EUROPEAN CENTRAL BANK
EUROSYSTEM

Occasional Papers Series

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Energy security and industrial competitiveness: the case for a European Energy Union

No 388

Contents

Abstract

The European energy market remains heavily reliant on imported fossil fuels and fragmented across Member States. This leaves the EU exposed to high and volatile energy prices, posing risks to its growth outlook and its international competitiveness. As the EU advances its energy security and climate neutrality objectives, the role of electricity and renewable energy is set to increase at the expense of fossil fuels. This paper argues that achieving a genuine European Energy Union would help to reach these goals and identifies five key policy priorities to support this process: strengthening cross-border infrastructure; mobilising innovative green finance; investing in tools to support flexibility and matching of supply and demand; improving the efficiency and harmonisation of energy taxation; and establishing a coherent industrial policy for clean tech.

JEL codes: Q40, Q41, Q48, O25, F15

Keywords: EU energy market integration; renewable energy; industrial competitiveness; clean-tech industrial policy; European integration.

Executive summary

The EU is highly dependent on fossil fuel imports, making it particularly exposed to global energy market developments. The EU imports almost all the oil and gas it uses, which makes it vulnerable to external shocks, such as the Russian invasion of Ukraine in 2022 and the Middle East conflict in 2026. This places European energy security at constant risk, with potential adverse consequences for the economy, the prosperity of its citizens and the conduct of monetary policy in the euro area.

As a key input to virtually any production process, energy prices have a major impact on firms' costs and can harm their international competitiveness. From an international perspective, EU firms often face higher and more volatile energy prices than many of their global competitors, placing them at a structural competitive disadvantage, especially if operating in energy-intensive sectors. In this context, completing the green transition offers a dual benefit: it helps combat climate change, while at the same time reducing the EU reliance on imported fossil fuels, strengthening its energy security and competitiveness.

In the coming years, the role of electricity and renewable energy is set to rise as the EU pursues its objectives of energy security and climate neutrality. This will require adaptation of industrial processes and electricity infrastructure. EU-level collaboration will not only be essential to respond to these structural shifts, but also beneficial. While complete cost-optimisation models are necessary to support energy planning and policy decisions, this paper shows that a coordinated European approach, prioritising renewable energy investments where they have the highest output potential at the EU level, could increase average output by up to approximately 42% for solar and 110% for wind, compared with a scenario with less coordination among Member States.

The findings of this paper underscore the need for, and the benefits of, a genuine European Energy Union – an EU-level framework coordinating market integration, governance, energy security, decarbonisation, efficiency, funding and external energy policy – and identify five policy priorities:

- **First, enhancing investment in cross-border energy infrastructure.** Expanding interconnectors and electricity grids between Member States is vital to efficiently distribute energy from renewable-rich regions to areas with high industrial demand, stabilising energy prices and improving security of supply. Additionally, strengthening connectivity with non-EU countries can provide mutual support during energy crises.
- **Second, developing innovative financing solutions to address the funding gap for green energy investments.** While EU programmes already provide significant support, these funds are insufficient to meet long-term investment needs. Proposals for an EU fiscal capacity for green investment, green bonds, as well as enhanced private sector participation, are critical to bridging the gap

and stimulating investment in clean energy projects. Deepening the capital markets union (CMU) through the savings and investment union (SIU) agenda is equally essential to channel Europe's vast savings pool into productive investments, funding green technologies and start-ups.[1]

- **Third, investing in technologies and infrastructure that will support flexibility and a better matching of supply and demand, such as grid digitalisation and electricity storage.** The development and adoption of innovative technologies is key to achieving Europe's renewables transition. Digitalisation enables smart grid technologies to optimise energy distribution, integrate intermittent renewable sources and manage demand in real time. Energy storage systems, such as batteries and pumped hydro, and demand response programmes, are also vital to balancing supply and demand.

- **Fourth, moving towards more efficient and harmonised energy taxation across Member States.** The Commission's Clean Industrial Deal foresees recommendations to Member States on decreasing energy tax levels in a cost-effective way and adopting a harmonised design of tariff methodologies for network charges. This type of measure can promote more efficient and harmonised taxation, which would provide relief for industry, reduce price disparities and foster market convergence, ensuring a level playing field. Furthermore, tax frameworks need to factor in the environmental performance of different energy sources and set incentives that will support electrification and the development of clean energy.

- **Fifth, establishing a cohesive EU-level industrial policy to support clean technology sectors and strengthen strategic autonomy.** While China dominates global clean technology investments, the EU has a robust ecosystem in areas such as batteries, electric vehicles, wind energy and heat pumps. To maintain global leadership, the EU must support these industries. Initiatives such as the European Commission's Clean Industrial Deal (2025) can help to lower energy costs, promote clean technology markets and mobilise significant funding for industrial decarbonisation.

A genuine Energy Union constitutes a strategic European public good, that would strengthen the EU's security, competitiveness and long-term prosperity. While existing initiatives at the EU level have laid a strong foundation for the green transition, addressing the scale of the challenge requires further decisive action. By advancing cross-border infrastructure, fostering innovative financing mechanisms, embracing digitalisation, harmonising taxation and strengthening industrial policy, the EU can create a fully integrated energy market. This will bolster strategic autonomy, optimise resource allocation and unlock significant opportunities for European industries and capital markets, paving the way for a sustainable and resilient future.

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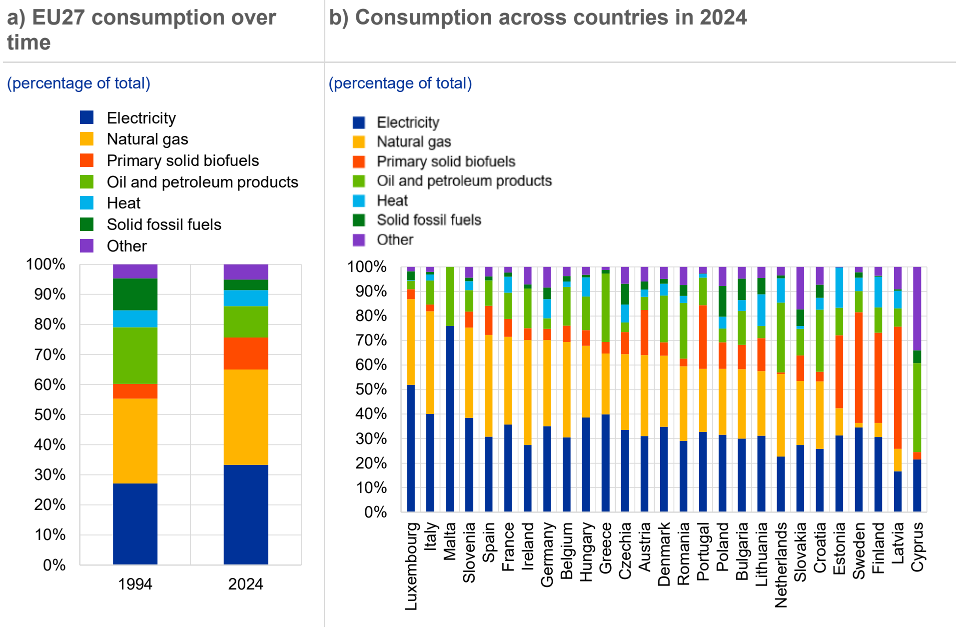
[1] See Arampatzi et al. (2025). See also Lagarde (2023) and Lagarde (2024).

1 Introduction: the energy-industry link in Europe

European industry relies primarily on electricity and natural gas as energy sources in production processes. The role of electricity and gas has grown over the past 30 years as industry has gradually shifted away from oil and petroleum products and solid fossil fuels (Chart 1.1, panel a). As of 2024, electricity and natural gas jointly account for around 65% of energy use in industry. While they dominate the industrial energy mix in most EU countries, there is significant cross-country heterogeneity: for instance, in Luxembourg, electricity and gas cover 87% of industrial energy needs, while in Cyprus they account for only about 22% (Chart 1.1, panel b).

Chart 1.1

Final energy consumption in the EU industrial sector



Source: Eurostat.
Notes: The chart represents the final product used by industry and does not take into account the underlying technology used to generate electricity (see the next chapter). For example, electricity generated via renewables, such as solar photovoltaic panels and wind turbines, falls under “Electricity”. Oil and petroleum products exclude the biofuel portion. Primary solid biofuels are organic, non-fossil materials such as fuelwood, wood residues, animal waste and vegetal material.

Energy can represent a significant expense for firms, especially in energy-intensive sectors. Analysis based on sectoral aggregates suggests that energy purchases typically accounted for 1-10% of total operational production costs in manufacturing sectors over the period 2014-21. For the most energy-intensive sectors, such as certain construction materials, they even exceeded 10%. These estimates do not take into account self-produced energy and use of waste products, which can also contribute significantly to energy costs in energy-intensive industries. The burden can be even higher in certain sub-sectors and in periods of high energy prices: for example, surveys of industrial plants found that in 2023, energy made up

38% of production costs for those active in the primary aluminium sector and 29% for those operating in the ferro-alloys and silicon sector.[2]

The 2022 energy shock had a particularly severe impact on the viability of operations in energy-intensive sectors. While some sectors were able to partially offset the increase in energy prices, also by passing on costs to consumers, others were not able to do so. According to surveys, the increase in energy costs contributed to a wave of production curtailments and plant closures in energy-intensive sectors, with the impact being much more severe than that of the pandemic restrictions. For example, the production output in the ferro-alloys and silicon sector fell by 43% between 2019 and 2023, with surveyed firms citing high electricity prices as a key contributing factor in the closure of furnaces.[3]

The energy sector and energy-intensive industries are key suppliers of intermediate inputs, therefore shocks to these sectors can propagate along supply chains amplifying their initial impact.[4] Chart 1.2 ranks euro area sectors according to their forward centrality in 2022, a measure of their importance as suppliers to the rest of the economy. Forward centrality captures the extent to which a sector provides inputs – directly and indirectly – to other sectors and therefore indicates how shocks originating in a given sector can propagate throughout the production network. The chart displays the top 21 sectors out of 64, based on normalised forward centrality scores, with values above one indicating above-average centrality relative to a country's sectoral mean. Manufacture of coke and refined petroleum products (C19) stands out as the most central sector in the euro area production network, with a forward centrality score well above all other sectors. Mining and quarrying (B) and electricity, gas, steam and air conditioning supply (D35) also rank among the most central suppliers.[5] This highlights the pervasive role of the energy sector, in its various forms of extraction, transformation and generation, as upstream input into a wide range of economic sectors. As a result, shocks to energy prices or supply conditions may be transmitted across the whole economy, affecting production costs and output well beyond the energy sector itself. Importantly, the chart also shows that several energy-intensive sectors are themselves highly central suppliers. Sectors such as basic metals (C24), chemicals (C20), paper (C17), rubber and plastic products (C22), wood products (C16) and other non-metallic mineral products (C23) all feature prominently among the most central sectors. These industries not only rely heavily on energy as an input but also provide key intermediate goods to many downstream sectors. This dual role implies that an energy shock would first affect energy producers directly, then energy-intensive sectors through higher input costs, and subsequently propagate further through the economy via these sectors' central supplier positions. Overall, this evidence underscores the macroeconomic relevance of energy shocks.[6] The high centrality of both energy-producing and energy-intensive sectors is a factor that

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[2] See European Commission: Directorate General for Energy et al. (2025).

[3] See European Commission: Directorate General for Energy et al. (2025).

[4] Furthermore, all sectors, both energy-intensive and non-energy-intensive, were affected by the increase in energy costs via its impact on purchasing power and final demand.

[5] One reason for the high centrality of petroleum products and mining and quarrying is that they are themselves used as inputs in electricity generation (sector D35).

[6] For further discussion, see Gunnella et al. (2022).

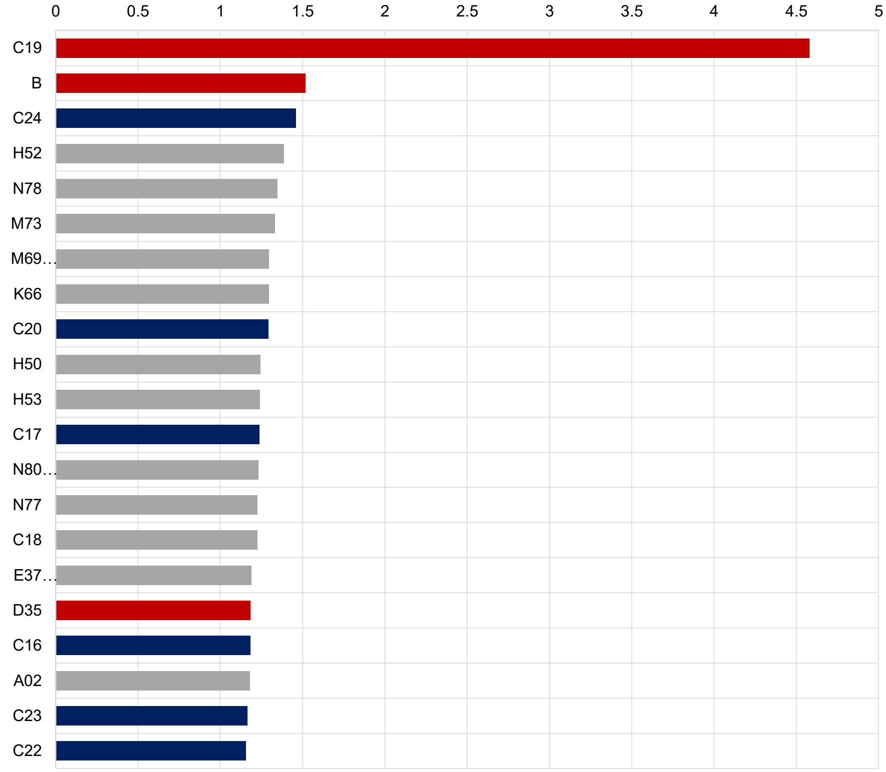
helps to explain why energy price increases can have substantial and persistent effects on economic activity and inflation, even in sectors that are not directly energy-intensive themselves.

Chart 1.2

Sectoral importance as a supplier to the rest of the economy

2022

(normalised forward centrality)



Sources: Eurostat FIGARO input-output tables and ECB calculations.
Notes: The data refer to sectoral forward centrality at the euro area level in 2022. The chart displays the top 21 sectors (out of 64) ranked by forward centrality. Forward centrality measures a sector's importance as a supplier to the rest of the economy and is defined following Miller and Blair (2009).
Forward centrality scores are computed at the country-sector level for 20 euro area countries and 64 NACE sectors (approximately corresponding to the NACE 2-digit classification). The scores are then normalised by each country's average in the corresponding year – so that values above one indicate above-average centrality – to ensure comparability across countries, and subsequently averaged to obtain the euro area aggregate.
Sectors related to energy generation are highlighted in red: *C19 – Manufacture of coke and refined petroleum products; B – Mining and quarrying; D35 – Electricity, gas, steam and air conditioning supply*. Energy-intensive sectors are highlighted in blue: *C24 – Manufacture of basic metals; C20 – Manufacture of chemicals and chemical products; C17 – Manufacture of paper and paper products; C16 – Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials; C23 – Manufacture of other non-metallic mineral products; C22 – Manufacture of rubber and plastic products*. All remaining sectors are shown in grey.

The energy crisis also affected the international competitiveness of EU industry. The increase in energy prices was higher for EU firms than for many of their key international competitors. Firms in EU energy-intensive sectors estimated that their competitors were able to benefit from energy costs that were at least 20% lower than their own, and total production costs that were at least 10% lower.[7] This cost differential led to a substitution effect: the decrease in EU production of energy-intensive goods from 2022 onwards was associated with an increase in imports from

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[7] See European Commission: Directorate General for Energy et al. (2025).

trade partners that were less affected by the energy price shock (Chiacchio et al., 2023). Beyond these short-term effects, the energy crisis may also have affected the competitiveness of EU firms through longer-term channels, such as investment and innovation (Anaya Longaric et al., 2024).[8]

Similarly to the 2022 energy crisis, the 2026 war in Iran could adversely affect the European economy through multiple channels, including higher energy prices, heightened uncertainty and disruptions transmitted through trade and supply-chain dependencies. By increasing the risk of renewed supply constraints and exposing Europe's continued dependence on imported fossil fuels and other strategic inputs, the conflict may once again place upward pressure on inflation while weighing on economic activity. More broadly, it underscores Europe's persistent structural vulnerability to externally driven shocks and the importance of policies aimed at strengthening resilience and reducing external dependencies.

This paper provides a comprehensive analysis of Europe's energy landscape, its critical role in shaping industrial competitiveness and the policies required to drive a sustainable and competitive energy transition. First, it examines the key drivers of energy price dynamics in Europe, including energy dependency, disparities in taxation policies, variations in the energy mix on the supply side and demand-side factors linked to the diverse industrial structures across EU Member States. These factors collectively contribute to significant energy price disparities, which affect competitiveness and pose challenges for market integration. Second, the paper explores how decarbonisation goals and competitiveness objectives can be aligned to address the needs of European industry. This alignment is particularly crucial in the context of escalating geopolitical tensions, which highlight the importance of an accelerated energy transition for strengthening energy security. Finally, the paper identifies the policy measures necessary to achieve these objectives, ensuring that Europe's energy transition supports both industrial competitiveness and broader sustainability goals.

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[8] Persisting high electricity prices may also affect European manufacturing jobs. Research by Bijnens et al. (2025) finds that a permanent 10% rise in electricity prices reduces employment in energy-intensive sectors by up to 2%. See also Hanson (2023) for an in-depth discussion of the labour market implications of the energy transition.

2 Industrial energy prices across Europe: forces at play

Over the past few years, energy prices in the European Union have been marked by extremely high volatility, as a result of a series of crises.[9] After tumbling during COVID, wholesale energy prices started to rise in 2021, mainly due to the rebound in global gas demand following the pandemic and further exacerbated by supply constraints. Subsequently, the Russian invasion of Ukraine in 2022 led to an unprecedented spike in gas prices, which more than doubled compared with the previous year. This had a knock-on effect on wholesale electricity prices because of the key role of gas in electricity price-setting under the merit-order mechanism system (see Box 1). In turn, the developments in wholesale markets translated into a spike in retail prices for industrial consumers (Chart 2.1). A few years later, the Middle Eastern conflict ignited by the United States-Israel strikes on Iran in February 2026 has confronted Europe with a new energy shock. The closure of the Strait of Hormuz, through which about 20% of global oil and liquefied natural gas (LNG) supply transits, led to a surge in global oil and gas prices and exposed Europe's energy vulnerability once again, showing the need to reduce dependence on fossil fuels.

Alongside price volatility, EU firms also face high and heterogeneous energy prices. Prices of electricity and natural gas for firms tend to be high in comparison with key international partners, particularly the United States (Chart 2.1).[10] Moreover, there are significant differences across EU countries: the shaded area in Chart 2.1 illustrates the range between the lowest and highest prices across Member States, which widened during the energy crisis. These factors can affect competitiveness both within the EU and vis-à-vis international counterparts. This chapter hence investigates the factors that affect the level, volatility and cross-country differences in energy prices for European industry.

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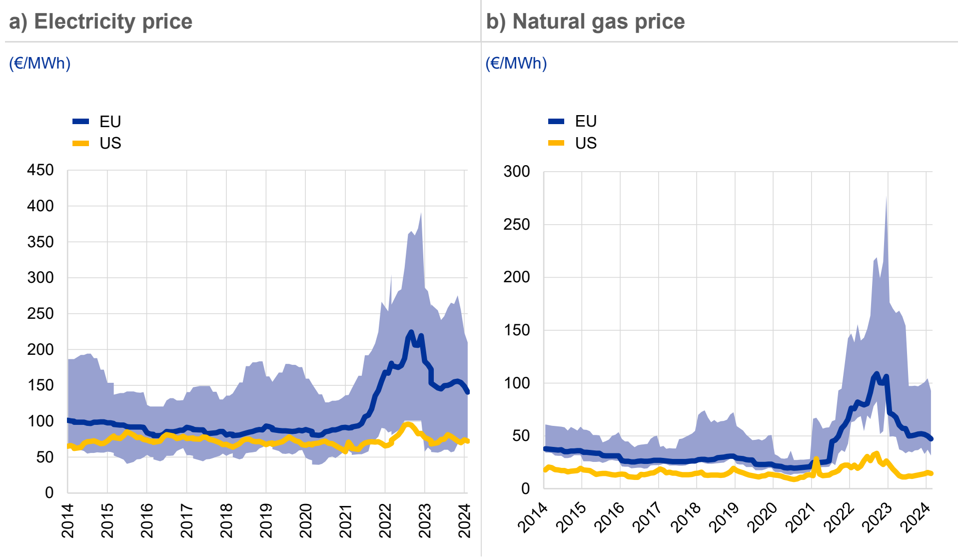
[9] For a detailed overview, see Kuik et al. (2022).

[10] The data for China are missing, but electricity prices for Chinese industrial consumers are expected to be lower than US prices, and therefore significantly lower than EU prices. In contrast, electricity prices for industrial consumers in Japan have evolved in a similar way to EU prices in recent years, while UK prices have been significantly higher. As regards industrial gas prices, both the UK and Japan saw significant spikes during the energy crisis, although these were not as pronounced as in the EU. As the crisis subsided in 2023-24, prices for all three jurisdictions evolved within a similar range. See European Commission: Directorate General for Energy et al. (2025).

Chart 1.1

Prices of electricity and natural gas for industrial consumers in the EU and United States



Source: European Commission Dashboard for energy prices in the EU and main trading partners 2024.
Notes: Prices are expressed in 2023 euro and adjusted for inflation. They exclude recoverable taxes and levies such as VAT. The solid blue line is a weighted average of prices for the EU27, while the top and bottom of the band represent the highest and lowest price recorded across the 27 EU Member States for that period. The prices refer to the consumption band with the highest market share in each EU Member State, typically IF for electricity and I5 for gas.

2.1 Energy imports and production

Europe is highly dependent on imports for its energy needs, especially for oil and gas, while electricity demand is mostly met by local generation capacity. The energy imports dependency rate, which measures the extent to which an economy's energy consumption exceeds its production, has been steadily increasing since 1990, reaching 67.2% in 2023 (Chart 2.2, panel a).[11] Conversely, international peers such as the United States saw their dependency rate fall and even turn negative (-9.7% in 2023), thus becoming net exporters, as a result of the shale revolution, which has boosted oil and gas domestic production. Europe imports mainly oil and petroleum products, for which the dependency rate is 98.6%, and natural gas, with a dependency rate of 89% (See Chart 2.2, panel b).

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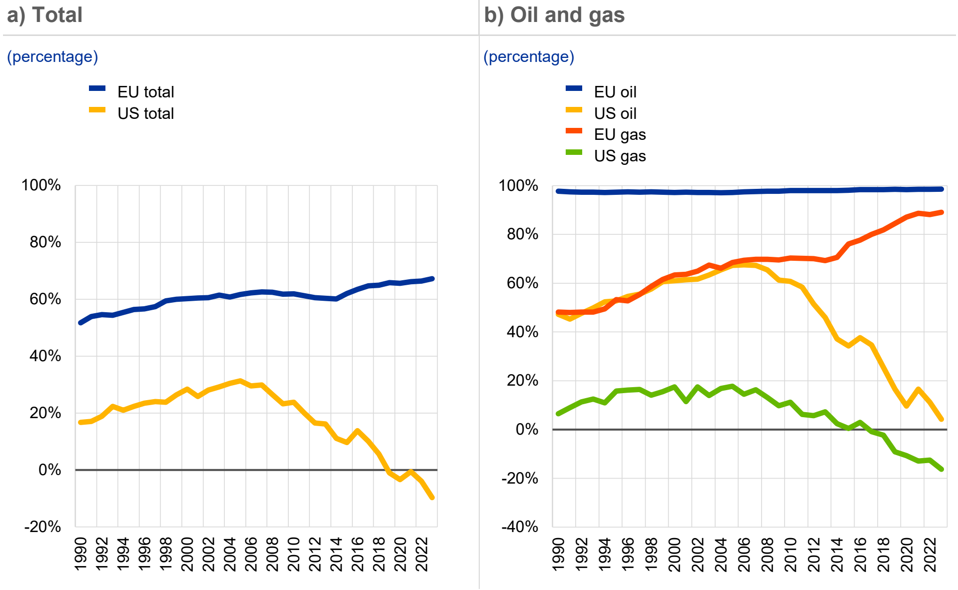
[11] We report data from the Energy Information Administration, as it provides an international comparison. Equivalent metrics from Eurostat show consistent results.

Chart 2.2

Energy imports dependency rate



Source: Energy Information Administration.
Notes: Dependency rate defined as consumption net of production, as a fraction of consumption (quad Btu). Oil defined as petroleum and other liquids, gas as natural gas.

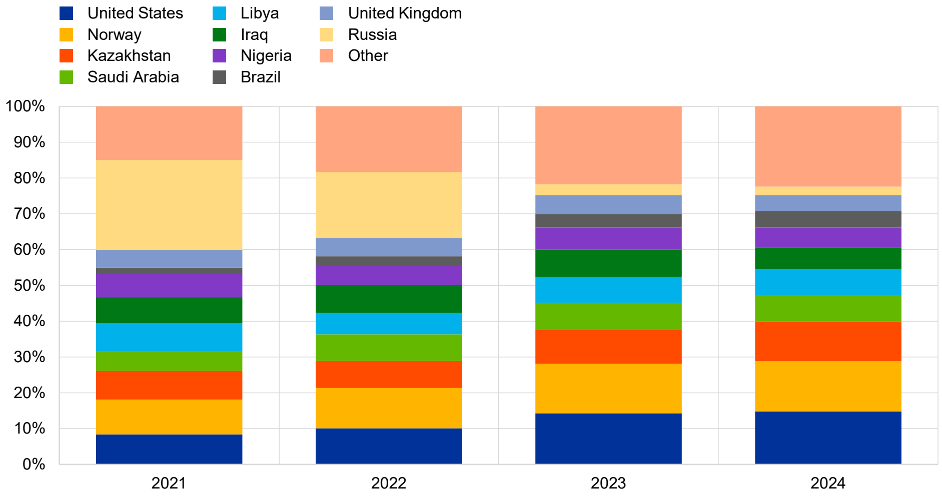
EU countries import oil and gas directly from non-EU partners, leveraging cross-border infrastructure. EU Member States primarily import oil and gas from other countries using cross-border infrastructure (Chart 2.3 and 2.4, panel a). As of, 2021, the transportation of gas and oil relied heavily on pipelines spanning long distances, and Russia was the EU’s leading supplier of crude oil, accounting for 25% of EU imports. This dependence declined sharply following Russia’s invasion of Ukraine, reaching 2.5% in 2024 (Chart 2.3). A similar adjustment occurred in the case of natural gas (Chart 2.4, panel a), as Russian imports decreased from 41% in 2021 to 11.4% in 2024, while the share imported from Norway and the United States increased by about 10 percentage points over the same period.

Chart 2.3

Oil imports into EU

Total crude oil imports into EU 2021-24

(thousands of tonnes)



Sources: Eurostat and ECB calculations.
Note: Data refer to crude oil imports from top ten trade partners.

Russia's invasion of Ukraine led to a rapid uptake of LNG, and a growing role for imports from the United States. Europe's efforts to diversify away from Russian energy dependence resulted in higher LNG imports and a shift in import shares.[12] While Russia's share declined over 2022 and 2023, it remained a notable LNG exporter to the EU, with import shares rising again in 2024, highlighting ongoing challenges in fully severing energy ties (Chart 2.4, panel b). Moreover, although imports are now more diversified than in the pre-2022 period, the 2026 Middle East conflict has shown that the underlying vulnerability to external energy shocks has not been eliminated, but has instead shifted to other regions, leaving the fundamental problem unresolved.

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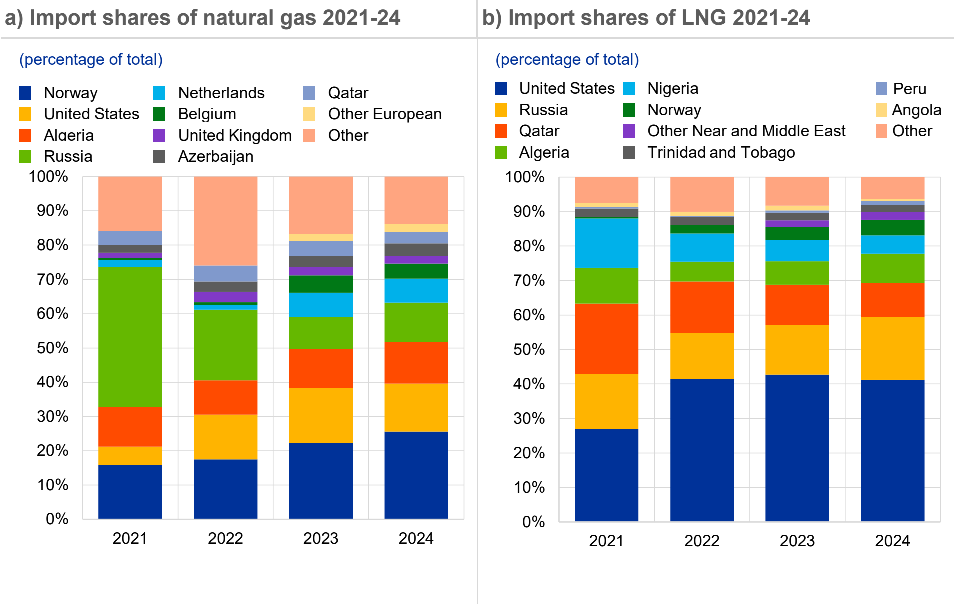
[12] In July 2025, the EU and the US reached a broad trade and energy framework agreement, aimed at deepening transatlantic cooperation and enhancing Europe's energy security. Under the deal, the EU announced its intention to purchase up to $750 billion worth of US energy products – primarily LNG, crude oil and nuclear fuel or technology – between 2026 and 2028.

Chart 2.4

Evolution of the top ten EU import shares of natural gas and LNG



Source: Eurostat.
Notes: Shares are calculated as the ratio of imported volumes (in millions of cubic metres) from each of the top ten EU import partners, relative to the total EU imports of natural gas and LNG. Natural gas includes LNG.

Unlike fossil fuels, electricity in the EU is largely produced domestically. Electricity trade with neighbouring countries mainly supports grid balancing, i.e. the real-time matching of electricity supply and demand. Since electricity cannot yet be easily stored at scale, maintaining this balance is essential to avoid blackouts or damage to infrastructure. Market coupling, which entails the integration of individual national electricity markets to optimise cross-border electricity flows, plays a crucial role in this process by automatically coordinating the electricity markets of individual countries. It optimises the use of available transmission capacity across borders, also leading to more harmonised electricity prices throughout Europe[13]. This approach enhances supply security and reduces generation costs. Imports and exports of electricity remain broadly balanced for the EU as a whole, but geography matters for trade flows across countries. Proximity drives EU countries' constellation of trade partners in electricity, as trade flows are constrained by existing physical infrastructure (Chart 2.5).[14] The degree of interconnectivity, i.e. the percentage of a country's electricity production capacity that can be imported from (or exported to) EU neighbouring countries through cross-border transmission lines, averaged 26% in 2025 according to European Commission calculations. However, there is substantial variation across EU countries, and 13 Member States remain below the EU's 15% target.

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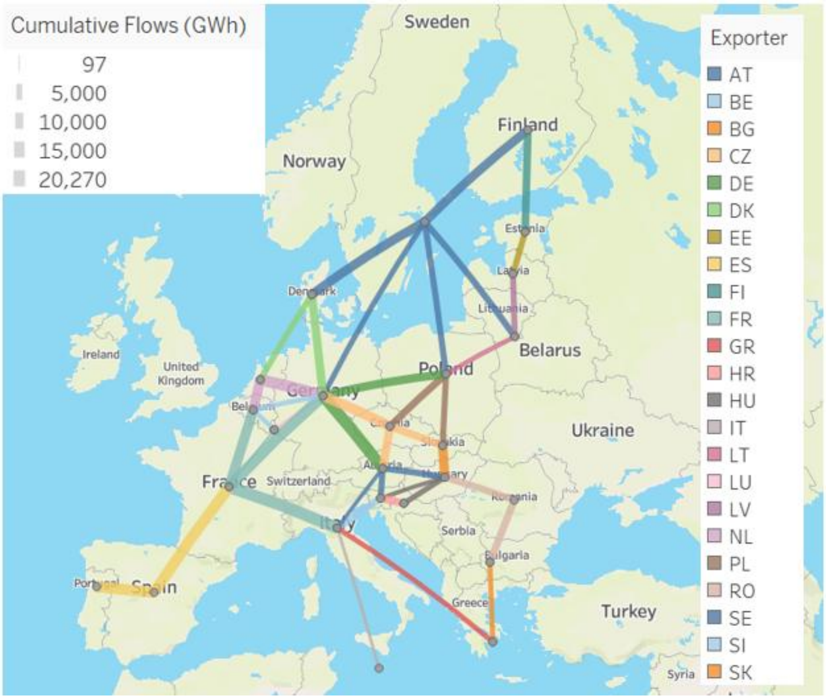
[13] See, for example, Ovaere et al. (2023).

[14] As discussed in Box 1, transport of electricity is inevitably associated with losses, which range between 3% and 7% of electricity per 1,000 km, depending on the type of transmission line employed.

Chart 2.5

Intra-EU electricity flows 2023

(GWh)



Sources: Eurostat and ECB calculations.
Note: The cumulative electricity flows are defined as the sum of imports and exports in gigawatt-hours (GWh).

While electricity generation is localised in Europe, imported natural gas and other fossil fuels also play a key role by powering electricity power plants. The EU's electricity is overwhelmingly generated by domestic power plants. These facilities are increasingly powered by homegrown green energy sources, with the share of renewables and biofuels rising from 15% in 1993 to 48% in 2024 (Chart 2.6, panel a). However, electricity generation still remains heavily reliant on mostly imported natural gas and other fossil fuels, which allow for easier ramp-up and ramp-down of production compared with weather-dependent solar and wind power. These fuels still made up over a quarter of the electricity generation mix in 2024, although their share has been steadily decreasing over the last 30 years. In addition, the EU average masks significant differences across Member States in the share of generation from renewables and biofuels, which ranged from 15% to 91% in 2024 (Chart 2.6, panel b). There are also significant differences in the types of renewables and non-renewables used, reflecting different national energy policies and geographic conditions (see Chart 2.7). It is important to note that carbon emission intensities can differ markedly across energy sources, even within the non-renewable and renewable categories. In particular, fossil fuels are associated with significantly higher emissions than nuclear generation.[15]

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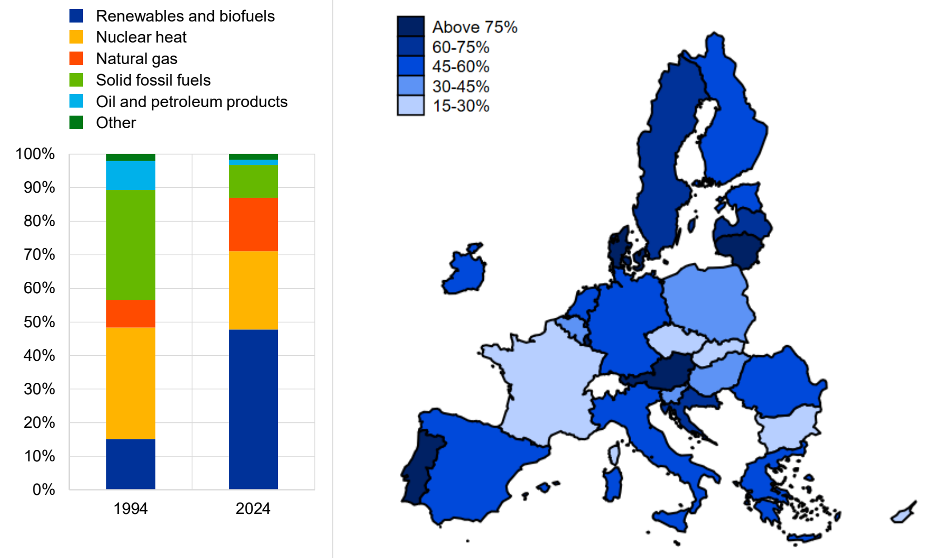
[15] For a quantification of the carbon intensity of different electricity generation technologies, see Scarlat et al. (2022).

Chart 3.6

Electricity production in the EU by source



a) Electricity mix over time

(percentage of total)

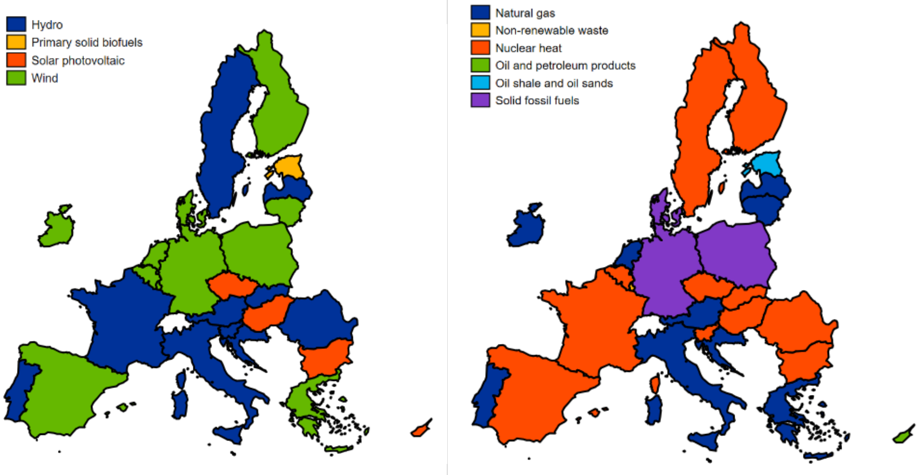
b) Share of renewables across countries in 2024

(percentage of total)

Source: Eurostat.
Note: Oil and petroleum products exclude the biofuel portion.

Chart 2.7

Main energy sources used in electricity production in EU countries



a) Main renewable source in 2024

b) Main non-renewable source in 2024

Source: Eurostat.
Notes: The charts indicate the energy source that makes up the largest share of gross electricity production in each country, within the renewable (panel a) and non-renewable (panel b) categories. This does not necessarily entail the energy source having an absolute majority in the given category: for example, in Portugal, hydropower is the main renewable source (representing 37% of production with renewables) but is closely followed by wind (36%). As in the other charts, oil and petroleum products exclude the biofuel portion.

2.2 Energy prices for EU firms

Despite the increasing integration of the EU energy market, price dispersion remains. In his 2024 report, Enrico Letta stressed that the energy sector was not a frontrunner in early Single Market integration.[16] While EU Member States started to open their monopolistic national electricity and gas markets to competition in the 1990s, these steps were more limited and gradual than in other areas, such as trade in goods. In the following decades, the EU adopted several packages that aimed to further liberalise and integrate EU energy markets. The objective of achieving a fully integrated energy market was prominently stated in the 2015 Energy Union Strategy, which stressed the need to further integrate the internal energy market in terms of both “hardware” – physical interconnection infrastructure – and “software” – a strong regulatory framework. Yet despite these efforts, the empirical evidence on price convergence is mixed. Bastianin et al. (2019) find evidence that there has been convergence in wholesale natural gas prices, but analysis by Cassetta et al. (2022a) suggests that this has not been the case for retail gas prices. As regards electricity, there appears to have been no convergence in retail prices at the EU level, although there is some evidence of “club convergence”, i.e. convergence within groups of Member States (Cassetta et al., 2022a, 2022b).

The prices that industrial actors pay for energy vary significantly across EU countries. In the second half of 2024, on average, medium-sized firms in the EU paid around 0.19 €/KWh for electricity and 0.06 €/KWh for natural gas.[17] However, these averages masked very marked differences across countries: for example, the price of electricity for firms based in Cyprus was more than three times the price paid by their Finnish counterparts, while a unit of gas in Sweden cost around 2.5 times the price of a unit of gas in Bulgaria (Chart 2.8).

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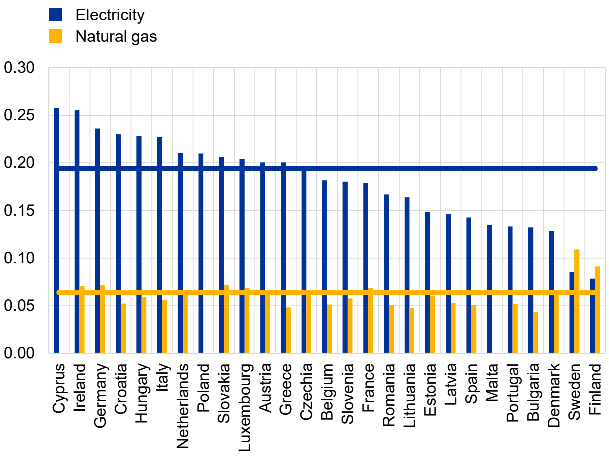
[16] See Letta (2024).

[17] This section refers to prices excluding recoverable taxes and levies. Since these taxes and levies can typically be claimed back, they do not have a material impact on firms’ costs.

Chart 2.8

Prices of electricity and natural gas for medium-sized firms across EU countries in the second half of 2024

(€/KWh)



Source: Eurostat.
Notes: The prices refer to medium-sized industrial consumers (band IC for electricity and I3 for natural gas) and exclude recoverable taxes and levies, such as VAT. The solid lines represent the EU average. Gas prices for Cyprus, Malta and Poland are not shown because they are not provided by Eurostat.

2.2.1 Factors affecting wholesale prices

Wholesale gas prices are largely driven by external supply factors, but country-specific factors can also have an impact and contribute to regional differences. As described in Section 2.1, the EU is highly dependent on imports of gas and therefore strongly exposed to developments in global markets. Kuik et al. (2022) highlight the impact of the post-pandemic rebound in energy demand on global energy commodity prices. They note that supply factors were an important contributor to the European gas price rally in particular, citing reductions in gas supplies from Norway and Russia in 2021, further exacerbated by the Russian invasion of Ukraine in 2022. While these external developments tend to affect the entire EU, they can also be modulated by country-specific factors, such as the energy mix, weather conditions, storage levels and economic activity, which have an impact on demand and on the ability to leverage alternative energy sources. The set-up of existing energy contracts and pricing structures are also important. For example, in 2021, oil-indexed contracts, which are more common in the Mediterranean region, traded at a discount relative to hub-based prices, which dominate in northern Europe. As crude oil prices increased more gradually than gas prices, adjustments in oil-indexed contracts were slower and less pronounced.[18]

The availability of infrastructure such as LNG terminals and gas pipelines also plays a key role in gas transport and price convergence. Bastianin et al. (2019) find that convergence in wholesale gas prices tends to be associated with the existence of gas trading hubs and the availability of physical interconnections. More

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[18] See European Commission: Directorate General for Energy et al. (2024).

recently, Buquet and Stalla-Bourdillon (2024) analysed the spike in prices of the Dutch Title Transfer Facility (TTF) – a virtual natural gas trading hub in the Netherlands that serves as Europe's main wholesale gas price benchmark – in August 2022. This reflected a combination of precautionary demand and supply constraints. Storage filling intensified ahead of winter, following the sharp reduction in Russian pipeline flows, while congestion at LNG terminals in north-western Europe limited the region's ability to absorb additional cargoes. These bottlenecks amplified scarcity at the TTF hub and drove prices up sharply. By contrast, Great Britain and France were less affected during the summer of 2022 due to their substantial LNG regasification capacity along the Atlantic coast, which provided greater flexibility in sourcing global supplies. As a result, although European gas benchmarks had historically moved closely together before the Ukraine war, significant price spreads emerged from May 2022 onwards. In late August 2022, the differential between the French Point d'Échange de Gaz (PEG) and the Dutch TTF exceeded €75/MWh, highlighting infrastructure constraints and increasing market fragmentation within Europe.

Wholesale electricity prices are determined by the merit-order system, which results in gas prices having a major influence. As described in Section 2.1, electricity in the EU is generated by a range of different sources, including renewables, nuclear power, natural gas and other fossil fuels. Under the merit-order mechanism, electricity prices in short-term markets are determined by the production cost of the most expensive facility that is needed to meet demand at any given point in time. A consequence of this mechanism is that gas often acts as the price-setter, even though it generates a relatively low share of the EU's electricity (see Box 1).

National electricity generation mixes contribute to differences in prices across countries. While gas was the most common price-setter in most of the EU in 2022, there were differences across countries: gas was more important in western Europe, while coal and lignite played a more prominent role in eastern Europe and renewables and biomass made a larger relative contribution in the Nordic and Baltic countries. The impact of different national energy mixes is moderated by existing interconnection capacity, with some countries being strongly exposed to dynamics in neighbouring countries (Gasparella et al., 2023).

Box 1: Understanding the merit-order mechanism in short-term electricity markets

Prepared by C. Grynberg

The price of electricity in short-term markets is determined by the marginal cost of the most expensive facility needed to meet demand. This set-up is known as the merit-order or marginal pricing mechanism.[19] It is designed to balance supply and demand on a short-term basis and ensure an efficient allocation of resources. For every 15-minute session, each generator submits a bid to the market operator that reflects its marginal cost, i.e. the cost of producing an additional unit of electricity.[20] Electricity generation plants have different marginal costs, depending on the energy source they rely on: renewables such as wind and solar have near-zero marginal costs, as they rely

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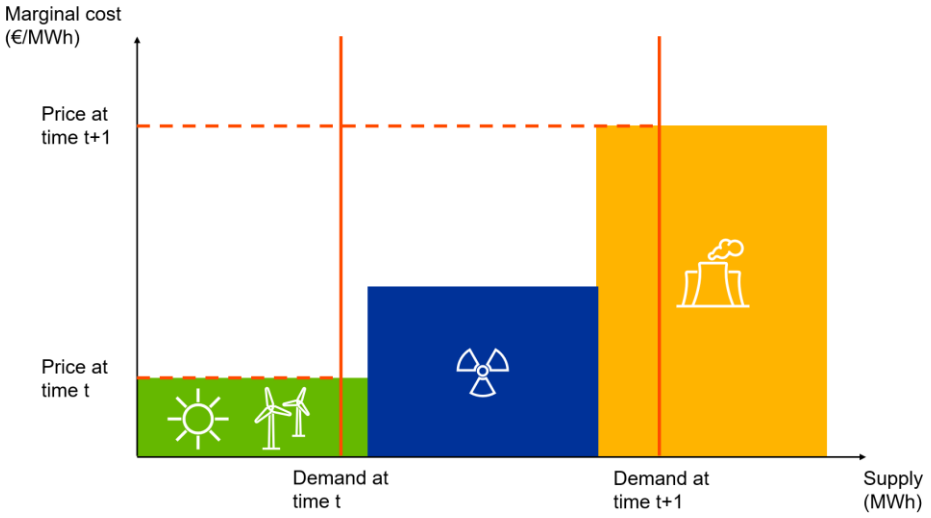
[19] For a detailed overview of the merit-order mechanism, see Gasparella et al. (2023).

[20] The marginal cost typically has three main components; fuel, ETS allowances and operational and management costs.

on free natural inputs; at the other end of the spectrum, generation based on fossil fuels entails high and volatile marginal costs because of its reliance on expensive and mostly imported commodities. Once the market operator has received all the bids, it ranks them in ascending order and orders the dispatch of electricity, starting with the lowest-cost units. Typically, this means that renewables are dispatched first, followed by nuclear power and then fossil fuels such as coal, lignite and natural gas. The last accepted bid determines the market-clearing price, which is paid to all accepted generators, regardless of their own marginal cost. This means that generators with lower marginal costs benefit from an "inframarginal rent" – the difference between the market-clearing price and their own marginal cost – which they can use to recoup fixed costs. This is particularly important for renewables, which have very low marginal costs once they are operational, but require significant upfront investments.

Chart A

Stylised representation of price formation according to the merit-order system in short-term electricity markets



Source: own elaboration.
Notes: The chart illustrates a highly stylised version of the merit-order curve with only three technologies: renewables, nuclear power and fossil fuels. Demand is assumed to be inelastic. At time t, demand is low and can be fully met by renewables, leading to a low price. At time t+1, demand is high and fossil fuel plants need to be activated, leading to a high price. In practice, there are many different technologies in use and there is variation in marginal costs among plants within a given technological category. Each plant submits its bid and they are ranked in ascending order, forming an upward-sloping merit-order curve. For numerical examples, see for example Cludius et al. (2014), Ganz et al. (2022) and Gasparella et al. (2023).

Gas is often the marginal technology, and therefore plays an important role in price-setting. In 2022, gas power plants set the price 55% of the time in the EU, despite only generating 19% of electricity (Gasparella et al., 2023). This link was a key factor behind the rise of electricity prices in that period, as the spike in the price of imported gas led to a massive increase in the cost of production for gas-powered plants. These events contributed to the emergence of a policy debate on the merit-order mechanism and calls for a reform to "decouple" gas and electricity prices. In an assessment carried out in 2022, ACER concluded that the design was "worth keeping", underlining that in normal circumstances it provides for an efficient and secure electricity supply. The agency acknowledged the exceptional nature of the crisis, but cautioned against interventionist approaches with the potential to distort markets and investment signals.[21] The EU's short-term policy response included certain interventions in the market, such as the inframarginal revenue cap, which limited

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[21] See ACER (2022).

the profits of lower-cost generators. However, the subsequent reform of the electricity market finalised in 2024 left the merit-order mechanism unchanged. Instead, it placed the emphasis on the promotion of long-term contracts such as power purchase agreements (PPAs) and contracts for difference (CfDs) to support the deployment of renewables and reduce the dependence of electricity prices on fossil fuels.[22]

The green transition has the potential to eventually bring about a reduction in wholesale electricity prices as the role of renewables grows. When renewable supply is abundant, it displaces higher-cost, fossil fuel-based generation in the merit order and exerts downward pressure on prices. Renewables can even become price-setting when renewable generation is sufficient to meet the entire electricity demand, leading to periods of very low or even negative prices.[23] Empirical studies on different EU countries have found evidence that an increase in renewable generation is associated with a decline in wholesale electricity prices (see, for example, Gelabert et al., 2011; Cludius et al., 2014; Clò et al., 2015; and Cevik and Ninomiya, 2022). Modelling by the International Energy Agency suggests that the installation of new wind and solar photovoltaic capacity in the EU over the period 2021-23 pushed the most expensive coal and natural gas power plants out of the merit order. If this new capacity had not been installed, wholesale electricity prices would have been 3% higher in 2021, 8% higher in 2022 and 15% higher in 2023.[24]

However, there are important caveats and policy aspects to consider when assessing the relationship between renewable generation and prices. First, gas will remain an important driver of short-term electricity prices in the coming years. Gasparella et al. (2023) project that gas's role in electricity generation will drop from 19% in 2022 to 11% in 2030, but that its influence on price-setting will remain steady at 55%. Fossil fuel plants will still be needed to meet demand during periods when intermittent renewables fall short, particularly during peak times. For renewables to take on a larger role in price-setting, there will need to be an increase in the number of hours in which their generation surpasses EU demand, as well as improved storage and system flexibility to reduce reliance on fossil fuels. Second, renewable generators will still need to recoup large upfront investment costs. It will be important to ensure that investment in renewable generation remains attractive, despite the possibility of declining prices in the future. One way to achieve this is through an increased use of long-term contracts such as PPAs and CfDs, which allow generators to benefit from predictable revenue streams over a longer time horizon. Finally, the growth of renewables will also require significant investments by system operators to improve grids, storage and flexibility solutions. These costs are typically passed on to consumers in the form of network charges. This

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[22] These are long-term contracts between electricity producers and either corporate buyers (in the case of PPAs) or public entities (in the case of CfDs), whereby the two parties agree on a pre-determined price per unit of output. Given the lower generation cost of renewables, the parties can agree on lower prices than those formed in short-term markets. The time horizon for such contracts typically ranges from five to 20 years. These arrangements offer benefit both for consumers (who benefit from lower prices) and for electricity generators (which benefit from a stable revenue stream, thus facilitating investment decisions).

[23] Renewable energy generation is non-responsive, meaning that it does not adjust its output to short-term changes in demand. This can lead to periods of very low or even negative prices at times of surplus renewable energy generation. According to ACER (2024a), in 2023 the EU saw a record 7,117 hours of very low electricity prices. This has downsides, as it can create uncertainty about future revenues and deter investment in renewables. Tools to counter this include the expansion of demand response and storage (which allow consumption to adjust to changes in production) and the increased use of long-term contracts (which give investors certainty by setting a long-term price that is not affected by short-term fluctuations).

[24] See IEA (2023a). A similar analysis by Quintana (2024) on the Spanish market estimated that electricity prices would have been 25% higher in 2023 and over 40% higher in the first half of 2024 if solar and wind generation had remained at 2019 levels.

means that the growing penetration of renewables, while putting downward pressure on wholesale prices, is also likely to contribute to a rise in certain components of retail prices (see Section 2.2.2.).

2.2.2 Factors affecting retail prices

Retail prices tend to broadly follow wholesale prices, but they integrate several additional components. One important element is energy taxation.[25] Direct taxes applied to energy include environmental taxes, such as those on greenhouse gas emissions, and renewable taxes, which are used to support projects related to renewables or energy efficiency. Consumer bills are also affected by network charges, which are applied by system operators to cover the cost of investment and operating the transmission and distribution systems. This component is likely to be increasingly relevant, particularly for electricity. ACER (2024b) underlines the need for large-scale investment in electricity grids in the coming decades to accommodate the rise in renewables and in electricity consumption. As a result, grid costs for consumers could increase by 60% to nearly 100% between 2022 and 2025 and are expected to become a main driver of electricity prices.

Many policies impacting retail prices – notably energy taxation – are set at the national level, which can lead to significant differences across countries. For example, in the second half of 2024, on average, non-recoverable taxes and levies accounted for 16% of the price of electricity and 15% of the price of gas paid by EU firms. Chart 2.9 illustrates the very substantial variation in the weight of taxes across countries: for electricity, it ranges from negative to more than 35%, while for gas, it ranges from close to zero to around 30%. In recent years, these differences have been amplified by national interventions to shield consumers from sharp fluctuations in energy markets. This uneven landscape underscores the scope for greater tax harmonisation across the EU to level the playing field and highlights the potential of energy taxation as a strategic instrument to accelerate electrification and support the clean energy transition. Importantly, the taxation lever should be employed while focusing on the joint objective of lowering energy prices and completing the transition, avoiding measures which would only address one objective, such as lowering taxes for retail gas. Currently, despite electricity's central role in achieving decarbonisation objectives, both energy sources are subject to a broadly comparable tax rate on average.

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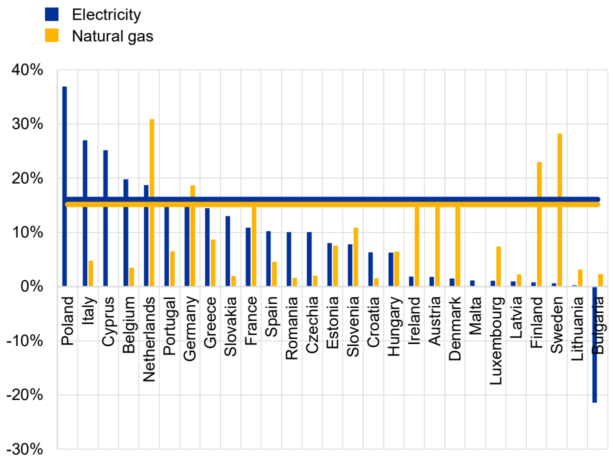
[25] This section focuses on non-recoverable taxes. It does not consider recoverable taxes and levies, which can typically be claimed back and therefore do not have a material impact on firms' costs. A key example is VAT: businesses can recover the VAT that they pay on their expenses (input VAT) by deducting it from the VAT that they collect on their sales (output VAT) and only paying the difference to their national tax authority.

Chart 2.9

Share of non-recoverable taxes in price of electricity and natural gas for medium-sized firms in the second half of 2024

(percentage)



Source: Eurostat.
Notes: the share refers to medium-sized industrial consumers (band IC for electricity and I3 for natural gas) and is calculated as the share of non-recoverable taxes and levies in the price excluding recoverable taxes and levies. The solid lines represent the EU average. Gas prices for Cyprus, Malta and Poland are not shown because they are not provided by Eurostat.

Governments can use retail price reduction policies to support firms in response to shocks or competitiveness pressures. This can reduce the pass-through from wholesale to retail price developments. Notably, many EU countries reduced energy taxes from 2021/22 onwards, in order to shield consumers from the spike in energy prices. Decisions on energy taxation lead to a host of distributional questions, notably including how to split the burden between households and industry and, within industry, the split between energy-intensive industries and others (McWilliams et al., 2024).

Additionally, large industrial consumers tend to pay lower energy prices per MWh due to scale effects, **creating further variations even within individual countries.** There are significant differences in consumption volumes across firms in the EU due to scale effects. Larger consumers, which tend to operate in energy-intensive industries, have both the incentive and the bargaining power to negotiate their prices. For example, they are more likely to be able to conclude favourable PPAs, rather than relying on regular retail contracts. They may also benefit from better access to infrastructure: for example, they may be directly connected to electricity grids and therefore avoid paying grid distribution fees. Firms in some energy-intensive industries can also choose to adapt their manufacturing processes to better exploit cheaper, baseload electricity, for example by ramping up production at times when prices are lower. Finally, larger consumers can sometimes benefit from reductions or exemptions for certain taxes and levies.[26]

In summary, a range of different factors contribute to the relatively high and volatile prices faced by EU firms, and to differences across countries. These

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[26] See European Commission: Directorate General for Energy et al. (2025).

include the EU’s dependency on fossil fuel imports, the role of fossil fuels in the electricity generation mix, the infrastructure constraints that limit energy flows across countries and differences in national policies (see Table 1).

Table 1

Key factors affecting EU industrial energy prices

	Price level	Price volatility	Price differences across Member States
Dependency on fossil fuel imports	High dependency on imported oil and gas exposes the EU to elevated prices, particularly in tight global markets.	International fossil fuel prices are highly sensitive to geopolitical shocks and supply constraints, leading to volatility in EU wholesale prices.	Countries vary in their degree of exposure to global fossil fuel markets, depending on import contracts and diversification strategies.
Role of fossil fuels in the electricity generation mix	High gas prices increase electricity prices due to the marginal pricing mechanism in wholesale electricity markets.	Gas price fluctuations are transmitted directly to electricity prices through marginal cost pricing, especially in gas-dependent systems.	National differences in generation mixes affect the prominence of fossil fuels in price-setting.
Infrastructure constraints	Constraints to energy flows can lead to inefficient use of resources, such as reliance on more expensive local generation.	Poor interconnection reduces the ability to balance supply and demand across borders, amplifying local volatility.	Cross-border infrastructure constraints limit the potential for price convergence.
National policies	Energy taxes and levies form a substantial part of final retail prices in many countries.	National governments can intervene through tax reductions or other policies, for example to buffer price shocks.	Significant variation in taxes, levies and retail market regulation leads to large cross-country differences in end-user prices.

3 The benefits of a European Energy Union

Two key trends will affect the EU energy landscape going forward: the growing role of renewables and the electrification of the economy. With the revised Renewable Energy Directive[27], the EU enshrined the target of increasing the share of renewables in total energy consumption from 24.5% in 2023 to a minimum of 42.5% by 2030 – with the aim of going even further and reaching 45%. More recently, the Commission made the electrification of the economy a key element of its Clean Industrial Deal, expressing the ambition of increasing the share of electricity in final energy consumption from around 20% to 32% by 2030. In conjunction, these two shifts will allow the EU to make increasing use of clean, domestically generated energy.

These shifts have the potential to contribute to multiple key EU strategic objectives. The increased use of renewables will be key to supporting the decarbonisation of the economy and achieving climate neutrality. From an economic perspective, the increased use of low-carbon renewables can also help to boost competitiveness by giving firms access to cheaper electricity. Finally, the shift away from imported fossil fuels will be essential to support the EU's strategic autonomy.

3.1 Looking ahead: the growing role of electricity in production

Geopolitical tensions, raising energy security concerns and the need for an energy transition imply that the importance of electricity in production processes will increase. Europe's historical reliance on external energy sources, notably Russian gas, has underscored the urgency of achieving energy independence, while simultaneously transitioning to a more sustainable economy. As the momentum towards renewable energy sources accelerates, electricity is set to become the linchpin of industrial operations, particularly in sectors traditionally dependent on fossil fuels. Moreover, the expansion of artificial intelligence represents an additional source of demand growth, although the rise in AI-related energy demand is expected to be met by natural gas power plants or renewables.[28] This transition implies that electricity demand will rise significantly. According to the European Commission (2023), EU electricity consumption is projected to rise by 60% between 2023 and 2030. International Energy Agency (IEA) data indicates that renewable generation is forecast to grow at an average annual rate of approximately 7.2% over 2025-27, more than covering additional electricity demand and replacing

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[27] Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023 amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652 (OJ L, 2023/2413, 31.10.2023).

[28] See Burian and Stalla-Bourdillon (2025).

fossil fuel sources in the region.[29] Looking further ahead, European Commission estimates point to mounting investment needs, as delivering the clean energy transition will require €660 billion of investment annually until 2030, rising to €695 billion between 2031 and 2040.

Substituting fossil fuels with electricity in European industries would bring several benefits. While many industrial processes currently rely on fossil fuels, the transition to electricity-based processes offers several advantages. First, it would cut emissions, as electricity generated from renewable sources significantly reduces carbon emissions compared with fossil fuel-based processes. Second, it could reduce costs in the longer term, as electricity from renewables can be more cost-effective than fossil fuels, especially with declining renewable energy prices.[30]

In addition to fighting climate change, a reduced reliance on fossil fuels would significantly strengthen Europe's energy security. The EU's dependence on imported oil and gas has long exposed it to geopolitical tensions, price volatility and supply disruptions, as starkly demonstrated by the recent energy crisis. For example, Anaya Longaric et al. (2024) show that European firms significantly reduce their capital and R&D expenditures in response to oil shocks, unlike their US counterparts. They also show that the United States shale revolution played a role in determining this outcome by increasing domestic energy supply for United States firms. By shifting towards domestically produced renewable energy and investing in electrification, Europe can significantly reduce its vulnerability to external shocks while strengthening strategic autonomy.

Technological development and substantial investment are necessary conditions. Production processes can be electrified using technologies such as electric arc furnaces, heat pumps and electrolysis. Moreover, hydrogen is emerging as a crucial element in the decarbonisation of energy-intensive industries, serving as a clean energy carrier for various processes, including steelmaking, ammonia production and heavy-duty transportation. Hydrogen can be produced with various methods, including electrolysis using renewable electricity (green hydrogen) and steam methane reforming with carbon capture and storage (blue hydrogen). However, realising the full potential of hydrogen energy is challenging, due to the high capital expenditure required, as well as high hydrogen transportation costs, which require infrastructure to be further developed and competitive industrial clusters to be established.[31]

In order to fulfil its renewable energy ambitions, estimates suggest that the EU will need to almost double its solar photovoltaic and wind turbine capacity between 2024 and 2030. In 2024, the EU's installed capacity stood at around 332 GW for solar photovoltaic and around 231 GW for wind turbines.[32] The European

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[29] See IEA (2025b).

[30] See IRENA (2025).

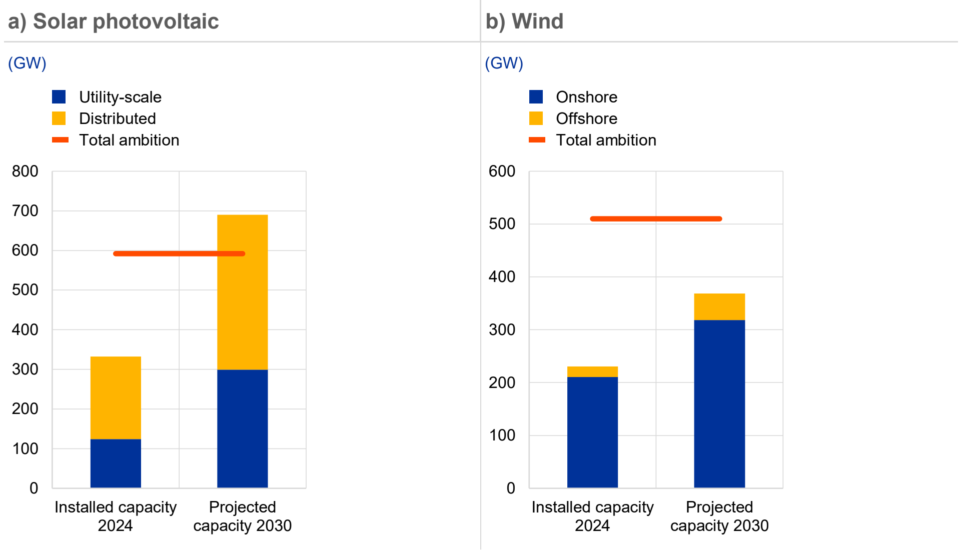
[31] See Draghi (2024).

[32] See IEA (2025a). Note that the figures and analysis in this section are based on data from the IEA Renewable Energy Progress Tracker, for which the latest release covers 2024 (data extracted in December 2025). More recent estimates cited in European Commission (2026) suggest that solar photovoltaic capacity reached 406 GW in 2025. Estimates of wind capacity in 2025 are not yet available at the time of writing.

Commission (2022) estimated that the EU's solar and wind capacity would need to increase to 592 GW and 510 GW, respectively, to reach the 45% ambition by 2030. The IEA projections for 2030 suggest that the objective for solar photovoltaic is within reach and could even be exceeded, while the wind target is likely to be missed (Chart 3.1).

Chart 3.1

Current and projected solar and wind capacity in the EU



Source: IEA Renewable Energy Progress Tracker 2025 (data extracted in December 2025).
Note: Projected capacity refers to the main case scenario.

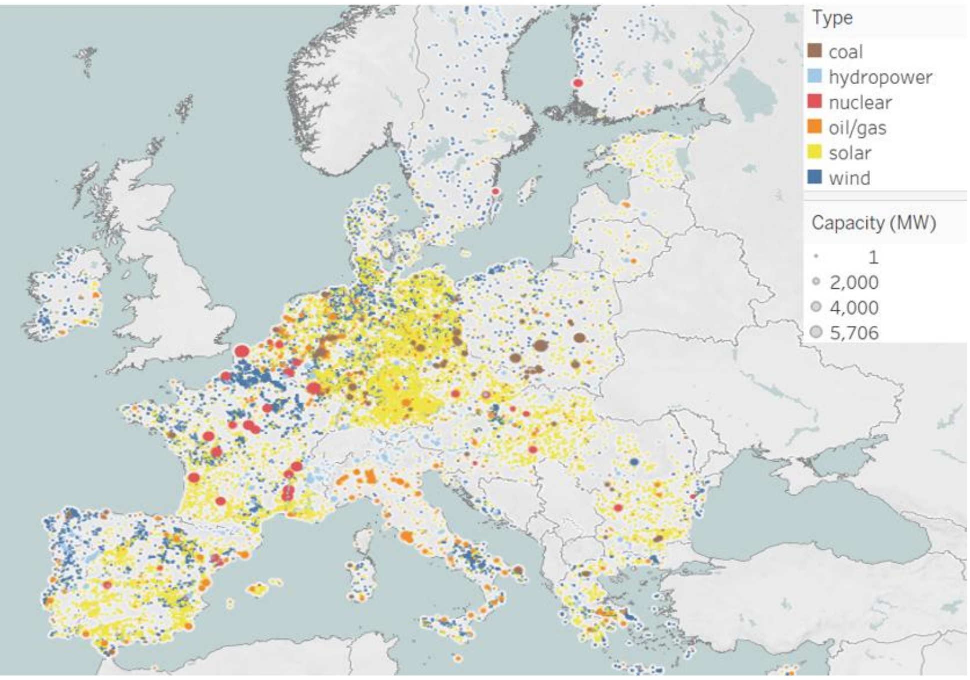
3.2 Electricity production and industrial geography: the gains of a coordinated approach

Power plants are located all over Europe, but production technologies vary substantially. As shown in Chart 3.2, renewables installed capacity, including solar, wind and hydropower, is widespread across Europe, but a high share is concentrated in Germany, Spain and France, contributing to a higher share of the energy mix. Nevertheless, several regions in Germany, Italy, Spain and Poland continue to rely on fossil fuels, including coal, oil and natural gas. In nuclear power, France remains the leading country, followed by Spain and Sweden.

Chart 3.2

Installed electricity capacity by type

(MW)



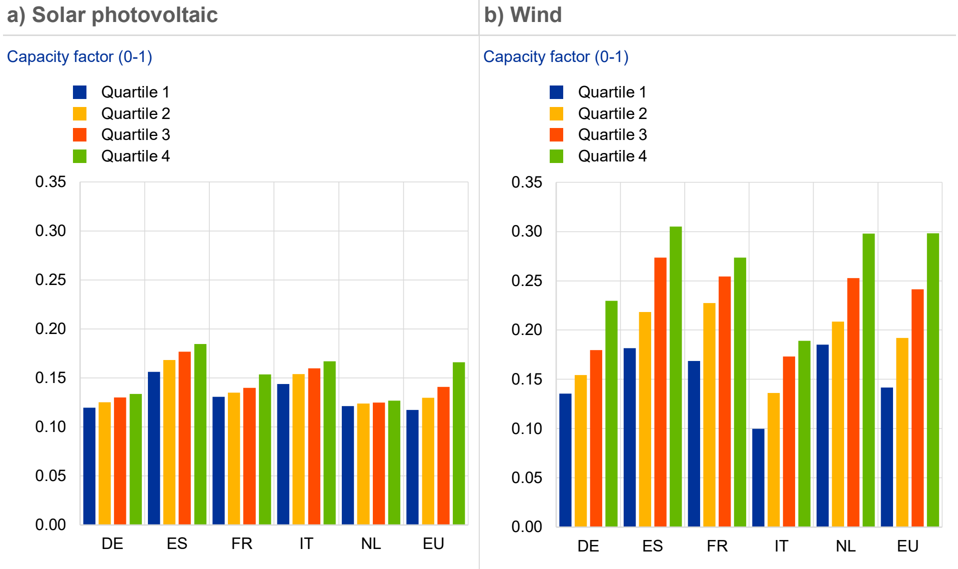
Sources: GEM Global Integrated Power Tracker September 2024 (installed capacity) and ECB calculations.
Notes: The data displayed in the chart include power facilities above the following capacity thresholds: Coal (≥30 MW), Oil and Gas (≥50 MW; ≥20 MW in the European Union), Solar (≥1 MW), Wind (≥10 MW; data ≥1 MW included for selected countries when available), Nuclear (no threshold applied) and Hydropower (≥75 MW).

The installed capacity of renewable energy in the EU is highly unbalanced, with some countries leading others in both wind and solar generation, in some cases despite less favourable meteorological conditions. Germany, Spain and France dominate the sector, accounting for most large-scale renewable energy installations, whereas countries such as Poland and Romania have more limited installed capacity, despite recent growth. Wind energy in particular is concentrated in a few nations, with Germany alone hosting 25% of installed capacity, followed by Spain (15.9%) and France (13.4%). Utility-scale solar power shows even greater asymmetries, with Spain leading with 31.8% of installed capacity, followed by Germany with 26.7% and France with 11.7%, while other countries with favourable meteorological conditions, such as Italy, Poland and Romania, still have relatively lower installed capacities.

Against this backdrop, Europe’s solar capacity factors – measuring actual versus potential power output – vary across geographies due to differences in weather and geographic conditions. Capacity factors depend on geography and weather. Europe’s latitude and solar irradiance conditions determine the efficiency of solar and wind installations. Southern countries, such as Italy and Spain, naturally present higher capacity factors for solar, while wind capacity factors have wider ranges within countries and across Europe (Chart 3.3).

Chart 3.3

Average NUTS2 capacity factors by within-country quartile

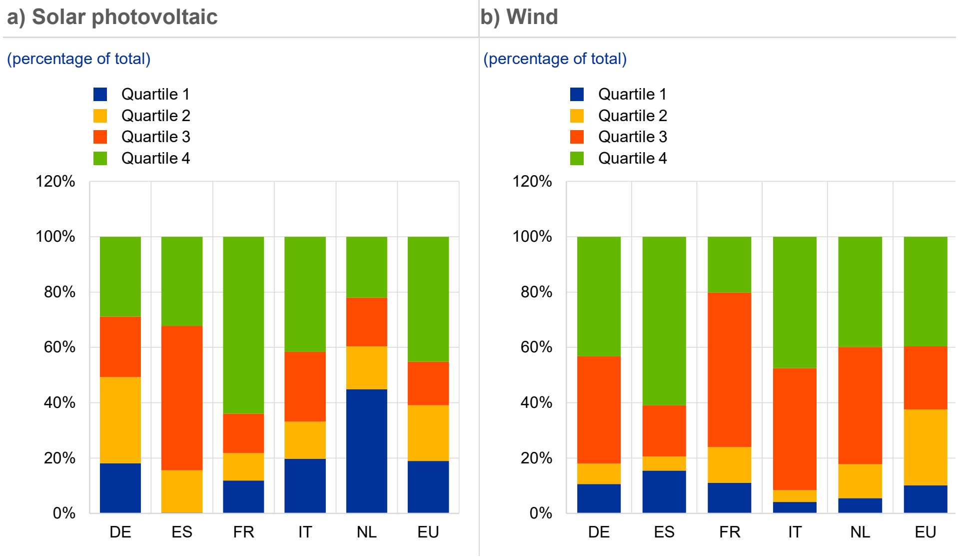


Sources: Pfenninger and Staffell (2016) and ECB calculations.
Notes: The data comprise averages of regional annual capacity factors at NUTS2 regional level, by within-country capacity factor quartiles. Reference year: 2019.

Solar installed capacity allocation varies widely across EU countries. Southern countries tend to place more solar capacity in high-capacity factor regions, whereas northern countries, such as Germany and the Netherlands, allocate more to areas with lower capacity factors (Chart 3.4). However, smaller variations in capacity factors in these regions limit the impact on output. Overall, over 60% of EU solar capacity is in the third and fourth quartiles, concentrated in a few high-performing countries (Chart 3.5). For wind, far less capacity is placed in the bottom quartile, though EU-level allocation remains somewhat less efficient than in the top five countries.

Chart 3.4

Shares of installed capacity by capacity factor quartiles



Sources: Pfenninger and Staffell (2016), GEM Global Integrated Power Tracker September 2024 (installed capacity) and ECB calculations.
Notes: The data comprise annual average capacity factors, available at NUTS2 level. Reference year: 2019. Data on power facilities included above the following capacity thresholds: Coal (≥30 MW), Oil and Gas (≥50 MW; ≥20 MW in the European Union), Solar (≥2 MW), Wind (≥10 MW; data ≥1 MW included for selected countries when available), Nuclear (no threshold applied) and Hydropower (≥75 MW).

As the EU expands its installed capacity for wind and solar energy, the selection of optimal locations remains crucial in maximising energy output. According to IEA projections, the EU will increase its *utility-scale* solar capacity by 175.4 GW and its *total* wind capacity by 137.8 GW by 2030.[33] The resulting gains in output will depend, at least in part, on the location of the newly installed capacity. To understand the potential range of output gains, we explored three hypothetical deployment scenarios. In a baseline scenario, the new capacity is assumed to be deployed equally across capacity factor quartiles. In a low-efficiency scenario, all new capacity is built in locations with the lowest productivity, matching the bottom quartile of existing EU capacity factors. Finally, in the high-efficiency scenario envisioned, all new capacity is placed in the most productive locations, mirroring the top quartile of capacity factors. While this scenario analysis is necessarily stylised and subject to a number of caveats[34], a comparison of outcomes across alternative deployment strategies can nonetheless provide a useful benchmark for assessing the potential coordination gains associated with a more integrated European approach.

According to the scenario analysis, installing new solar capacity in the most efficient locations delivers an output gain of 42% compared with installation in the least efficient locations. The planned cumulated increase in solar capacity of

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[33] See IEA (2025a).

[34] This analysis is subject to several limitations and should therefore be interpreted with due caution. In particular, it does not account for potential technical constraints, such as transmission losses and grid integration challenges, nor does it incorporate physical and geographical limitations, including land availability in areas with the highest capacity factors. Moreover, the analysis abstracts from socio-political considerations, notably public acceptance and the willingness of local communities to host renewable energy installations.

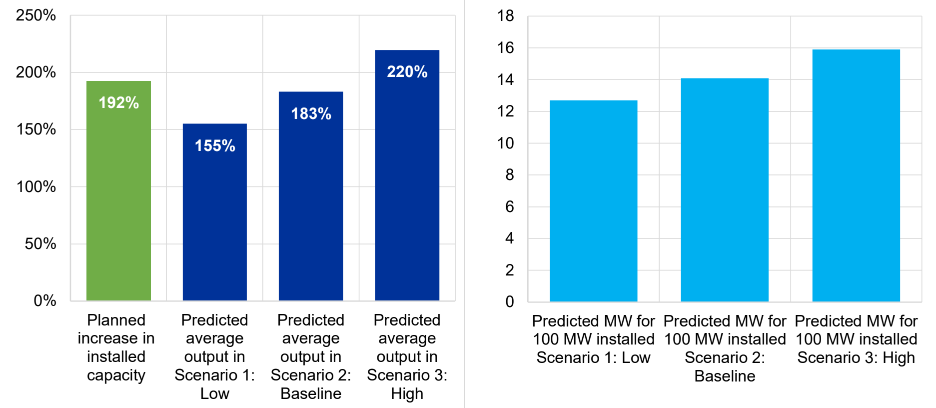
192% would result in an increase of 155% in output in a low scenario, an increase of 183% in the baseline scenario and an increase of 220% in a high scenario (Chart 3.6, panel a). This implies that a 1% increase in installed capacity would result on average in 0.8% more output in the low scenario, 1% in the baseline scenario and 1.1% in the high scenario. Additionally, for every 100 MW of installed capacity, the expected realised output would be, on average, 13 MW in the low scenario, 14 MW in the baseline scenario and 16 MW in the high scenario (Chart 3.6, panel b).

For wind, the potential gains from more efficient allocation of new installed capacity are even larger, as the increase in output in the high-efficiency scenario is twice as large as in the low scenario, with a gain of 110%. The planned cumulated increase in wind capacity of 84.9% would result in an increase of 50.1% in output in a low-efficiency scenario, an increase of 77.2% in the baseline scenario and an increase of 105.5% in a high-efficiency scenario (Chart 3.6, panel c). This implies that a 1% increase in installed capacity would result on average in 0.6% more output in the low scenario, 0.9% more in the baseline and 1.2% more in the high scenario. Moreover, 100 MW installed in the low scenario would translate into 19 MW of output in the low-efficiency scenario, 23 MW in the baseline scenario and 27 in the high-efficiency scenario (Chart 3.6, panel d).

This scenario analysis indicates that both solar and wind installations can achieve significantly higher output efficiency when sited in areas with superior capacity factors, where their output efficiency is higher, but complete cost-optimisation models are required to support energy planning and policy decisions. A coordinated European approach to renewable energy deployment that prioritises the most efficient sites could therefore yield output gains of around 42% for solar and 110% for wind when comparing the high-efficiency and low-efficiency scenarios. The larger gains for wind reflect the greater heterogeneity of capacity factors across Europe, which creates more scope for optimisation. At the same time, concentrating large numbers of wind turbines in the most favourable locations may generate “wake effects”, where airflow disruption from upstream turbines reduces wind speeds for downstream units, ultimately lowering overall capacity factors and partially offsetting these efficiency gains. Nevertheless, from an energy systems point of view, places with the strongest solar or wind capacity factors are not always the best choices for new power plants. Other factors also matter, such as how far a site is from existing roads and grid infrastructure, and how much power output changes over time. To support energy planning and policy decisions, cost-optimisation models are required, and they need good data on possible variable renewable electricity sites, including resource-related costs, grid expansion needs and hourly power generation profiles.

Chart 3.6

Scenario analysis on predicted average output depending on installation location.

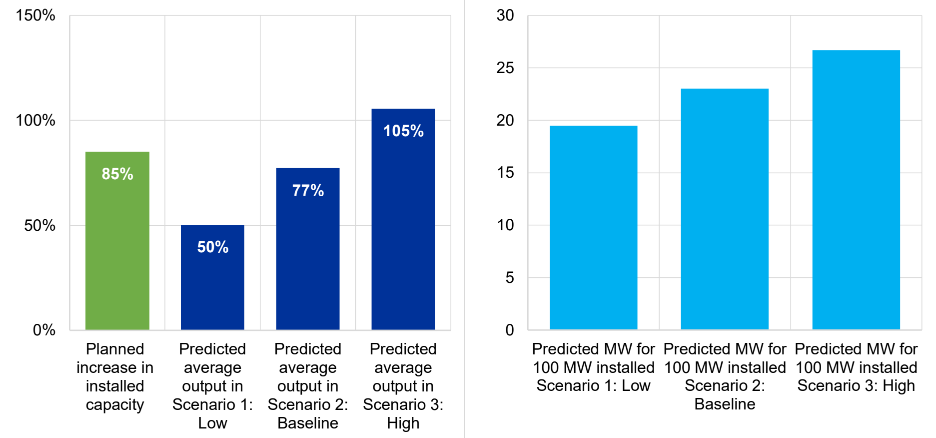


a) Solar photovoltaic

(percentage)

b) Solar photovoltaic

(predicted MW for 100 MW installed)



c) Wind

(percentage)

d) Wind

(predicted MW for 100 MW installed)

Sources: Pfenninger and Staffell (2016), GEM Global Integrated Power Tracker September 2024 (installed capacity) and ECB calculations.
Notes: The data comprise annual average capacity factors, available at NUTS2 level. Reference year: 2019. Data on power facilities included above the following capacity thresholds: Coal (≥30 MW), Oil and Gas (≥50 MW; ≥20 MW in the European Union), Solar (≥2 MW), Wind (≥10 MW; data ≥1 MW included for selected countries when available), Nuclear (no threshold applied) and Hydropower (≥75 MW).

Our analysis highlights the benefits of optimising renewable electricity deployment at European level, as well as the relative advantages of wind technology, consistently with several studies. Research into the costs and benefits of transition pathways toward a fully renewable energy economy in Europe has consistently highlighted the value of integration and coordination. For instance, Bruegel (2024) identified key benefits of a more integrated energy market, such as increased energy security, reduced fossil fuel burn, more flexibility with fewer storage investments and a fivefold reduction in price volatility. In a similar spirit, Child et al. (2019)[35] put forward a model to compare two pathways towards a 100% renewable

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[35] See Child et al. (2019).

energy power sector by 2050: a "Regions" scenario, where each region is modelled independently, and an "Area" scenario, which includes transmission and interconnections across regions. Their analysis indicates that the price of electricity could decrease by 19% in the Regions scenario and by 26% in the Area scenario. The Area scenario would also see a reduction in overall costs of 9%, equivalent to €26 billion annually, compared with the Regions scenario. Additional savings could be achieved through increased interconnections, supporting the notion that a more integrated European energy market would enhance efficiency. Similarly, Potrč et al. (2021)[36] conducted a supply network optimisation exercise to identify the optimal path to carbon neutrality by 2050, using sustainability net present value as the objective. This approach balances economic, environmental and social factors. They found that EU-level optimisation yields a 16% higher sustainability net present value compared with country-level optimisation. They also identified wind farms as a crucial driver in transitioning to a renewable electricity system, particularly in the early stages, due to their stable generation profiles, while solar photovoltaic technologies may gain prominence in later stages due to expected performance improvements.

Wind energy also offers advantages in terms of industrial competitiveness. The investment efforts of European countries have also driven significant advances in clean industries and technologies, leading to the establishment of more than 400 clean tech manufacturing plants. Europe is a key player in the clean tech sphere, with a notable competitive advantage in wind manufacturing. The global wind turbine market is dominated by ten major manufacturing companies, satisfying 88% of demand, and five of those companies are headquartered in the EU. Moreover, the EU's dependence on imports in this area is still modest. Conversely, the EU does not benefit from a comparative advantage in other clean tech sectors, such as the manufacturing of solar photovoltaic cells, as the value chain is dominated by China.[37] According to the IEA, China is the most cost-competitive location to manufacture all components of the solar photovoltaic (PV) supply chain. Costs in China are 10% lower than in India, 20% lower than in the United States, and 35% lower than in Europe.[38]

Overall, these studies demonstrate that a more integrated and coordinated European energy market can significantly enhance cost efficiency, resource utilisation and sustainability in the transition to a renewable electricity system. Strategic policies will be crucial in driving this transformation. While individual EU countries have optimised their installed capacity in line with their investment capabilities, significantly advancing clean industries and technologies, further progress now necessitates leveraging the broader EU framework. To achieve this, the development and adoption of advanced transport technologies is vital. These technologies represent key enablers to deliver efficient and reliable electricity transmission and distribution across Member States, ensuring that the benefits of

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[36] See Potrč et al. (2011).

[37] Source: Keliauskaitė et al. (2024), Bruegel (2025) and European Investment Bank (2025).

[38] See IEA (2022).

increased capacity and innovation in clean energy are fully realised at the EU level (see Box 2).

3.3 The role of the European electricity grid

Future wind and solar energy investments should also address crucial challenges for the European electricity grid. The European electricity grid is well developed but faces significant challenges in becoming fit for purpose in a renewable dominated world. The grid is a complex and interconnected system, the largest synchronous grid in the world, with 126 GW of cross-border capacity among the Member States, providing flexibility. However, the grid also faces challenges, linked to several factors.[39] First, its infrastructure is ageing: around 30% of the grid is over 40 years old, and more than 50% has been in operation for over 20 years, i.e. approximately half of its average lifespan. This leads to inefficiencies, including energy loss during transmission and limitations in connecting new renewable energy sources. Second, the existing grid infrastructure is not up to standard to cope with the rapid growth of renewable energy sources and the increasing electrification of heating and transportation. This may lead to grid congestion, delays in connecting new renewable energy projects and curtailment of renewable energy generation. Third, much of the European grid operates on a centralised model, relying on long-distance transmission. This structure is not optimal for integrating decentralised renewable energy sources, such as rooftop solar panels and small-scale wind farms, which are often located closer to consumption centres. Fourth, despite the recognised need for modernisation, grid upgrades and digitalisation are progressing slowly. This is partly due to technical challenges, such as legacy infrastructure and limited interoperability, as well as the multitude of distribution system operators (DSOs) across the EU. Permitting procedures also cause significant delays in Europe, The IEA highlights that in Europe, over a quarter of electricity projects of common interest (PCIs) are subject to delay, most frequently due to permit granting.[40]

Against this backdrop, the concentration of energy – intensive industries, especially in northern Europe – underscores the strong link between electricity production and regional demand. The established industrial base faces unique challenges, as its competitiveness depends on consistent and affordable energy supplies. The proximity of energy-intensive facilities to fossil fuel plants slated for decommissioning to meet sustainability targets (Chart 3.7) further highlights the need for regional coordination and policy alignment to achieve energy security and sustainability goals. Strengthening cross-border electricity flows can help address both near-term energy security concerns and long-term sustainability objectives.

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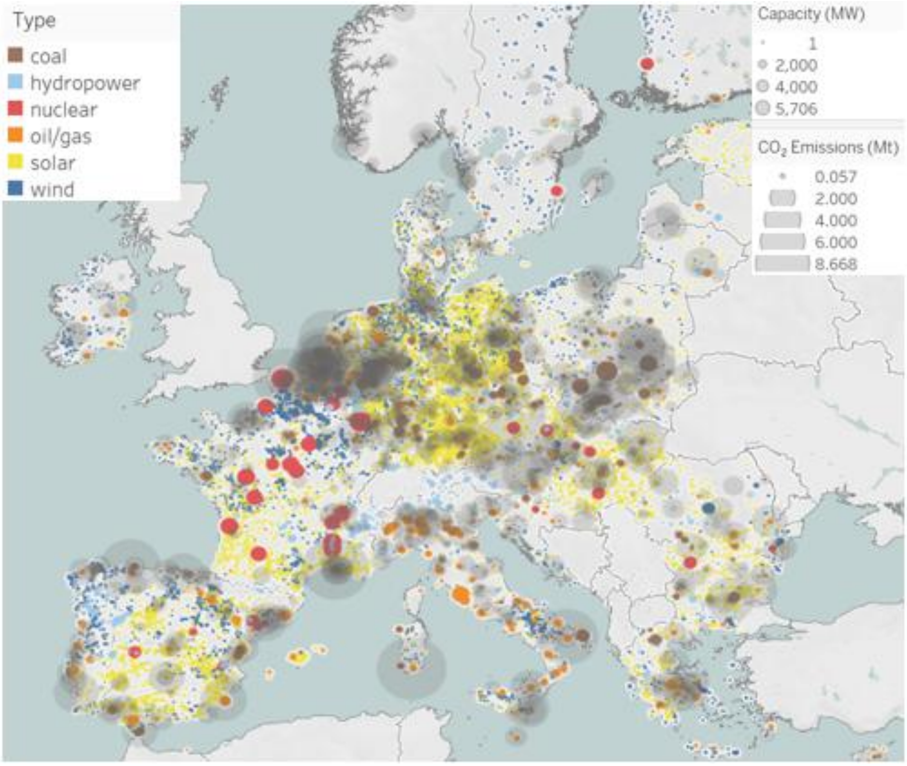
[39] See ENTSO-E (2025a) and ENTSO-E (2022).

[40] See IEA (2023b).

Chart 3.7

Emissions of energy-intensive industries and power plants installed capacity

Installed capacity (MW)
Emissions (Mt)



Sources: GEM Global Integrated Power Tracker September 2024 (installed capacity) and data retrieved from the Energy and Industry Geography Lab, a tool maintained by the Joint Research Centre of the European Commission 2023 (Emissions) and ECB calculations.
Notes: The data comprise CO_2 emissions of facilities of energy-intensive industries, defined as Non-metallic minerals, Refineries & petrochemical industry, Iron & steel, Production of steam, Chemical & petrochemical, Domestic aviation, Non-ferrous metals, Paper, pulp & printing, Food, beverages & tobacco, Coke ovens, Mining & quarrying, Commercial & public services, Pipeline transport, Machinery, Not elsewhere specified (industry), Transport equipment and Wood & wood products (Emissions).
(Installed Capacity) The data displayed in the chart include power facilities above the following capacity thresholds: Coal (≥30 MW), Oil and Gas (≥50 MW; ≥20 MW in the European Union), Solar (≥1 MW), Wind (≥10 MW; data ≥1 MW included for selected countries when available), Nuclear (no threshold applied) and Hydropower (≥75 MW).

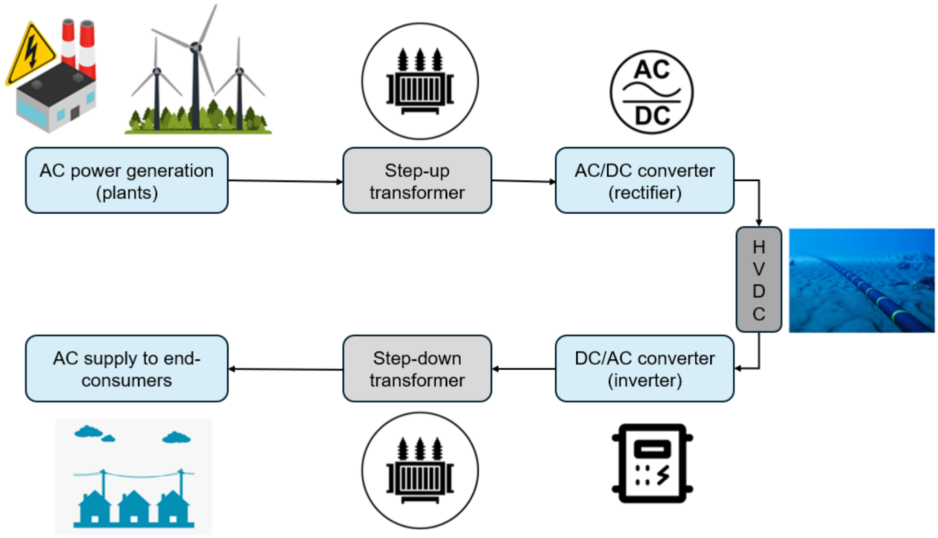
Box 2: Technological enablers: long-distance energy transport innovations

Prepared by Prof. L. Di Renzo and R. Prioriello

To fully realise the benefits of renewable energy integration, it will be essential to adopt advanced electricity transmission technologies – such as high-voltage direct current (HVDC) – that can efficiently transport energy over long distances. HVDC relies on direct current (DC) rather than the more commonly used alternative current (AC). The technology emerged in the late 19th century, but early adoption remained restricted by substantial technological barriers, particularly the lack of efficient and reliable converters necessary for transforming DC power into AC and vice versa (Chart A). Instead, AC transmission systems were favoured, due to their lower initial investment costs and simpler methods of voltage regulation. These practical and economic advantages enabled AC technology to overshadow HVDC for several decades. HVDC only regained attention after technological advancements in converter technology in the 20th century, which enabled cost-effective and reliable long-distance and underwater transmission solutions. More recent advances have significantly reduced the size, cost, and complexity of converter stations. This trend has lowered the economic threshold for HVDC, making it increasingly competitive with AC systems, even at medium distances and in complex grid environments.

Chart A

Typical steps from power generation to end-consumer with HVDC technology over long distances



Source: ECB elaborations.

HVDC transmission significantly reduces electrical losses over long distances compared with traditional AC systems. When electricity travels through power lines, some energy is inevitably lost as heat due to resistance, making transmission over long distances challenging and often unviable. AC transmission systems are particularly inefficient, as they suffer from reactive power losses, meaning that extra energy is required just to maintain voltage stability along the line. Conversely, as HVDC uses direct rather than alternating current, it experiences fewer inefficiencies, enabling electricity to travel more effectively over long distances, which saves energy and reduces overall costs. For a given cable conductor area, the line losses with HVDC cables can be about half those of AC cables.

Modern HVDC transmission systems utilise advanced cable and converter technologies specifically designed to optimise efficiency and reliability. HVDC cables present reduced electrical losses and improved durability, especially for subsea or underground applications, minimising dielectric losses, and flexibility of installation. HVDC does not require phase synchronisation, making it easier to link asynchronous or distant grids. This flexibility is critical for integrating variable renewable energy sources (e.g. wind farms in the North Sea or large solar installations in desert regions) and for enhancing the stability of interconnected power systems.

Selecting between HVDC and AC transmission technologies involves a clear trade-off based primarily on transmission distance and specific project characteristics. As indicated by the IEA[41], HVDC systems become economically advantageous over AC for distances exceeding approximately 600-700 km for overhead lines and considerably shorter tens of kilometres for subsea or underground installations. While HVDC provides superior efficiency and reduced losses for long-distance and underwater transmission, it demands higher initial investments due to the

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[41] See IEA (2023b).

need for expensive converter stations. Conversely, AC technology remains more cost-effective and simpler to implement for shorter distances, primarily due to lower upfront costs and reduced complexity, as converters are unnecessary. Choosing the appropriate technology thus requires consideration of factors such as project scale, geographical terrain, transmission distance and the overall economics of energy delivery.[42]

Only a small share of Europe's 500,000 km transmission grid consists of lines longer than 500 km, yet replacing them with HVDC could yield substantial efficiency gains. According to the IEA, Europe's electricity grid is made up of relatively short high-voltage power lines because its network is tightly connected, and cities and power plants are usually close to each other. Most power lines in Europe are much shorter than what is considered "long-distance". While comprehensive detailed data on line lengths are not available, reports from the Ten-Year Network Development Plan show that new power line projects (covering 43,000 km in total) typically span just 80 km each. In fact, lines longer than 500 km make up less than 5% of Europe's 500,000 km total power grid. Crucially, if approximately 25,000 km of long AC lines were converted to HVDC, the resulting reduction in transmission losses would be significant, as AC systems typically lose about 7% of electricity per 1,000 km, compared with just 3-4% for HVDC, justifying the investment.

Looking ahead, numerous large-scale HVDC projects are planned or under development, in the face of substantial investment needs. For instance, Europe is significantly expanding its network of HVDC interconnectors in the North Sea to facilitate bulk power transfer from offshore wind farms to multiple onshore grids. These initiatives include extensive networks of underwater cables designed to integrate offshore wind generation with mainland power systems, thereby enhancing Europe's overall energy security and stability. Hybrid interconnector projects are increasingly being pursued to simultaneously connect multiple countries and offshore wind resources, providing greater flexibility, market integration and improved reliability for renewable energy distribution. Additionally, projects involving the creation of artificial energy islands are being explored. These could act as centralised hubs connecting vast offshore wind capacities, efficiently distributing renewable electricity across various European grids.[43] Overall, planned projects of common and mutual interest (PMIs/PCIs) for electricity transmission are estimated to require around €60 billion in investment to 2035, including €28 billion for cross-border projects. HVDC lines are expected to represent approximately 65-80% of equipment used for subsea transmission, and 30-50% of that used for onshore lines. In addition, future investment needs for expanding cross-border transmission capacity are estimated to fall within the range of €14 billion to €37 billion by 2040.[44]

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[42] See JRC (2023).

[43] Examples of projects include the Princess Elisabeth Energy Island in Belgium, North Sea Wind Power Hub (NSWPH), Denmark's North Sea Energy Island and Bornholm Energy Island, and hybrid interconnectors such as LionLink and Nautilus. Sources: European Investment Bank, ENTSO-E.

[44] European Commission (2025).

4 Conclusions and policy implications

4.1 Key findings

The EU energy market faces significant challenges due to its reliance on imported fossil fuels and internal fragmentation. Fossil fuel prices, particularly natural gas, heavily influence electricity costs under the merit-order mechanism, despite the growing role of locally generated renewables. Energy-intensive industries, which rely on electricity and natural gas for approximately two-thirds of their energy needs, face higher and more volatile energy costs than international competitors, impacting their global competitiveness. Moreover, energy prices within the EU vary significantly, due to differences in national energy mixes, taxation policies and industrial concentration. This fragmentation affects internal competitiveness, as firms in high-cost countries face higher production expenses compared with those in low-cost nations. These findings underscore the need for energy independence while transitioning to a sustainable economy.

Electricity is set to play a central role in the EU's transition to a low-carbon economy. The electrification of industrial processes – using technologies such as electric arc furnaces, heat pumps and electrolysis – will significantly increase electricity consumption and require substantial investments in renewable energy capacity and infrastructure. To meet its climate objectives, the EU will need to roughly double its solar photovoltaic and wind generation capacity, making the choice of deployment locations crucial for maximising energy output and overall system efficiency. Scenario analysis shows that the efficiency of renewable energy installations can vary significantly based on where they are deployed, with high-efficiency locations yielding up to double the output of low-efficiency sites. Moreover, the choice of renewable technology matters. For example, while the EU has a competitive edge in wind turbine manufacturing, it faces challenges in areas such as solar photovoltaic cells, where China dominates global production.

4.2 Policy implications

The findings of this paper highlight the need to advance towards a genuine Energy Union, which demands concerted action across several policy priorities. Completing the green transition and achieving energy independence requires progress towards an Energy Union – a comprehensive EU-level framework coordinating market integration, governance, energy security, decarbonisation, efficiency, funding and external energy policy, as set out by the European Commission since 2015.[45] Achieving a complete Energy Union would involve the

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[45] The Energy Union agenda is an EU-level policy framework of coordinated measures and legislative initiatives designed to align Member State action on energy. It bundles market integration reforms, governance mechanisms, energy security measures, decarbonisation and efficiency policies, funding and innovation instruments and external energy diplomacy into a single strategic framework to ensure coherent, mutually reinforcing outcomes across the European Union. The term and agenda were launched by the Juncker Commission in the 2015 Energy Union Strategy (COM/2015/080).

seamless integration of energy markets, resulting in decreased price disparities, reduced price volatility and strengthened security of supply. This approach not only aligns with the EU's energy goals, but also ensures a competitive and resilient industrial landscape, by strategically aligning industrial development with renewable energy resources. The realisation of a true Energy Union hinges on coordinated efforts and advancements in key policy areas.

First, it is crucial to enhance investment in cross-border energy infrastructure. This is essential for bolstering energy security, stabilising prices and integrating renewable energy sources. Expanding electricity grids and increasing interconnectors between EU Member States will create a more resilient and interconnected energy market, ensuring efficient distribution from renewable-rich regions to high-demand industrial areas. Strengthening connectivity with third countries will also allow for mutual support during emergencies. According to ENTSO-E, an additional 88 GW of cross-border capacity and 56 GW of storage by 2030 could reduce power system costs by €8 billion with just €5 billion in investments. However, current projects will only deliver 35 GW, highlighting the urgency of addressing the investment gap.

Second, it is essential to develop innovative financing solutions to stimulate investment in the energy sector through EU public resources and private sector contributions. There is a substantial public funding gap in meeting green investment needs to 2030 (Nerlich et al., 2025). While significant public funds are available at the EU level, primarily through the Recovery and Resilience Facility (RRF) of NextGenerationEU and the EU budget, there remains a noticeable shortfall anticipated after the RRF expires in 2026, increasing to around €54 billion by 2030. Proposals for an EU fiscal capacity for climate have been suggested to address this gap, aiming to support large cross-border projects that serve as European public goods.[46] Moreover, the private sector has a crucial role to play to meet green investment needs, but the limited scale of European capital markets poses significant challenges. Diverse financial instruments, including green bonds, are essential to support the transition, with private equity markets playing a major role in funding innovative start-ups and advancing green technology projects. The relatively small size of innovation funding markets in Europe underscores the need for faster progress in deepening the CMU, which would accelerate the development of these markets and further support the green transition.[47]

Third, commitment to technologies and infrastructure that will support flexibility and a better matching of supply and demand is paramount. Enhanced digitalisation, storage capacity and demand response programmes are important to ensure grid stability, which requires improvements in flexibility, managing intermittency and ensuring sufficient backup capacity. Digitalisation of the grid is crucial to enhance grid management, optimising energy flows in order to integrate intermittent renewable energy sources effectively. Digitalisation enables smart grid technologies, which utilise digital communication technologies to monitor and control

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[46] See, for example, Abraham et al. (2023).

[47] For an in-depth discussion of how the CMU agenda can support green investment, see Nerlich et al. (2025).

electricity flows in real time. This allows for dynamic adjustments to grid operations, optimising energy distribution and integrating renewable energy sources more effectively. Moreover, energy storage systems, such as batteries, flywheels and pumped hydro storage, play a crucial role in balancing the intermittency of renewable energy. Improving storage capacity would also imply being better able to store renewable energy when it is abundant for use during times when renewable energy generation is low. Lastly, demand response programmes, meant to incentivise consumers to adjust their electricity consumption patterns in response to grid conditions or price signals, can help balance supply and demand, reduce peak loads and integrate renewable energy more smoothly.

Fourth, there is scope to make energy taxation more efficient and harmonised across Member States, in order to reduce price disparities, foster market convergence and incentivise electrification. Optimising and harmonising energy taxation can help level the playing field for firms across different Member States and enhance competitiveness. However, progress in this area has historically been challenging, due to different national preferences and the EU's unanimity requirement on taxation issues. With the Clean Industrial Deal, the Commission has put forward recommendations to Member States on instruments to lower taxation levels in a cost-effective way, as well as a harmonised tariff methodology for network charges. While there is no obligation for Member States to follow such recommendations, if they are taken up, they can help to promote more efficient and harmonised taxation in the EU. Furthermore, tax frameworks need to factor in the environmental performance of different energy sources and set incentives that will support electrification and the development of clean energy. To this end, it will be crucial to reach agreement on the review of the Energy Taxation Directive, which is the last remaining outstanding file of the Fit-for-55 package.

Fifth, achieving these goals demands a cohesive EU-level industrial policy to strengthen competitiveness in sectors where European firms can excel globally while safeguarding strategic autonomy. In 2023, China dominated clean technology manufacturing investments, accounting for 80%, compared with just 20% from the EU and US combined.[48] Despite China's established dominance, Europe has a prominent clean tech ecosystem, with substantial manufacturing capacity in batteries, electric vehicles, wind energy and heat pumps.[49] These industries need to be supported by European-level industrial action, in order to build and maintain global leadership. At the same time, maintaining key domestic capacities, even in areas where other regions have a competitive edge, would ensure resilience and independence in critical sectors. Furthermore, fostering industrial development in regions with abundant renewable energy resources can enhance energy efficiency and sustainability and align industrial growth with the EU's clean energy transition.

Against this background, the EU has several programmes in place to support green energy investment. The European Green Deal serves as the overarching strategy to make Europe the first climate-neutral continent by 2050. Within this framework, initiatives such as the InvestEU Programme, the Just Transition

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[48] See IEA (2024).

[49] See Bruegel European Clean Tech Tracker (2025).

Mechanism, the RRF and the Innovation Fund provide targeted financial and technical support to projects that promote sustainable energy, digitalisation, circular economy and low-carbon technologies. In addition, the EU Structural and Investment Funds, including the European Regional Development Fund and the Cohesion Fund, play a key role in financing green transition efforts across regions – particularly in less developed areas – by supporting energy efficiency, renewable energy deployment, digitalisation and sustainable transport. The European Investment Bank (EIB) – often referred to as the EU's "climate bank" – further complements these efforts by mobilising public and private capital for green infrastructure and environmental innovation. Together, these instruments channel investment towards a more sustainable, resilient and competitive European economy. Additional initiatives to foster cross-border investments include the revised Trans-European Networks for Energy (TEN-E) policy (2022), which reduced red tape by simplifying and accelerating permitting, enabling projects of common and mutual interest (PCIs and PMIs) that contribute to the development of cross-border energy infrastructure. Moreover, the European Grid Action Plan (2023) underscores the EU's commitment to meeting significant investment needs in electricity infrastructure to accommodate rising demand and effectively integrate renewable energy sources.

Moreover, several EU initiatives are set to provide industrial policy steer. EU policies support industrialisation through green technologies, including batteries, solar panels, green hydrogen and low-carbon steel. These include the Green Deal Industrial Plan (2023), which built on the earlier EU Industrial Strategy, and Important Projects of Common European Interest (IPCEIs), which enable Member States to provide State aid to jointly support large-scale, cross-border projects in strategic sectors such as clean technologies, batteries, hydrogen and microelectronics. The Clean Industrial Deal, launched in 2025, is focused on the joint objective of industrial decarbonisation and growth, aiming to lower energy costs, promote clean tech markets and mobilise significant funding for EU clean manufacturing. The Deal also sets ambitious goals for recycling and efficient use of resources, planning joint initiatives for negotiating better terms for raw materials. On the financing side, it also foresees the introduction of an Industrial Decarbonisation Bank to support green projects, while also strengthening the domestic manufacturing of clean technologies. These coordinated efforts not only aim to bolster Europe's green industrial base but also strive to create a more interconnected and resilient energy market across the continent.

Lastly, the European Grids Package proposals aim to strengthen system-level planning and accelerate infrastructure delivery across the EU. Introduced in December 2025, the package aims to significantly improve EU cross-border capacity planning by establishing a more coordinated and forward-looking approach to network development. At its core is a new central EU energy system scenario, developed by the European Commission and applied across electricity, hydrogen and gas. This scenario provides a unified and policy-aligned basis for identifying future infrastructure needs and coordinating transmission and distribution grid planning. It is complemented by an enhanced focus on non-wire alternatives, including flexibility resources and advanced digital tools, to maximise the use of existing assets before engaging in physical grid expansion. The package also elevates smart grids and digitalisation to a strategic priority by promoting real-time system monitoring, automation, cybersecurity and the uptake of grid-enhancing technologies capable of increasing network capacity at a substantially lower cost. To accelerate project delivery, the proposal introduces a harmonised EU-wide permitting regime covering grids, renewable energy installations, storage facilities and electric vehicle charging infrastructure. This regime sets a maximum two-year authorisation period, or three years for complex projects, and includes simplified environmental procedures, digital permitting portals, clear cut-off dates for information requests and mechanisms for tacit approval. Taken together, these measures can address persistent structural bottlenecks, modernise power system operation and support the development of a more resilient and future-proof European energy network.

Overall, the case for a genuine Energy Union is compelling, as it embodies a key European public good essential to the EU's long-term prosperity and security. While existing EU policy initiatives mark an important step in the right direction, they must be complemented by additional decisive action to meet the scale of the challenge. The increasing frequency of externally driven energy shocks, from Russia's invasion of Ukraine to the more recent conflict in the Middle East, has once again laid bare Europe's structural vulnerabilities, which need to be addressed. By cultivating a fully integrated energy market, the EU can bolster its economic resilience, strategic autonomy and industrial competitiveness, optimise resource allocation and unlock opportunities for European capital.

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Acknowledgements
We would like to thank, in alphabetical order, Daniela Arlia, Giuseppe Barillà, Francesco D'Ignazio, Emma Domingo Enrich, Andrei Dumitrescu, Irene Heemskerk, John Hutchinson, Daniel Kapp, Friderike Kuik, Laura Parisi, Fatima Pires, Raffaele Prioriello, Arthur Stalla-Bourdillon and Sebastian Sterl.
The views expressed are those of the authors and all errors and omissions are their own.

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PDF ISBN 978-92-899-7629-9, ISSN 1725-6534, doi:10.2866/7510850, QB-01-26-017-EN-N