customer willingness to bear additional costs for low-carbon goods, further constrain deployment. Although R&D is advancing, targeted innovation to ensure inclusive decarbonisation trajectories across all glass sectors is required.

The decarbonisation of the EU glass industry is technically feasible in the long term but remains highly challenging due to current technological, economic and other exogenous constraints.

Achieving climate targets requires a strong support from the EU and Member States and will depend on the rapid deployment and scaling of breakthrough technologies, substantial investment in renewable energy and supporting infrastructure, strong and consistent policy support across all Member States and coordinated industry-wide innovation. Without these enablers, meeting the 2040 milestone is unlikely; however, a net-zero trajectory by 2050 remains achievable if these critical barriers are addressed.

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