STRATEGIC PERSPECTIVES

Boosting electrification in Europe

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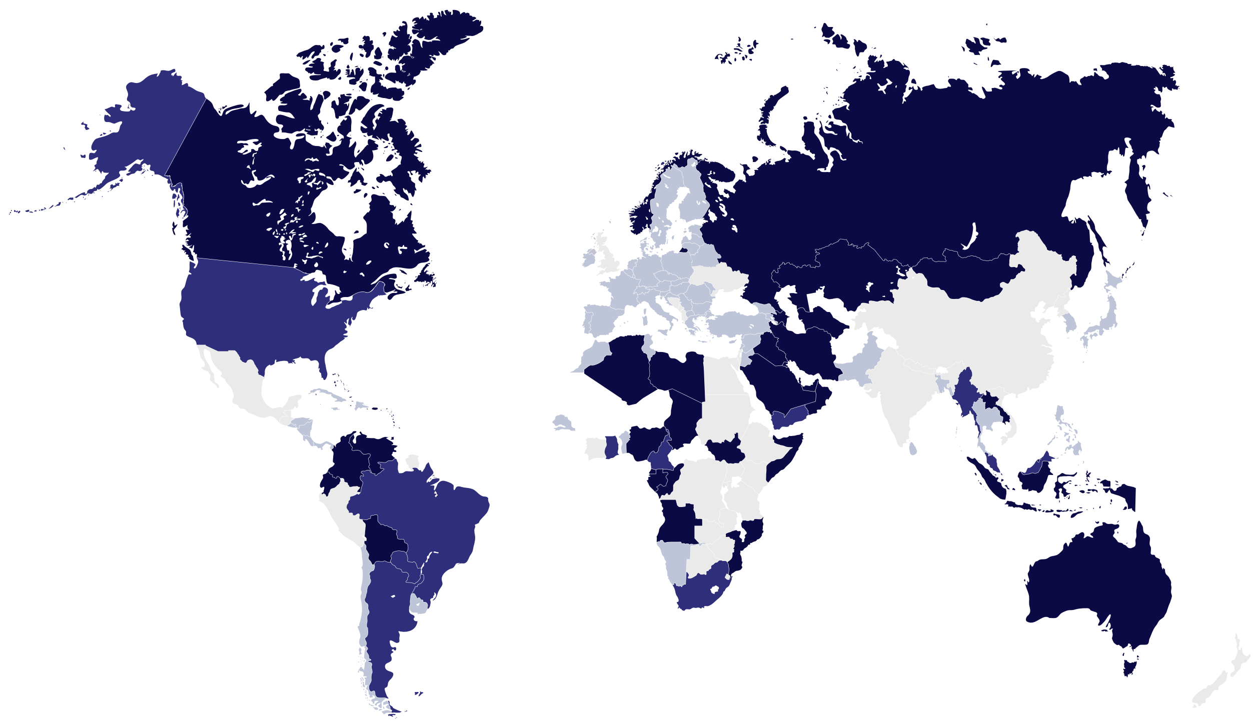
Introduction

Electricity is nearly the only form of energy that can be fully produced in Europe, yet only 23% of the European Union's (EU) final energy consumption comes from electricity, and this share has remained stagnant for over a decade. 90 million European households still heat their homes with gas and oil boilers,[1] more than half of the industry's energy consumption comes from fossil fuels,[2] and only 4% of cars are electrified.[3] Instead, Europeans have chosen to outsource their energy supply to oil, gas and coal producers, leading to dependence for 63% of the EU's primary energy on imports. It has cost the EU €1.8 trillion in imports between 2021 and 2024.[4] The EU is one of the most energy-dependent economies in the world.

Figure 1.
World map of the energy dependence level - in percentage of energy imports and exports (2022)
(source: World Bank data)

- High energy import dependence (above 40% of the energy use)
- Moderate to low energy import dependence (below 40% of the energy use)
- High energy exporter (above 30% of the energy use)
- Moderate energy exporter (below 30% of the energy use)



At a time of geopolitical turbulence and energy blackmail from fossil fuel producers, Europeans are paying the high price of this dependence. Russia's war in Ukraine has resulted in energy prices being four to five times higher than in the United States (US) and China,[5] the EU's main economic competitors. It damages industrial competitiveness and social stability while raising clear concerns over the security of supply. Even if prices decrease again, **this dependence will remain a structural vulnerability and a security threat for the EU**.

Aware of this challenge, the European Council has repeatedly called for "ambitious electrification".[6] Consequently, the new European Commission has placed energy at the heart of its political agenda, with energy security and affordability at the forefront, and the centre of the Clean Industrial Deal. Even if the short-term imperative implies partly replacing Russian gas imports with the US's liquefied natural gas imports, only the rapid electrification of the economy, combined with a robust decarbonisation of the power sector, can reverse a decade of deepening energy dependence. **Electrification is a strategic choice for a continent with limited oil and gas resources**. By replacing fossil fuel use in power generation, buildings, transport, and industry, the EU can strengthen its energy security, reduce the cost for its economy, and unlock new industrial opportunities and innovation.

In comparison, China has seen impressive results in its "electricity revolution", reaching an overall electrification level of over 32% in 2023[7] and increasing by one point every year.[8] Through large-scale deployment of electric vehicles (EVs), solar and wind power, coordinated manufacturing strategies, and rapid grid development, China has driven down technology costs and achieved significant gains in electrification. These policies not only advance decarbonisation and mitigate dependence on imports, but also turn China into an 'Electrostate'. It firmly positions its economy at the forefront of global electrotech[9] value chains and as a clear leader in the new net-zero industrial era.

The contrast with Europe is striking. The recent attempts to roll back key Green Deal laws, such as the shift to EVs, risk damaging the business case for electrotechs. A strong political support and direction of travel in favour of electrification is the only way to break this vicious cycle. The Clean Industrial Deal and the Action Plan for Affordable Energy highlighted the importance of clean electrification for the EU's political and economic prosperity. **The upcoming Electrification Action Plan and the EU's Energy Union package are key opportunities to turn good intentions into a proper 'electrification first' principle.**

This report assesses the current state of electrification in the EU, quantifies the benefits of higher electrification, and proposes some policy recommendations. This will help rebuild the political momentum around the fact that electrification can reconcile the EU's competitiveness, energy security and climate agenda.

Methodology

Scenario

The electrification booster scenario is largely inspired by Scenario S3 of the Impact Assessment of the 2040 climate target,[10] particularly regarding demand, production, and deployment rates of the four studied electrotechs (building heat pumps, industrial heat pumps, electric vehicles, and green-steel production). The business-as-usual scenario is constructed from the electrification booster scenario by applying tendential deployment rates to these electrotechs. The power system is then modelled using the Artelys Crystal Super Grid platform[11] to determine suitable power-generation, storage, and cross-border transmission capacities for both scenarios.

Modeling approach

The Artelys Crystal Super Grid modelling platform was used to perform simulations of the two scenarios within the timeframe of 2040. Each simulation consists of the joint optimisation of investment and hourly operations of the European power system over a full year (8760 consecutive timesteps), for a perimeter that covers all EU-27 countries and relevant non-EU countries (Switzerland, Norway, the United Kingdom, and the Western Balkans). All modelling runs are performed over a full year. Investment decisions are based on annuities computed according to investment parameters.

The baseline power system model is built according to the 2040 National Trends + scenario from ENTSO-E's Ten-Year Network Development Plan 2024.[12] This includes capacities and main techno-economic parameters from all generation technologies, as well as time series for power demand and renewable generation.

Commodity prices and technology costs

The commodity prices used in the study are aligned with 2040 projections from TYNDP NT+ 2024 and the technology costs are based on the technology assumptions used in the European Commission's impact assessment.[13]

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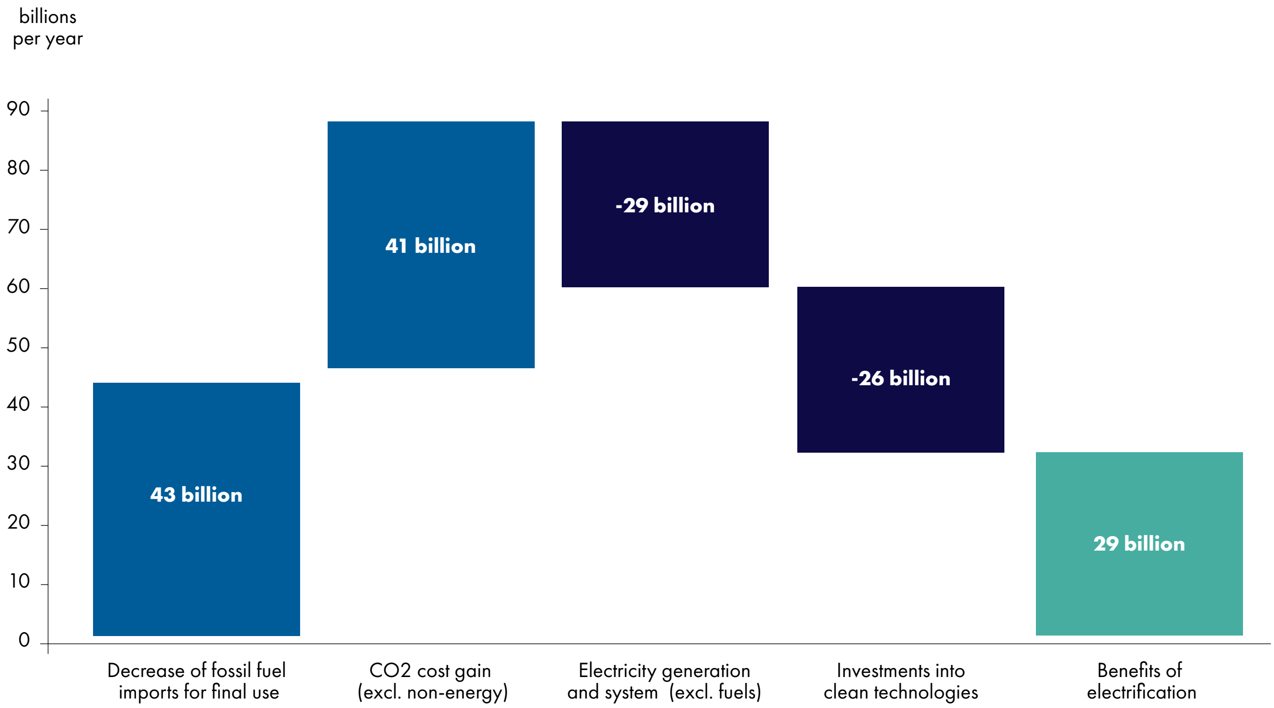
Executive Summary

Electrification is the new foundation of competitiveness and energy security. This is true in China, where 26% of GDP growth came from electrotech production in 2024.[14] It is also true in California, where over 545,000 jobs were in the clean energy sector in 2023,[15] and it is true in the European Union, where the electrotech sector represents at least 742,000 jobs[16] and accounted for 30% of the GDP in 2023.[17]

The international race for electrification is on, and the European Union is perfectly positioned to take a leading role. With limited oil and gas reserves, but home to some of the world's trailblazing electrotech companies, **electrifying half of the European economy by 2040 is the best strategy** for its international competitiveness and energy security. This level of electrification (modelled as the "electrification booster scenario") requires additional EU policies and substantial investments, but the benefits are clear: The savings made each year by reducing fossil fuel imports exceed the additional cost of electrification by €29 billion, even before accounting for efficiency gains and additional industrial activity in the EU.

Figure 2.
Cost-benefit analysis of the electrification booster scenario compared to the business-as-usual scenario in 2040.



The EU's economy is ready for broad-ranging electrification

Most of the technologies to electrify the European economy are ready to be deployed at scale. With the right policy, in only 15 years, 150 million EVs could be on European roads, 84 million heat pumps deployed and half of the industry's energy needs could be met by the grid, particularly through the use of industrial heat pumps. Not only do these electrotech replace outdated and highly inefficient technologies based on the combustion of fossil fuels, but they also offer pilotable and smart services to the economy and generate major efficiency gains. On average, heat pumps and EVs are two to four times more energy-efficient than gas boilers and diesel or internal combustion engine (ICE) cars.[18] By supporting electrification, the EU will focus on **the most cost-competitive decarbonisation route and modernise its economy.**

Electrification is the best business case for the EU's industries. Many of the technologies needed for electrification, such as EVs, wind power, and industrial heat pumps, are already more competitive than their fossil-based alternative, or close to reaching price-parity. Electrifying energy-intensive industries can contribute to restoring their business case, lowering their costs, and, more importantly, allowing them to reach new markets. It will also boost European strategic electrotech industries, **allowing the EU to participate in the new global net-zero industrial race.** The demand for industrial heat pumps in 2040 in an electrification booster scenario is expected to be double the demand in a business-as-usual scenario, providing the sector with a solid business case. In other words, electrification could shift EU spending from imports to industrial renewal and competitiveness.

Cheap, abundant and clean power to meet the electrification pace

A clean electricity system maximises the business case of electrification by limiting the economy's exposure to volatile gas prices. In the electrification booster scenario, **an increase of 80 Gigawatt (GW) of renewable capacities per year** can entirely meet the **additional electricity demand while decarbonising the power mix**. The EU is on track already with 77 GW of renewable power installed in 2024.[19] The ongoing energy transformation will be completed by a stable nuclear and hydropower baseload, along with the uptake of storage and flexibility, especially through the use of batteries. At least 134 GW of batteries could balance and ensure a stable supply of renewables, making fossil fuel-based capacity markets redundant. **The EU can cut its fossil fuel import dependency by two-thirds by 2040.** This can save €44 billion in fossil fuel imports per year compared to a business-as-usual scenario, cutting dependence on oil, gas and coal producers and strengthening energy security.

A new energy architecture centred on electrification is necessary

A business-as-usual scenario leads the EU to achieve a 39% electrification rate by 2040, which is far behind the potential 51%. Without a change in speed, the EU risks unnecessarily prolonging its dependence on fossil fuels and missing its opportunity to become an electrotech leader or even catching up with China. Boosting electrification requires a new optimised energy architecture to send a clear signal in favour of electrification, aligning investments, policies and taxation around this goal.

This new Energy Union architecture will focus on four main pillars:

- **A direct electrification target of 50% of final energy consumption by 2040,** outlined in a Clean Electrification Directive, could provide a robust basis for planning and investment. This would drastically optimise the current framework by removing complex sector-specific renewable energy targets and providing clearer guidance on electrification.

- **A zero-emission power capacity production target** will also be central to synchronise electricity demand uptake with supply. Complying with the technological neutrality approach, the Commission could, nevertheless, set benchmarks per technology to provide sectors with predictability over the period.

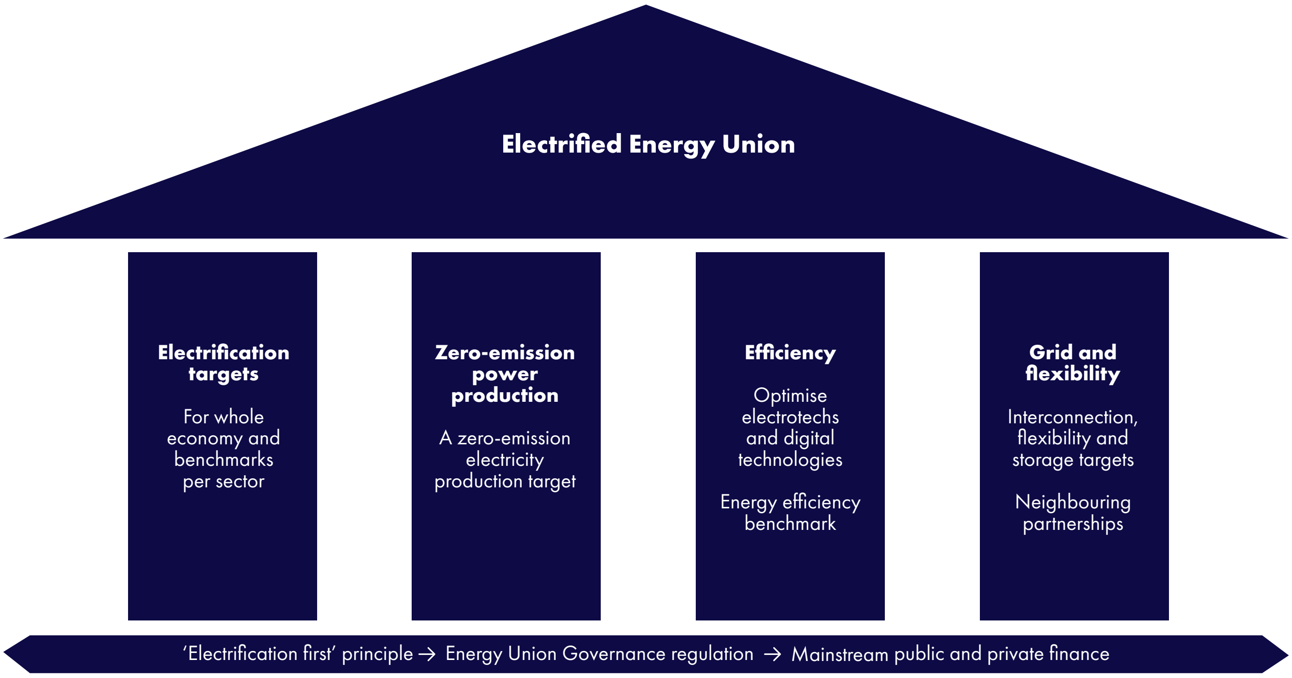
- A solid **pan-European infrastructure plan, particularly in grids and storage**, will be critical to ensure the free flow of electricity from production to demand. The Grid Package can help unlock some of the current bottlenecks for upgrading the grid.

- **Energy efficiency maximises the benefits of electrification** by mitigating electricity demand. In itself, electrification will already generate major efficiency gains. Additional efficiency can be developed through Ecodesign standards for electrotechs.

The introduction of the 'electrification first' as a horizontal principle for funding can unlock the benefits of electrification for the economy and households, as it is the most cost-effective way to decarbonise. It also implies seeking to realign energy taxation to support electrification.

Figure 3.

Principles of a new architecture for the Energy Union, focusing on electrification



Electrifying half of the European economy by 2040 can:

Deliver an additional

€29 billion of savings

for the EU economy each year

Cut

two-thirds

of fossil fuel imports

Double

the electricity production

Strengthen the business case of electrotech manufacturing in Europe by

Deploying

150 million EVs

on European roads

Installing

84 million heat pumps

in buildings

Rolling out

1,896 GW of wind and solar

and **134 GW of batteries**

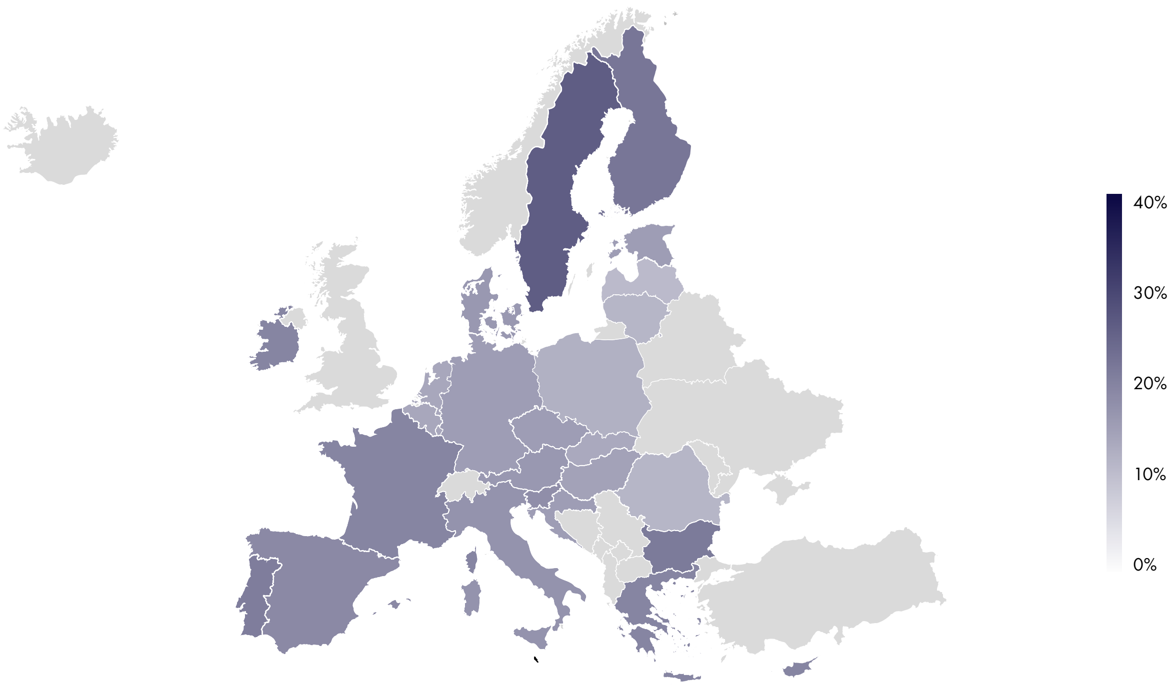
Wind turbines, Spain

CHAPTER I

Launching the electrification era

Electrification is the best business case for the EU's economy and a key asset for energy security. It is highly pilotable and smart, generates efficiency gains and displaces outdated and inefficient technologies based on the combustion of fossil fuels. With limited oil and gas reserves and hosting some of the world's electrotech champions, **the EU is well-positioned to lead the electrification race.** Unfortunately, the potential for electrification is largely untapped. The share of electricity in final energy consumption has been stagnating at around 23% for the last 15 years,[20] while the EU should be **on course to electrify a third of its economy by 2030 and half by 2040.**[21] Not all Member States are at the same level of electrification, which risks leading to a two-speed Europe.

Figure 4.
Electrification level across the EU in 2023
(source: Bruegel data)

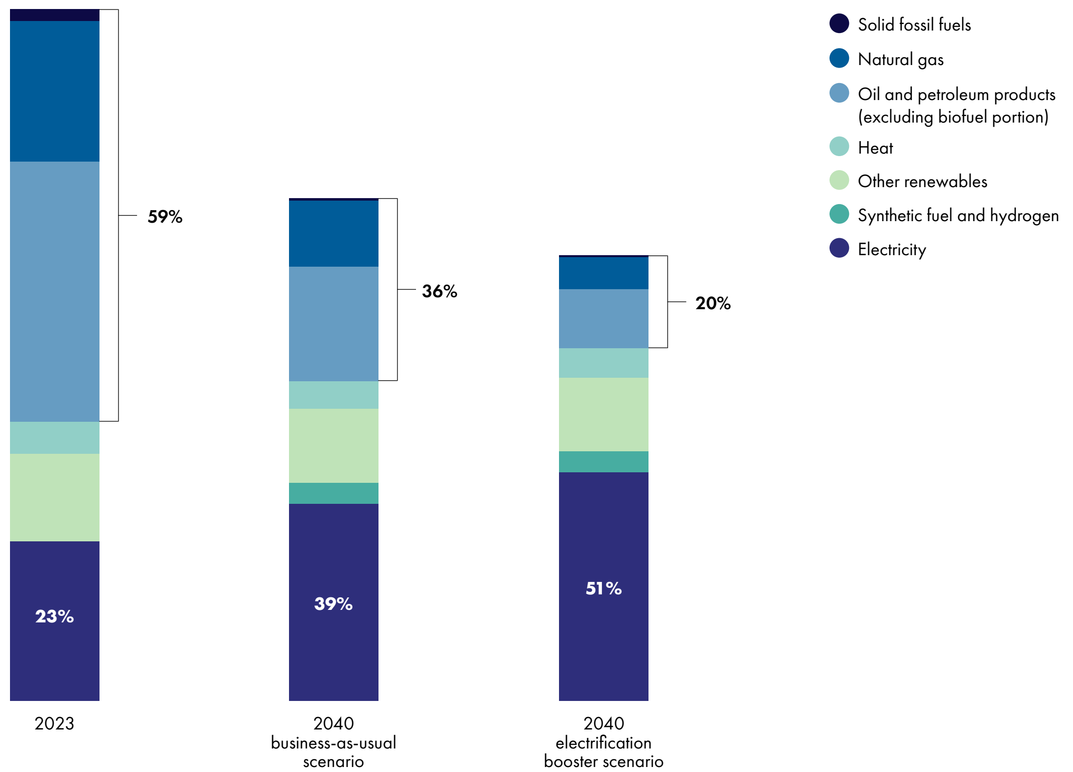


A European approach to the potential for electrification can prevent fragmentation. **Making the clear and explicit choice to electrify the economy for the next decades is an investment in the EU's energy sovereignty.** It will require higher upfront investments, but it maximises the security gains for Europeans and has the potential to turn into an industrial agenda.

1. The electrification potential

Under the electrification booster scenario, **the share of fossil fuels is expected to be divided by more than three by 2040.** €44 billion more fossil fuel imports will be saved every year compared to a business-as-usual scenario. Electrification offers a direct pathway to replacing fossil fuels with clean electricity. The technologies are available and most of them can be quickly deployed to electrify transportation, industries and buildings. 150 million EVs could be on European roads, 84 million heat pumps deployed and 35% of industrial heat produced by heat pumps and other electrotech by 2040.

Figure 5.
Final Energy Consumption in the EU



Achieving the EU's electrification potential will not happen on its own or through existing market signals. **Without a supportive policy framework, electrification would be slow, leading to a 10-year delay in reaching the targets, with a 39% share in 2040 instead of 2030** according to a business-as-usual scenario.

a. Industry

By 2040, 49% of the industry can be electrified in an electrification booster scenario. This can reduce the use of gas, oil and coal to less than 20% by 2040 compared to 60% today, securing a reliable and affordable energy supply for industrial companies. Large parts of the electrification of the industry, such as machinery and certain processes like electrolysis, can be electrified rapidly.[22]

In the process heating segment of industrial energy use, the untapped potential is particularly important. Almost half of industrial energy demand comes from process heating, and two-thirds of it is currently made up of fossil fuels.[23] Industrial processes vary widely in temperature requirements, operational continuity, and other energy needs. Not all sectors can be electrified directly, and some are more readily electrifiable than others. In **processes up to 200°C, technologies such as electric boilers, resistance heating, and heat pumps are already mature** and can be easily deployed to replace fossil fuels. These applications concern a broad variety of sectors, including food and beverages, paper, textiles, and others, and make up around 40% of industrial energy use.[24] **The EU is a leader in a range of technologies needed to electrify** these sectors, chief among them industrial heat pumps, which can electrify around half of the heat in this temperature range. There are manufacturing sites for industrial heat pumps throughout 18 Member States, with a particular concentration in Germany, Italy, France, and the Czech Republic. These technologies are a major competitive advantage for the continent's industry, as they enable certain sectors to transition from imported fossil fuels to clean electricity generated in Europe, providing significant energy security and price stability.

For higher-temperature processes, such as chemicals, metals, and non-metallic minerals, the shift to electrification is based on a different set of technologies. For example, the electrification of steel production will increase the use of Electric Arc Furnaces (EAF) to melt steel scrap (recycled steel) and produce primary steel from direct reduced iron (DRI). The production of the latter will need to be indirectly electrified through the use of green hydrogen. As the share of recycled steel is expected to grow and account for more than 68% of steel production by 2040,[25] the **direct electrification potential through electric arc furnaces is even higher.** It is estimated that an additional 21% of the steel sector can be electrified indirectly, largely securing steel production from volatile fossil fuel prices.

Overall, the electrification of most parts of industry is technically feasible, and **there is a path to price competitiveness over fossil-based alternatives, including for heavy industries, such as chemicals[26] and steel.[27]** However, this path depends on financial support for the important CAPEX investments needed for certain technologies, as well as a carbon price above €140 per tonne of CO2 that incentivises decarbonisation. As the price of gas is expected to decrease in the short term due tto an increase in LNG coming on the market, the market signals to invest in direct electrification are still too low. If some sectors, such as paper, food and beverage, and glass manufacturing, have started electrifying following the effects of the energy crisis, others see a limited business case for that in the short term. Delays risk causing significant disruptions when free allocation gets phased out under the Emissions Trading System. **Industrial companies in the steel and lower process heat sectors could pay an additional €7.5 billion in carbon prices by 2040 in the business-as-usual scenario** compared to the electrification booster scenario, not even accounting for feedstock-related emissions. Additionally, growing markets for low-emission products and technologies are also essential to ensure industries have the security to invest in their decarbonisation. Lead market policies,[28] in particular when coupled with Made-in-Europe provisions, can restore the business case for electrification. The upcoming Industrial Accelerator Act will be crucial in boosting demand for EU-made net-zero products.

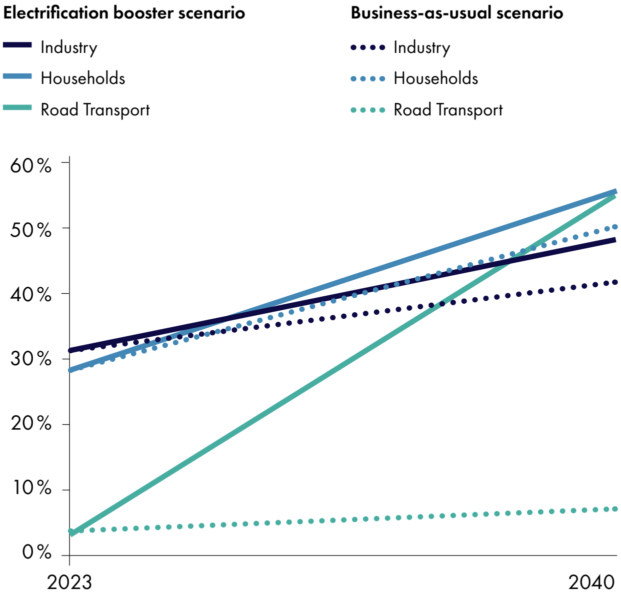
b. Transport

150 million electric vehicles could be on European roads by 2040 in an electrification booster scenario, accounting for 73% of the total fleet of passenger cars. According to our modelling, €33 billion of oil imports could be saved per year with this shift. As innovation scales up, improvements in battery energy density, charging power, and cost reductions will make electrification of transport even more competitive compared with other technologies.

First trends in 2025 indicate that sales for EVs are catching up after a year of stagnation and now exceed 15% of the total sales. European car manufacturers have seen their EV sales grow by 38% in the first half of 2025,[29] putting most of them on track to comply with the EU's CO2 standards. Some countries reach a significant electrification share of their entire fleet: Denmark managed to electrify 12% of its fleet, thus saving 3.3 million barrels of oil in 2024.[30]

However, **one major bottleneck of the electrification of the sector is the affordability of EVs.** While the price parity between an EV and an internal combustion engine vehicle was reached in China in 2024,[31] driving a rapid electrification of the sector, it is not yet the case in Europe. Despite more affordable models entering the market in 2024 and 2025, small electric cars are, on average, 45% more expensive than their equivalent conventional cars. The European automotive companies' strategies to focus on high margins and thus on the expensive segments of the car market are slowing down the electrification of road transport.[32] The recent plan to reopen the CO2 standards to bring more flexibility to the 2035 goal of reaching 100% zero-emission new vehicle sales may divert even more investments from the EV and battery value chains in Europe. It will slow the development of affordable electric cars and thus the rapid electrification of the fleet. Only 17 million EVs would be added by 2040 if the market followed the current trends. Rather than rolling out the signal in favour of electric vehicles, structuring the market with social leasing policies and a larger second-hand market can support low- and middle-income households to equip themselves with EVs. The renewed social leasing scheme in France contributed to boosting EV sales by 63% in October 2025, reaching 25% of total car sales.[33] Measures such as **social leasing for EVs are another key enabler for a robust electrification pace.** The European Commission's proposal to green corporate fleets is key to this development, as it is likely to significantly increase the size of the second-hand market for EVs in the coming years.

Figure 6.
Sectoral electrification trend in a business-as-usual scenario and an electrification booster scenario (2023-2040)



Belgium's success in greening its corporate fleet

The change of the tax deduction regime for corporate cars since 2021 has progressively incentivised companies to purchase or lease more electric vehicles, as no fiscal advantage will be offered to internal combustion engines or hybrid engines as of 2028.[34] This reform has led to an unprecedented surge in EV sales in Belgium, reaching more than a third of the new car sales.

c. Buildings

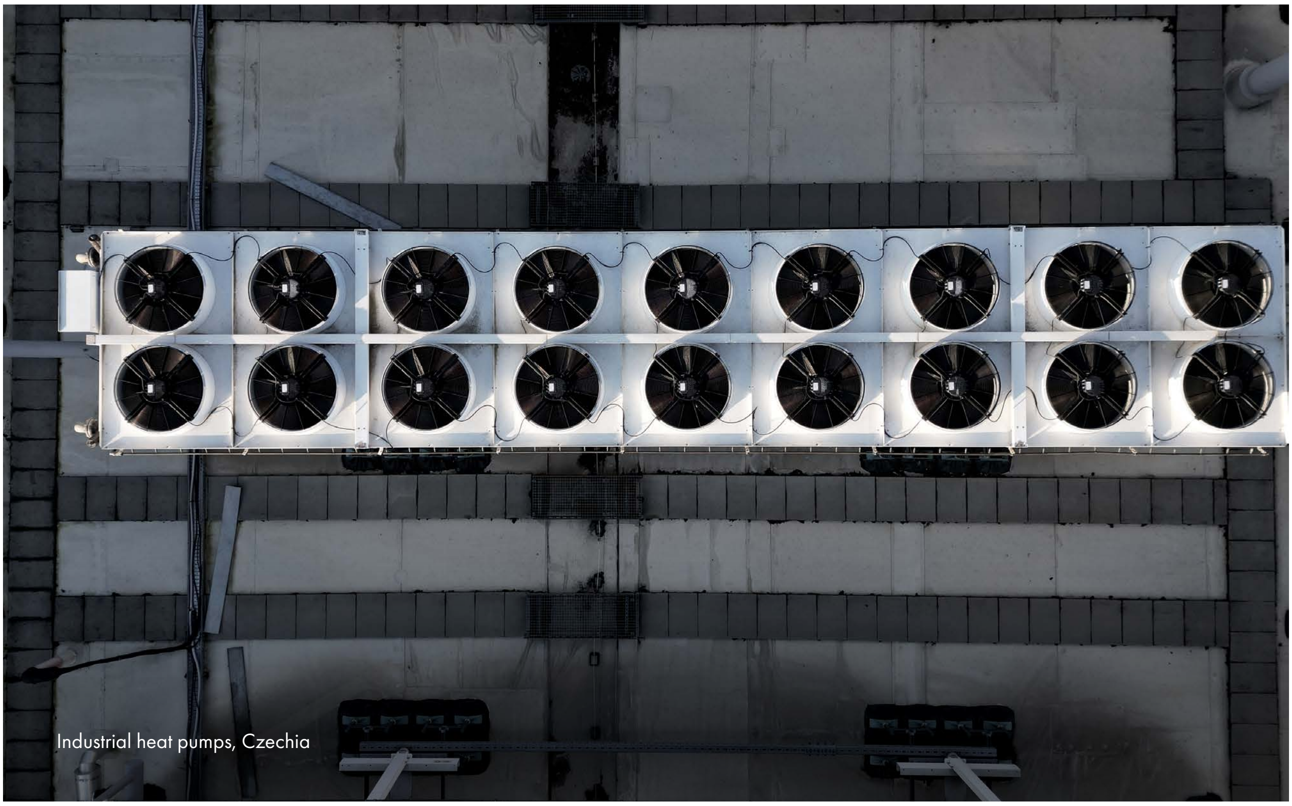
84 million heat pumps could be deployed in homes and offices by 2040 in the electrification booster scenario. The rest would mainly rely on electric heating, district heating, including the possible use of industrial heat pumps, and biomass. 56% of households' final energy consumption in Europe will come from electricity. The stock of gas boilers will become marginal by 2040, with their operational cost, as well as the high volatility of gas prices, **making electrotech the most cost-efficient way to heat and cool homes.** This will reduce energy bills and contribute to making households more resilient to price shocks. In total, an additional €3.8 billion per year could be saved in gas and oil imports compared to a business-as-usual scenario.

Sweden's recipe for clean heating

Sweden has entirely decarbonised its building sector, eliminating gas and oil. Today 46% of households are equipped with a heat pump.[35] The rest is covered by district heating. This result can be explained by a 'carrot and stick' approach. Taxation policy favours electrification, with electricity taxes being almost on par with gas taxes[36] and a carbon tax has been operational since 1991. The government also supports equipping households with heat pumps. The maturity of the industry and installation companies also contributed to the rapid rollout of this technology.

However, despite the encouraging market uptake during the energy crisis, the deployment of heat pumps slowed in recent years, going from 2.8 million heat pump units sold in 2022 to 2 million in 2024. If no additional policies are implemented, the risk is that the number of heat pumps deployed will only reach 59 million by 2040. As 90 million gas and oil boilers are still functioning in Europe,[37] a slow deployment of heat pumps could unnecessarily expose households to volatile gas prices set on international markets. The lack of fiscal incentives favouring electrification is a major bottleneck for heat pump deployment. In countries in which a bigger share of consumers depend on gas for heating, such as Italy, Germany or Belgium, electricity is taxed up to four times more than gas.[38] **Rebalancing fiscal policies, deploying social leasing policies for heat pumps, and coupling heat pump installation with building renovations can contribute to resetting the market.** Some tipping points are encouraging. For instance, in 2025, heat pump sales were more popular than gas boiler sales in Germany for the first time.[39] It is even more critical to mitigate the cost of the Emissions Trading System on mobility and buildings, starting from 2028.

Maintaining a high rate of renovation, as set by the Energy Performance of Buildings Directive (EPBD), will also be critical to maximise the benefits of electrification. In the midterm, a **new approach to construction and renovation could transform buildings into 'local electricity hubs'**, providing services to the grid. France introduced a progressive obligation for new buildings, warehouses and large car parks to have vegetation or solar panels installed on the roof, or for this to be done when renovations are carried out.[40] This gives buildings the opportunity to become more than just energy consumers. They can progressively become producers, storage sites and balancing nodes. The Energy Performance of Buildings Directive scales this approach up to the EU level, and could lead to powering 56 million homes.[41]



Industrial heat pumps, Czechia

2. Efficiency gains as a major benefit of electrification

While electricity demand is expected to double, **the total energy consumed in the economy will fall by at least 12% due to the scale of electrification.** This can be explained by the high efficiency gains of electrotechs compared to combustion technologies. On average, **heat pumps and EVs are two to four times more energy efficient than gas boilers and internal combustion engines.** Renewables are two to three times more efficient in producing electricity than gas or coal power plants.[42] By shifting from a highly inefficient and wasteful energy system based on combustion technologies to an optimised energy system with electrotech, **electrification will modernise the economy.** Electrotech can save further energy through robust Ecodesign requirements. Applying continuously progressing efficiency standards can incentivise innovation in electrotech. For instance, standards or labels for electricity use in vehicles (per kilometre) and on the weight of the car could eventually support the emergence of better-performing batteries. Linked to lead market policies, **it can drive innovation and reward frontrunners, while making electrification constantly more cost-effective.** Ecodesign measures will be a cornerstone of an electrification policy framework.

Energy efficiency will be particularly critical with the adoption of **Artificial Intelligence (AI) and the uptake of data centres.** The International Energy Agency (IEA) estimates that the data centres' consumption will account for 6% to 10% of the growth in electricity demand in Europe by 2030.[43] Ensuring that AI and data centres are powered with clean electricity and sufficiently well-designed to manage the increased power demand will be key in the coming decade. AI integration in energy systems can also optimise the use of the grid, demand-side responses, batteries, and storage, thereby generating efficiency gains. The IEA indicates that energy efficiency can be boosted by 3% to 10% across various sectors through the adoption of AI.

CHAPTER II

Powering the EU's economy and households with Made-in-Europe electricity

The single most important factor in electrifying half of the EU's economy by 2040 is abundant, clean and affordable zero-emission electricity. To avoid shortage or high prices, its production will need to synchronise with the pace of electrification, as its demand is set to double. The **EU can power its electrification plan with clean electricity produced in Europe.** According to the electrification booster scenario, the power mix could be decarbonised by 2040, with renewables, particularly solar and wind, accounting for 83% and nuclear remaining an important baseload.

This **clean electrification will give Europe a clear competitiveness advantage** compared to other major 'Electrostates' such as China. The reliance on imported fossil fuels for electricity generation has proven to be financially burdensome for citizens and businesses, as the least efficient fossil fuel power plants set the electricity price on the EU market. This situation exposes the European economy to volatile and unnecessarily high prices set on international gas and oil markets, where the EU has little control. As a result, electricity prices in the EU are still two to three times higher than in the United States (US),[44] impacting the EU's industrial competitiveness and energy security. In addition to the economic threat, the high dependence on gas presents a particular challenge. To move away from Russian gas altogether by 2027, Europeans have turned to American liquified natural gas (LNG), accounting for more than 45% of the LNG imported into the EU in 2024.[45] However, the change in the US administration poses a real threat to the EU's energy security, as LNG exports are used as a bargaining tool to pressure the EU into making trade and policy concessions. The same goes for other suppliers such as Qatar,[46] pressuring the EU to abandon key sustainability laws in exchange for LNG supplies. Only Norway appears to be a reliable and politically aligned supplier, but it only accounts for a third of the EU's gas imports.[47] **With clean power, Europeans will control the energy fueling their economy,** from production to consumption, leading to major security benefits.

1. Shifting to electricity produced in Europe

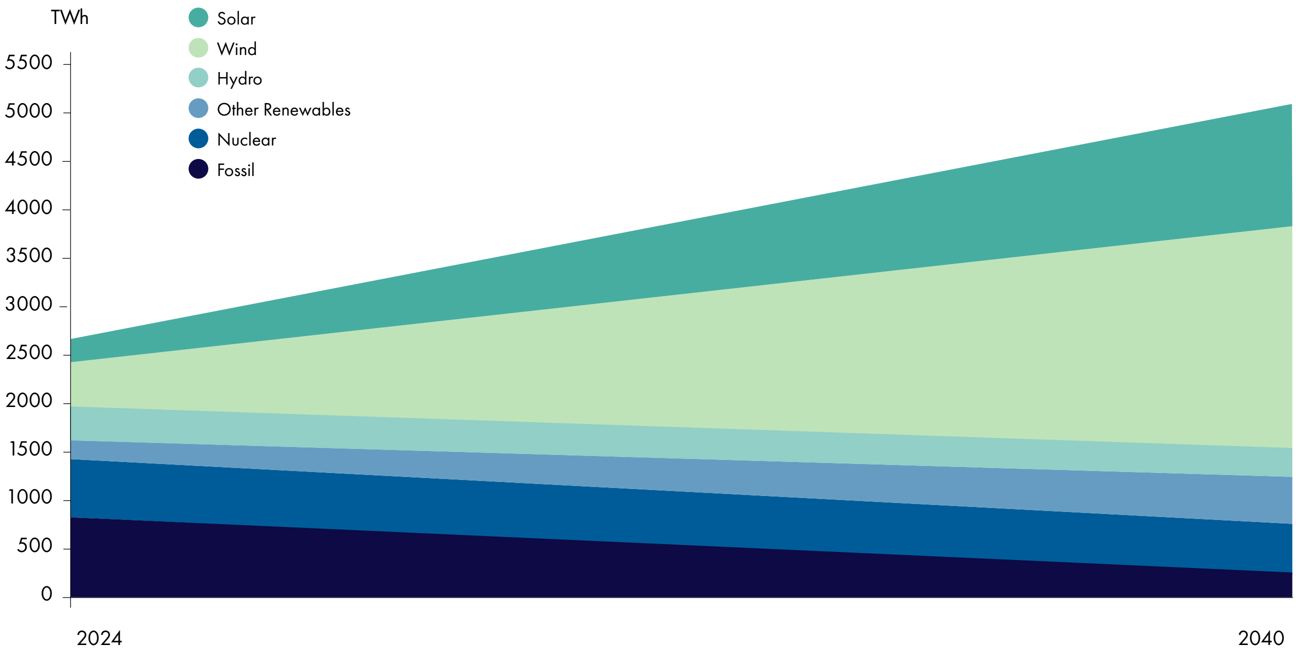
The EU is on the verge of a rapid transformation of its power sector. **Renewables produced almost half of the EU's power in 2024,** largely led by a massive solar and wind rollout. Solar power generation has been multiplied by three since 2018. According to Ember,[48] the equivalent of 450,000 solar panels have been installed every day. Despite a worrying slowdown in 2024, wind power has also increased and overtook gas power generation in 2023.

Taking into account nuclear, **more than two-thirds of European electricity is generated from clean sources.** This rapid development was driven by the double effect of the Green Deal laws and the security imperative following the war in Ukraine. Making renewables the best economic and security choice. Households, companies, and public authorities have quickly invested in the deployment of renewables to reduce dependence on Russian fossil fuels and lower electricity prices. **Central and Eastern European countries have largely taken advantage of this development to strengthen their energy security.** Poland has multiplied the share of solar power in its electricity mix by nine since 2019, Lithuania by six, and Bulgaria by five. Hungary produces a quarter of its electricity through solar panels, opting for cheaper electricity based on renewables over imported gas. Those drastic changes have led to a decrease in gas power for five consecutive years and a sharp decline in coal. Both only account for 28% of the power generation mix in 2024. It was 41% in 2018.

The rapid decarbonisation of the power mix is set to continue. In the electrification booster scenario, renewables are projected to reach approximately 4,501 TWh of electricity generation by 2040. To meet the electricity demand while decarbonising the power sector, **80 GW of new solar and wind capacities are expected to be installed per year until 2040.** The current deployment rate indicates that it is not only feasible, but that the EU is actually on track to reach this level. In 2024, 77 GW of renewable power were installed.[49] Solar deployment is reaching the right pace, and the EU mandate to install solar panels on major renovations and car parks will maintain the speed of its deployment. Given the necessary planning phase for the construction of new reactors, nuclear power is likely to remain stable until 2040 at 98 GW. It will ensure sufficient baseload and provide additional security.

Figure 7.

Evolution of the power generation under an electrification booster scenario (2024-2040)



Given the low levelised cost of electricity produced by renewables,[50] this could have a positive impact on reducing electricity prices, and thus boost electrification further.

Spain's clean power has turned into a competitive advantage

With 57% of its power coming from renewables in 2024, Spain serves as a good example of how a cleaner power mix results in more competitiveness. The country has almost phased out coal and has reduced gas power from 30% of the mix in 2022 to 18% in 2024. As a result, wholesale electricity prices are on average 32% less expensive than in the rest of the EU. It is likely one of the main factors behind the decision of the leading Chinese battery maker, CATL, and Stellantis to invest €4.1 billion in Zaragoza to open a battery manufacturing plant. It also explains why Spain is a very attractive location for green hydrogen investments, accounting for about 20% of all announced European projects.

Measures that improve market visibility, such as public guarantees or mechanisms that support **commercial Power Purchase Agreements (PPAs) on non-subsidised projects,** could also contribute to offering a secure long-term price for developers and providing long-term price stability for industrial consumers in their electrification path. In 2024, a cumulative 36 GW of renewables were covered under PPAs.[51] Two sectors are leading contracts, Information Technologies (IT) and energy-intensive industries, as they allow them to stabilise prices and secure long-term access to energy.

By 2040, electricity generated with fossil fuels will have a very marginal role, and might be used as "a last resort" in the sector to allow for very limited demand flexibility in case of emergency situations. The role of fossil fuel power generation can further be reduced by the rapid uptake of batteries and storage, leading to a fully decarbonised power sector in 2040.

The shift to zero-emission electricity will largely strengthen energy security, as Europeans will be able to rely on energy sources produced within Europe, reducing the impact of international markets on household and industrial bills.

1. Building a secure and well-connected flow of electricity in Europe

As the share of clean electricity in final energy consumption increases, the power system will evolve from a centralised, fossil-based configuration towards a more diversified, renewables-based system with higher flexibility and cross-sectoral integration. Nuclear and hydropower can ensure a baseload, providing additional security. **To ensure the free flow of electricity in the EU, a robust expansion of the grid, storage, and flexibility will be required,** in particular to cut off gas from the grid.

a. Batteries and storage as cost-competitive strategic capacities

Storage and flexibility are critical components of a resilient and highly electrified economy. The development of batteries has almost doubled every year since 2020.[52] While large-scale utilities are increasingly deploying them, households largely dominate installations, which reduce energy bills. Germany and Italy are leading the expansion of batteries in the EU, accounting for more than half of annual installations. By 2040, at least 134 GW of batteries could be installed to ensure the flexibility of the electricity supply. Reaching this level would **enable the peak production of wind and solar and limit curtailment.** It brings numerous benefits, including balancing the grids and stabilising the price. This has the potential to further reduce the role of fossil fuels as strategic capacities or reserves for Member States. Here, EVs can play a major role in balancing the grid. Bi-directional batteries could account for 10% of the fleet by 2040, supporting cost savings for the grids. Investing in battery innovation and supporting its deployment can provide additional security.

Bulgaria's market-driven battery development

The solar boom is driving the uptake of batteries and providing a major flexibility service for the grid. Utility-scale batteries started with SolarPro's 55 MWh installation in Razlog in late 2024. A year later, the Transmission System Operator reported battery charging of over 600 MW during sunny days.[53] The exponential development in the country makes batteries a more cost-effective and flexible option than gas. In a country with limited gas capacities, battery expansion is outpacing the latter as a flexibility and making it increasingly irrelevant as a balancing technology.

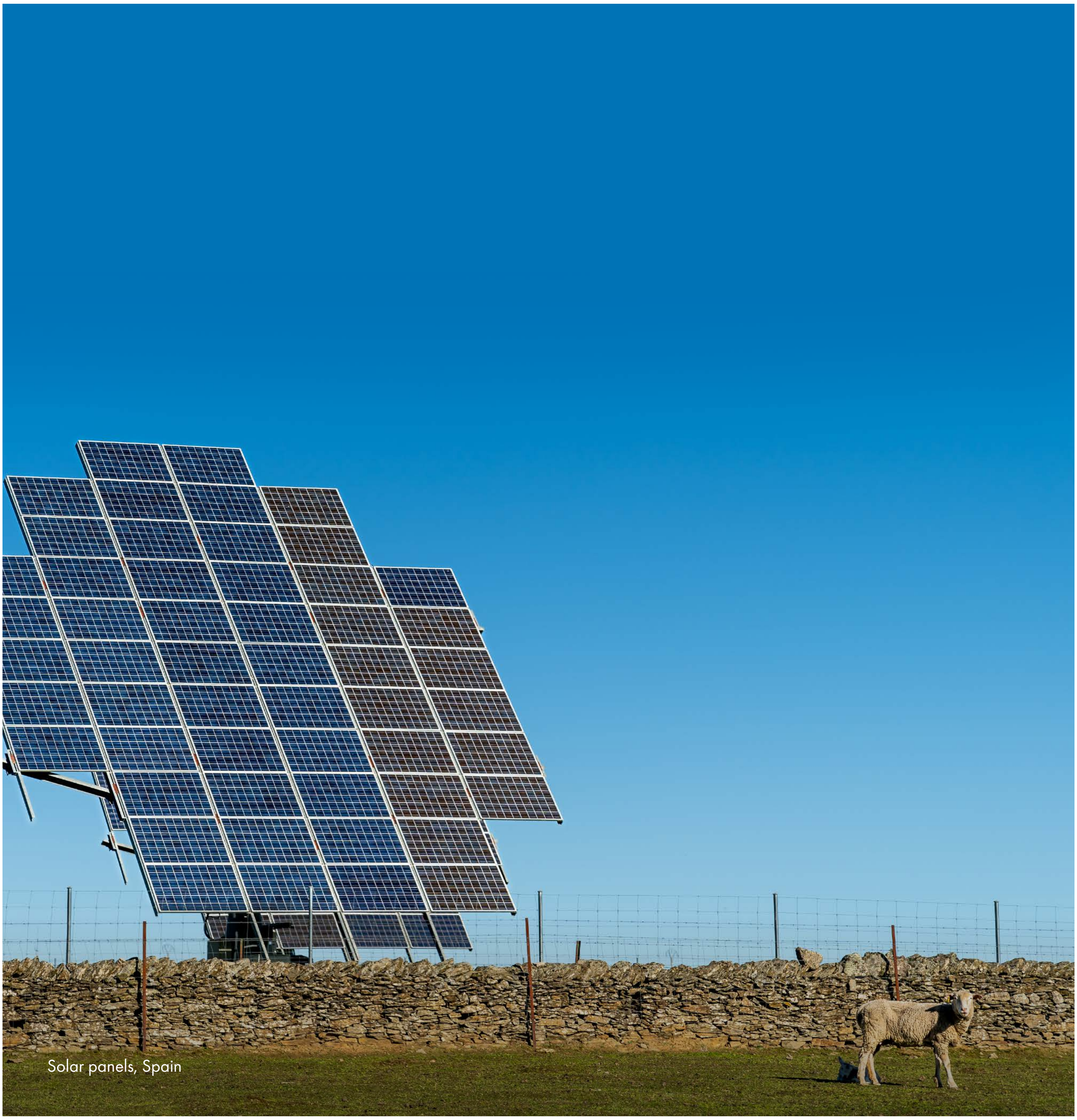
Similarly, the **use of hydropower as storage capacity is critical to ensure the continuous flow of affordable electricity.**[54] The upgrade of existing hydropower dams for both power generation and storage purposes offers security and stability potential for the grid. To maximise storage potential and ensure strengthened energy partnerships, the EU could work closely with neighbouring countries such as Turkey, Norway, and the Western Balkans, where the potential for hydropower upgrades and interconnections with the Energy Union is high. **The Western Balkans could position themselves as a European battery hub,**[55] with their 9 GW of hydropower. It represents a major opportunity for the EU to better integrate the region and avoid a gas and coal lock-in in those countries.

b. Building a grid fit for electrification

Similar to storage capacities, the expansion and upgrade of the **grid is key to ensuring a resilient electrification in Europe.** To achieve a 50% electrification goal by 2040, cross-border grid capacities will need to double, reaching 128 GW, according to the electrification booster scenario. But this only adds €2.1 billion to the already high investment needs for grids in Europe, estimated at about €32 billion per year by ENTSO-E.[56] In both the electrification and business-as-usual scenarios, the grid will require an upgrade.

At the EU level, the lack of interconnection prevents electricity from flowing between wind or solar power plants and industries, regardless of their location on the continent. Some Member States, such as France, Spain, Italy, the Netherlands, Greece, and Poland, did not reach their 10% interconnection target by 2020, limiting their ability to **share the benefits of the decarbonisation of the power sector.** The synchronisation between the Baltic States and the continental grid underscored the importance of accelerating interconnection for energy security. Similar connections are necessary in other parts of the continent, including between the Iberian Peninsula and the rest of the European electricity market. It could prevent potential supply disruptions and make the entire EU benefit from the high renewable uptake in Spain and Portugal. The upcoming Grid Package and the Connecting Europe Facility build a positive momentum and address this challenge. Solid coordination between Member States and joint investments will be critical to deliver. **Cross-border high-voltage direct current (HVDC) transmissions** are especially strategic as they will enable the large-scale integration of high renewable production centres to demand hubs, particularly for industry across the EU. European public guarantees could contribute to de-risking those projects at the EU scale.

At the Member State level, fast-tracking permitting for electrification projects will be key. The plan from Réseau de Transport d'Electricité (RTE), the French electricity transmission network operator, to accelerate access to the grid for industrial consumers in identified areas is a good example. Indeed, in July 2025, RTE already had contracts with 160 projects for a volume of 25 GW of electricity, in manufacturing, hydrogen production, electrofuel production or the development of digital applications.[57]



Solar panels, Spain

CHAPTER III

Electrifying the EU's industry to make it competitive

Today, and even more in the coming decades, **a competitive industry is an electrified industry. Electrotechs are swiftly becoming the new industrial standard.** In 2024, 26% of China's GDP growth came from electrotech production,[58] and many developing countries are leapfrogging fossil-based technologies and moving straight to electrotech.[59]

Supporting the industrial transition from its current reliance on fossil fuels to an electrified system is the right industrial strategy for the EU to reduce energy prices and take part in emerging net-zero markets. It is a major opportunity, as the **EU is home to many of the leading companies** that innovate and produce the technologies necessary for this transition. Even if parts of the industry rely on imports in the short term, especially from China, the development of the circular economy can contribute to developing more innovative business models and keeping the resources in Europe. Unlike fossil fuels, electrotechs can be used for decades and are recyclable in the EU.

France's Battery Valley: revitalising a region through electrotech

France's northernmost region, the Hauts-de-France, was heavily impacted by the deindustrialisation of the past decades. Unemployment reached 16.5% in Dunkirk, the heart of its industrial activity, in 2020.[60] However, since the beginning of this decade, the region has seen significant investments in battery production, with four gigafactories currently under construction. There have been investments into training people to work in this industry, with the goal of creating 20,000 direct jobs and 60,000 indirect jobs by 2030.[61]

In addition to nuclear power, a planned 40MW solar plant and a 400MW offshore wind farm will provide the additional electricity needed to attract new industrial activities. RTE, the French transmission system operator (TSO), plans to invest €1.5 billion into the grid by 2030, while other related projects, such as a hydrogen hub and France's most powerful electricity storage site, are being deployed.


Wind turbine blades, France

1. Winning the electrotech race

The race for leadership in the electrotech sector is on, and China has an undeniable edge on its competition. Taking advantage of the electricity revolution, Chinese companies lodged 75% of global clean energy patent applications in 2022, and the country's factories are producing about 60% of the world's wind turbines and 80% of its solar panels.[62] Under the Biden administration, the US also demonstrated its ability to implement a strong industrial policy to support these technologies, known as the Inflation Reduction Act. While many of these investments have been paused since, this Act came as a wake-up call for the EU, showing the ability of a democratic country to take the measure of the challenge ahead.

The EU is lagging behind, but it has strong potential to compete in the electrotech sector. It is home to many of the most innovative electrotech companies and has emissions reduction targets that provide visibility to its investors and manufacturers. Additionally, **the EU has developed the foundations of an electrotech industrial policy in recent years,** with policies such as the Net Zero Industry Act and, more recently, the Clean Industrial Deal. However, only a new electrification policy framework setting a clear direction of travel can provide the necessary boost for the electrotech industry. In the face of subsidised Chinese competition, these emerging sectors need a policy that delivers stable, predictable demand growth. **Boosting electrification will open new markets and drive innovation in Europe.**

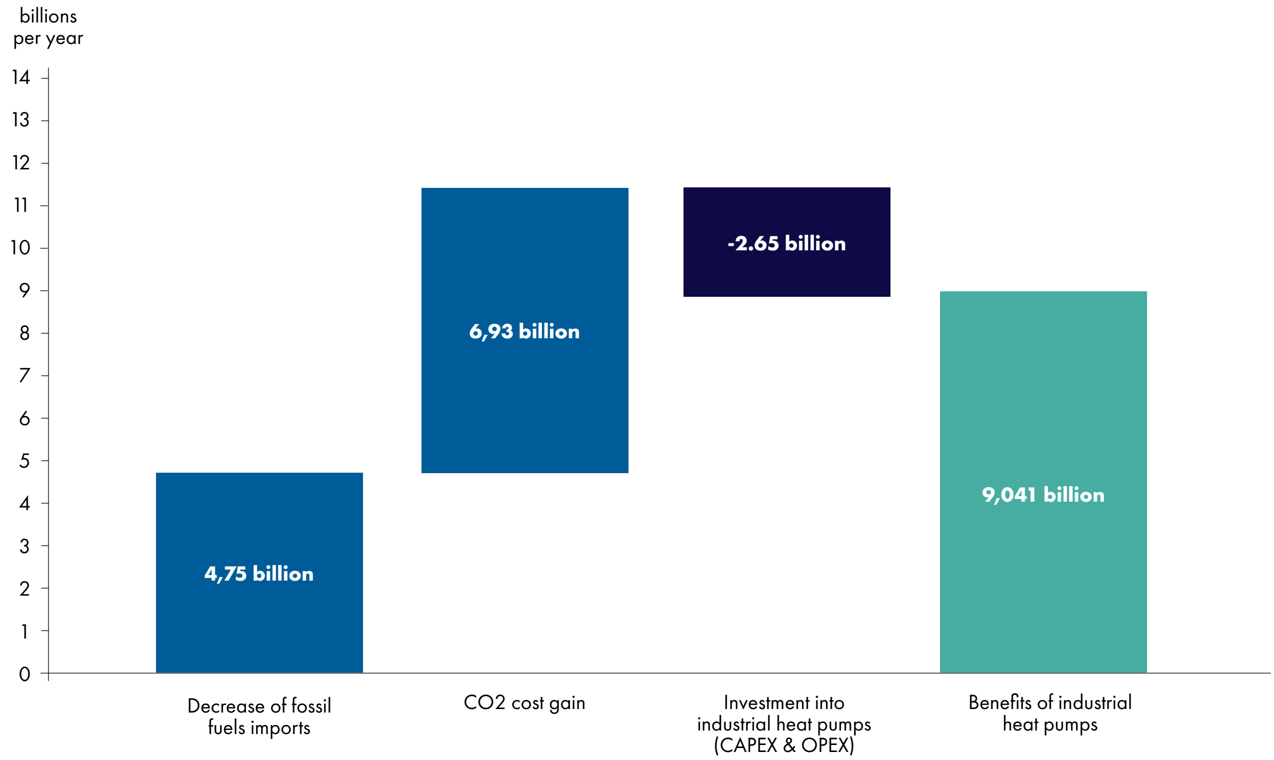
a. Building the EU leadership in industrial heat pumps

Industrial heat pumps can be a major competitive advantage for the EU. Much like their non-industrial counterparts, they generate heat by using renewable energy and waste heat recovery, but they have much higher capacities, reaching temperatures up to 200°C. The demand for industrial heat provided by heat pumps is expected to double by 2040 in an electrification booster scenario compared to the business-as-usual scenario. A large part of this electrification is set to happen for industries with low-to-medium temperature heat.[63] In an electrification booster scenario, industrial heat pumps could electrify 49% of the heat generation in industries that require heat up to 200°C, such as paper and pulp, wood, food, and textiles.[64] The market for industrial heat pumps is expected to reach between €1.7 and €3.5 billion in the EU already in 2030.[65]

This is a significant opportunity for the EU, which is a leader in the production of heat pumps. **Up to 73% of the heat pumps (industrial and others) installed in the EU were produced on the continent, in over 300 manufacturing sites.[66]** Among those, about 70 produce industrial heat pumps in 18 different Member States, in particular Italy, Germany and the Czech Republic.[67] They already account for 400,000 direct and indirect jobs in the EU.[68]

Industrial heat pumps are an important factor of energy security for the EU's industry. Running on electricity and waste heat, they offer protection from the high volatility of international fossil fuel markets. They also present significant energy efficiency gains, **being three to four times more efficient than a traditional boiler at medium temperatures.[69]** Apart from their strictly industrial uses, they can also be used for district heating systems, offering similar efficiency and independence advantages.

Figure 8.
Business case of industrial heat pumps: cost-benefit analysis



b. Maintaining a business case for offshore wind

Offshore wind energy, with its vast potential across Europe's coastal regions, stands out as a critical component in the electrification strategy. The EU's geographical advantages, combined with advancements in wind turbine technology, position it to lead in the global offshore wind value chain. Europe is home to some of the largest companies in the global offshore wind sector. Siemens Gamesa and Vestas as the top global manufacturers by installed capacity, and major developers like Ørsted, Iberdrola, RWE, and Vattenfall rank among the world's largest.[70] Keeping the manufacturing of key components of offshore wind turbines in Europe is a strategic asset, both for the EU's energy security and industrial competitiveness.

While only 13 GW were online in 2024 due to some supply chain disruption and delays during COVID, the European Commission estimates that **between 259 and 261 GW could be deployed by 2040**, in particular in the North Sea, Atlantic Ocean and the Baltic Sea.[71] Additional research and development can be undertaken to accelerate the uptake of floating offshore wind turbines for the Mediterranean and the Black Sea.

The current underperformance is caused by several headwinds,[72] including rising costs (e.g interest rates, inflation), slower-than-expected demand for electricity, financial pressure, and global competition. Electrification can act as a booster for offshore wind development in the EU by ensuring **a solid demand** for the industry. 785 GW of wind power could be installed by 2040. Combined with Made-in-Europe criteria in auctions, boosting electrification will **provide certainty and confidence for investors and project developers.**

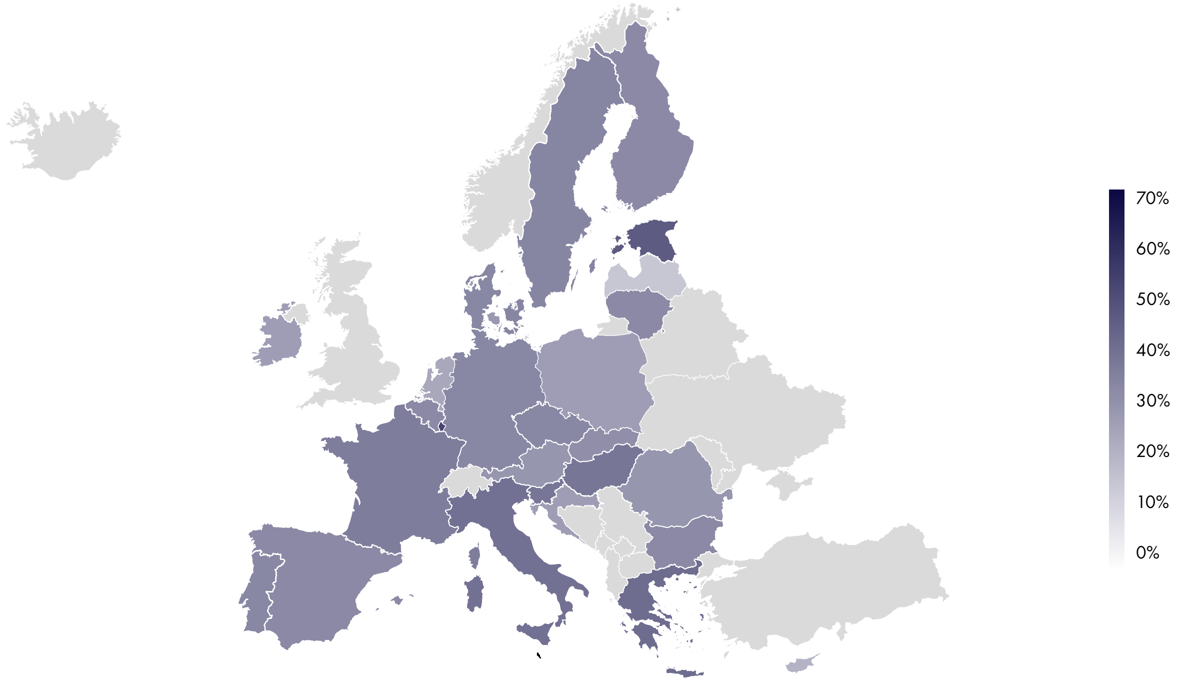
2. Rebuilding industrial competitiveness in the EU

To regain its competitiveness, the EU can turn its energy-intensive industries into electricity-intensive industries. Indeed, the EU's energy-intensive industries are in the midst of a competitiveness crisis due to high energy prices, insufficient domestic demand, and unfair price competition with subsidised imports, especially from China.[73] Faced with this challenge, the EU can turn its electrification into a competitive advantage. Indeed, the EU has the most decarbonised electricity system among major economies, a functioning Emissions Trading System (ETS) coupled with the Carbon Border Adjustment Mechanism (CBAM) and some of the most innovative electrotech companies.

Energy-intensive industries, such as steel, chemicals, glass, pulp and paper, as well as industries that require lower process heat, such as food and beverages, can substantially increase their electrification rates and take advantage of this emerging electrotech ecosystem. **Most of these technologies are ready to be deployed and can be produced in Europe, including industrial heat pumps, electric boilers, and electric arc furnaces.** Some less mature technologies, including some requiring indirect electrification, are set to scale in the coming years.

The electrification of these sectors brings numerous benefits for the EU's competitiveness. Firstly, they limit the risks of energy crises by transitioning from fossil fuel imports to local power production and by increasing energy efficiency. Secondly, they limit the carbon emissions associated with production, thus reducing the CO2 price impact under the EU ETS. This can lead to net savings of over €9 billion annually for the industry deploying heat pumps, primarily from avoiding fossil fuel imports and CO2 costs. Thirdly, they qualify for a possible upcoming lead market policy at the European level, opening new

Figure 9.
Industrial electrification rate (2023)
(source: Bruegel data)



markets such as low-emission steel and chemicals, and securing demand. Examples of this industrial transition include a pasta production plant in France, which reduced its heat costs by 68% with a heat pump,[74] or a plastic manufacturer in the Czech Republic saving €60,000 a year after switching from gas boilers to a heat pump.[75]

It is also the case of the steel sector. 68% of steel production could come from scrap by 2040. Electric arc furnaces will thus play a major role in the European economy. Electrifying the sector, directly or indirectly through green hydrogen, will increase energy efficiency by a third in the electrification booster scenario, reducing operating costs. This could result in €1.3 billion of savings each year from avoided fossil fuel imports and CO2 costs for the steel industry. Together with lead market policies and a functioning CBAM, **electrification has the potential to restore the competitiveness of the European steel sector** and to allow it to take its market share in the global green steel market.

Supporting the **EU's leadership in electrification can revitalise some of the very regions that have been most impacted by industrial decline.[76]** For instance, former coal regions are becoming centres of renewable energy production and are a competitive asset for the EU, such as the Stara Zagora and Plovdiv industrial zones in Bulgaria.[77] **The creation of zero-carbon industrial clusters can accelerate industrial synergies and prioritise industrial electrification.** This cluster approach could contribute to addressing bottlenecks in material and energy access by fast-tracking permitting processes for both direct and indirect electrification, as well as channelling investments.

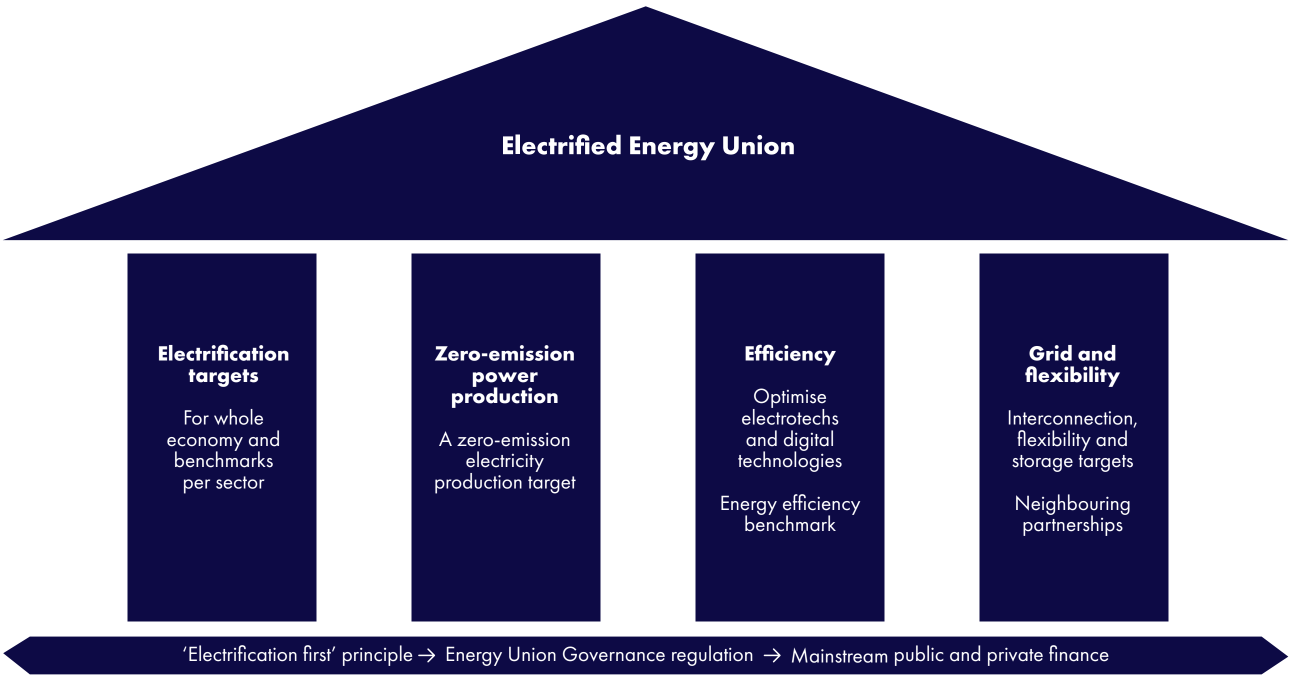
CHAPTER IV

An Electrification policy architecture fit for Europe

Electrification is the next strategic direction for Europe's economic growth and security. Without additional political signals and policies, the electrification level would only reach 39% by 2040, instead of 51%. In other words, the EU would be 10 years behind its electrification pathway and unnecessarily prolong its costly and risky dependence on fossil fuel imports if it stays in a business-as-usual scenario.

The design of the 2030 policy framework was mostly built on the 2020 framework, with a clear focus on scaling up renewable energy and energy savings. Since then, geoeconomics have become increasingly tense and cost curves and technological innovation have advanced substantially. **The focus of its energy policy has shifted towards reducing external dependences to strengthen energy security.** The new Energy Union architecture can focus on the political challenges and needs of today with a 2040 horizon: reducing dependences, scaling up electrotech manufacturing and deployment, providing a secure and affordable supply of zero-emissions power and allowing the EU to catch up with China in electrification. A new architecture centred around electrification, abundant zero-emission power, large-capacity grids, storage, and efficiency will be fit for purpose.

Figure 10.
Principles of a new architecture for the Energy Union, focusing on electrification



A series of upcoming Commission legislative proposals and action plans will be published over the next year. They have the potential to operationalise those pillars and lay out **the foundation of this new architecture, boosting electrification.**

Figure 11.

Legislative opportunities to set up a new architecture for the Energy Union, focusing on electrification

Q4 - 2025

Industrial Accelerator Act

- **List of industrial sectors to electrify in priority**

Grid Package

- Fast-track permitting
- Identify priority projects
- Standardise grid technologies
- Stronger European supervision of cross-border connections

Q1 - 2026

Strengthening Energy Security

- **EU-wide flexibility and storage target**
- Recognise electrification as a key energy security asset

Electrification Action Plan

- Gap analysis of what the current laws deliver on electrification or not
- Assess electrification potentials and set benchmarks per sectors
- Outline the future Energy Union Package

Q2 - 2026

Q3 - 2026

Energy Union package for the decade ahead

- A **Clean Electrification Law**, setting combined electrification and zero-emission power production targets
- Energy efficiency benchmark for 2040
- Revision of the Governance regulation to **align Member States on energy taxes and levies**

Multiannual Financial Framework (MFF) applying an 'electrification first' principale

1. A Clean Electrification Law at the centre of the EU post-2030 framework

a. A direct electrification target for the EU economy of 50% by 2040

The Electrification Action Plan can assess the gap between existing laws and what might be required after 2030. A **Clean Electrification Law, setting a vision through an explicit and direct electrification target of 50% of final energy consumption by 2040**, can be considered as a solid option to fill this gap. It could be proposed as part of the Energy Union package, planned for mid-2026. An explicit target will be the basis of robust electrification planning and direct investments at times when the price signal in favour of electrification is still too weak. The objective of this policy change is to ensure that an 'Electrification first' principle is reflected in the legislation.

The overall electrification target could be broken down into sectoral benchmarks for industry, transport, and heating to ensure a more granular overview of the foreseen transformations. It could give guidance on the most efficient electrotech per sector by introducing a possible electrification taxonomy. This will contribute to drastically optimising the current framework, **removing complex sectoral renewable targets and being more explicit on electrification.** With this, the EU will focus on the most cost-competitive decarbonisation route per sector. In a 51% electrification scenario, 55% of the road transport sector, 64% of the buildings' final energy consumption and 49% of the industry's final energy use could be electrified. Based on these benchmarks, companies and public authorities that commit to contributing to reaching those sectoral goals could benefit from **a fast permitting process and possible additional financial support compared to less mature routes.**

In the electricity era, **Ecodesign requirements will be crucial to keep innovation high** and optimise the use of electrotech and high-consuming sectors such as AI or data centres. Performance standards per technology will improve the business case for electrification.

b. A zero-emission power capacity target

In combination with the electrification target, **a zero-emission power capacity target can be set. The aim is to synchronise electricity demand uptake with supply.** The benefits of setting the two targets together are to ensure there is no electricity shortage and that electrotechs, grids and storage capacity are deployed sufficiently rapidly to build the renewable and nuclear business case. To ensure the EU can turn electrification into a competitiveness asset, it will need to decarbonise the power sector at the same pace as it deploys electrified technologies. **The entire electricity production can be zero-emission by 2040, strengthening the security of the continent** to an unprecedented level. It will protect the European electricity market from exposure to volatile gas prices. Some "last resort" fossil fuel capacities may remain in strategic reserves, but batteries and other storage capacities will make their use quickly redundant. Given the pace of electrification required, 4501 TWh of electricity production will come from renewable sources, while nuclear could maintain its production, accounting for 566 TWh. To preserve a technological neutral approach, the zero-emission power capacity target is set to include both renewables and nuclear.

However, **benchmarks per technology could be developed** by the European Commission to provide sectors with predictability over the period and to enable proper long-term planning. The acquis from **the Renewable Energy Directive (RED) in terms of permitting, State aid framework, and support schemes would need to be preserved** and applied after 2040 to ensure operational stability for companies. An **efficiency benchmark and measures can** serve as a signal to the sector and **moderate the overall increase in electricity demand.**

2. Enabling an electrified economy

Electrification investments are the best use of taxpayers' money and the strongest business case for private finance, as they are the most cost-effective way to strengthen energy security and restore competitiveness. Delivering large-scale electrification requires clear infrastructure planning for the European grid, as well as public funding to unlock private investments in priority areas.

a. A solid pan-European infrastructure planning

Long-term planning of adequate grid expansion and upgrade is a major challenge when 27 Member States are responsible for their national parts of the grid. The Grid Package could recommend stronger **European supervision and joint investments, especially in cross-border projects.** It will be critical to ensure a harmonised development of infrastructures, matching demand and supply needs. This could be informed directly by national governments through the recently established **Energy Union Task Force to ensure the consistency between national and European grid and storage development.** The Grid Package could also identify priority power capacity, grid, storage and electrification projects that will benefit from fast-tracking permitting and EU financial support in the EU and neighbouring countries. To accelerate and reduce the cost of grid expansions and upgrades, the package could **standardise auctions for grid-related technologies**, such as transformers, at the EU scale. This would streamline participation in auctions for European companies, allowing much better scalability in the deployment of essential grid technologies, thus reducing prices.

In parallel, **the European energy security law,** planned for early 2026, could set an EU-wide **target for flexibility and storage,** as it will prove to be one of the most critical levers for stabilising power prices and building the business case for electrification. Batteries could be integrated into capacity mechanisms and strategic reserves to progressively remove fossil-based plants.

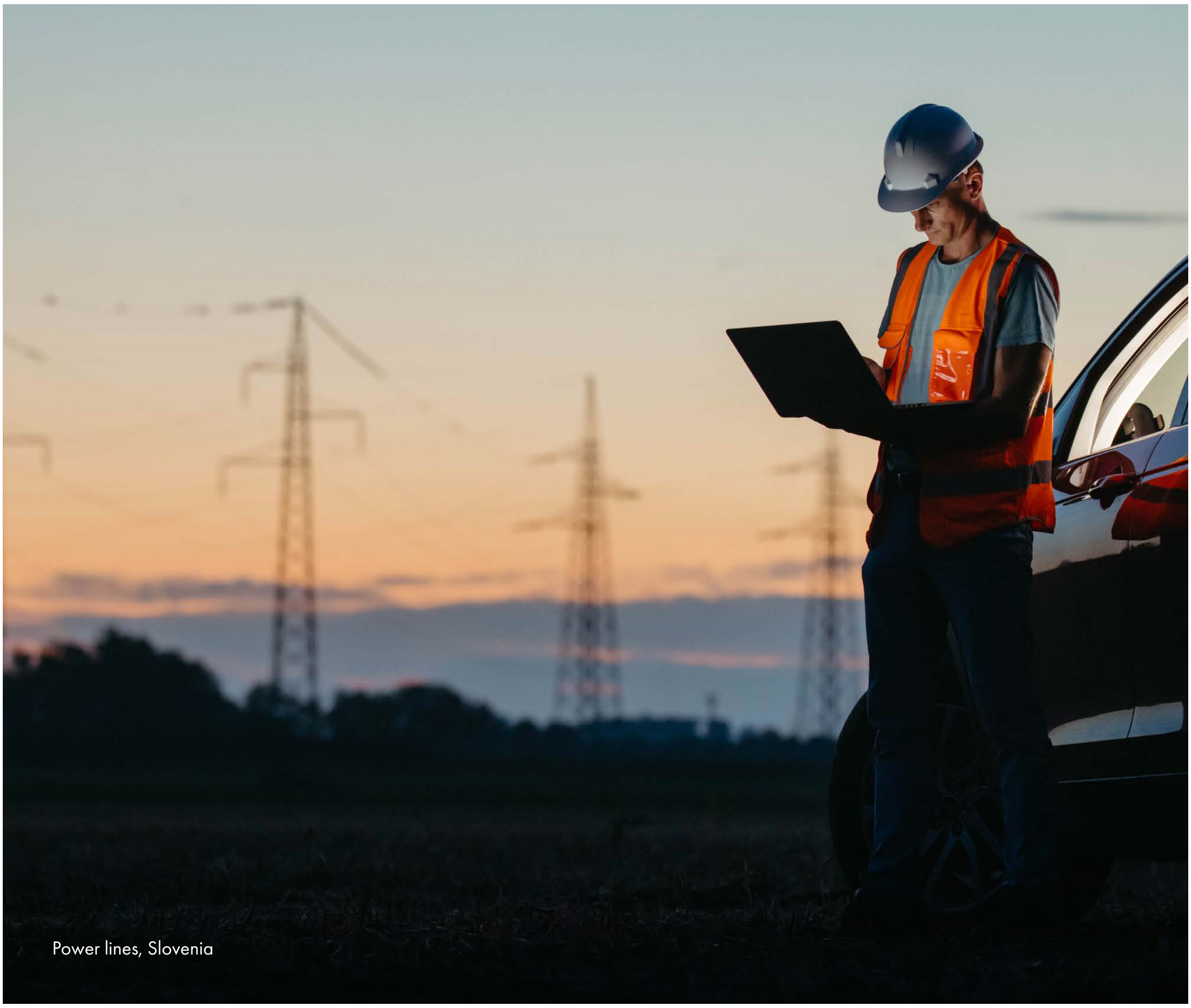
Finally, the revision of the **Energy Union Governance regulation could set progressive steps towards an alignment of energy taxes and levies in Europe.** The difficulties in adopting a revised Energy Taxation Directive show that an approach based on coordination might bring more short-term results, in particular if fully integrated as part of the European Semester, and conditioning EU investments into the grid. **Hence, the Governance regulation could be the appropriate place to tackle the lack of fiscal balance between electricity and gas.**

b. Applying an 'electrification first' principle to public and private finance

As the upfront investment for electrification is often high, **applying an 'electrification first' principle to public funding, leveraging private finance,** will contribute to unlocking quick benefits for households and companies.

Existing EU funds already target a direct electrification of both industries and households. The recent Innovation Fund set the tone by launching the first auction for industrial process heat electrification, with €1 billion split between low- and high-temperature heat. As the Social Climate Fund will be effective in 2026, Member States have the opportunity to scale up social leasing schemes for EVs and heat pumps, using the €86 billion of the fund to support low- and middle-income households. By attaching strong Made-in-Europe criteria to them, it can boost value chains in Europe and achieve two goals at once: electrification and resilient industries. Discussions are ongoing for the European Investment Bank (EIB) to front-load ETS2 revenues to support such social leasing schemes for EVs and heat pumps. In general, as 100% of the EU ETS revenues are supposed to be spent on 'climate action', **the priority could be given to Member States to invest in both efficiency and electrification.**

The 2028-2034 Multiannual Financial Framework (MFF) can maximise electrification by setting a clear priority for direct electrification projects.



Power lines, Slovenia

An 'Electrification first' principle could be included as part of the ongoing negotiations. It will contribute to implementing synergies between funds, in particular under the Competitiveness Fund, Connecting Europe Facility and Horizon Europe. For instance, these funds can boost research and development in key electrotechs such as industrial heat pumps, foster their deployment in critical sectors and coordinate grid updates to fuel them with clean electricity. Member States, as co-funders of projects, could channel state aid and public finance into those priorities. Europe has a competitive advantage to maintain in the industrial heat pump value chain. The same applies to battery research or floating offshore wind, manufacturing and deployment. The upcoming Industrial Decarbonisation Bank could also target electrification as a priority to support industrial decarbonisation.

This approach will strengthen European value chains in critical electrotechs.
The 'Electrification first' principle in public funding will likely leverage private finance, in particular if also applied to the EIB and national public banks for the guarantees and loans they provide to public authorities and companies. Supporting the private sector in electrifying and building zero-emission power capacities is key to ensuring that the market implements the electrification plan. **Scaling up public guarantees to de-risk commercial Power Purchase Agreements (PPAs)** on non-subsidised projects can make a difference for companies. The EIB started to play a role in promoting PPAs by launching a €500 million fund for counter-guarantees. Member States could also follow the example of Spain, which quickly boosted PPAs as a mechanism for reindustrialisation.

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