Our wind, our value

Creating value for Europe, living up to Europe's values

A Rystad Energy report in cooperation with WindEurope

WindEurope

Rystad Energy

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About this report

This report has been produced by Rystad Energy in cooperation with **WindEurope**. It is focused on the significance of wind energy generation targets for European energy security, job market, economic growth and nature.

The outset of the report is based on **WindEurope's** capacity outlook for wind power in Europe in its latest 2030 Targets scenario for wind capacity additions and implied generation through 2030.

In addition to the 2030 Targets scenario, Central (most likely) and conservative Low scenarios are considered in the report. Using this capacity outlook as an exogenous factor, **Rystad Energy** has applied its models and industry knowledge to quantify the impact of potential wind energy underperformance (i.e. Central and Low Scenarios) relative to the 2030 Targets Scenario on various dimensions of the traditional energy trilemma, European GDP, the job market within the wind sector and underlying emissions from power generation processes.

Through extensive research and modeling, **Rystad Energy** aims to identify the magnitude of positive environmental impact and value creation that wind energy brings to the European continent. As such, all analysis in this report has been done by **Rystad Energy**, if not explicitly mentioned otherwise.

Rystad Energy has also contributed to the background material in this report, describing the current status of the European wind market and its supply chain.

Based on the findings in this report, **WindEurope** has provided its policy recommendations.

Foreword

Europe remains at the forefront of the global energy transition and decarbonization. Fossil energy carbon dioxide (CO_2) emissions on the continent declined from nearly 5 gigatonnes per annum (Gtpa) in the early 2000s to around 3.5 Gtpa currently. The gradual integration of renewable energy sources and decarbonization of the European power mix has been one of the main drivers behind this improvement. Most of this renewable energy activity has occurred in the EU27, UK, Norway and a few other countries integrated into the overall European power system.

Direct fossil CO_2 emissions from the European power and heat generation sector peaked in 2007, two years after the introduction of the EU Emissions Trading System (ETS). The peak annual CO_2 footprint was recorded at 1.58 Gtpa, with Germany, Poland, Italy and the UK accounting for 57% of the power CO_2 footprint on the continent. Since 2007, European power CO_2 emissions steadily declined to around 0.84 Gtpa in 2020 before rebounding slightly to about 0.95 Gtpa in 2021-2022 on the back of the energy crisis and reintegration of coal into the European power mix. In 2023, the European power sector proved its commitment to structural decarbonization as record-high generation from renewable sources significantly impacted demand for both coal and natural gas from the European power mix. As a result, a record-low (in modern history) CO_2 footprint of the European power sector of 0.78 Gtpa was achieved in 2023.

While the total CO_2 footprint of the European power sector is important, the absolute emission levels do not reveal the full picture, as European electricity demand and total generation declined between 2007 and 2023. The carbon intensity of the European power mix peaked at about 450 kilograms (kg) of CO_2 per megawatt-hour (MWh) in the 21st century and declined from ~438 kg per MWh to ~239 kg per MWh between 2007 and 2023. Wind energy alone accounted for 131 kg out of 199 kg per MWh of improvements in the European carbon intensity of the power mix between 2007 and 2023. In other words, 65% of improvements were driven by the integration of wind into the European power mix, which is the largest contribution across all primary energy sources.

The contribution of wind energy to the decarbonization of the European power mix is just one of the benefits that this industry brings to the continent. Other benefits cover a wide range of themes including European energy autonomy, economic growth, and jobs. While Europe remains fully committed to its ambitious wind energy targets, the speed at which capacity deployment is achieved will determine the state of the European wind industry in 2030 and have implications for the extent of these benefits. In this report, we analyze what the speed of wind energy growth really means for Europe and discuss if the current industry sentiment and existing policy framework are sufficient to trigger the needed wind expansion and associated benefits.

In our previous report from April 2023, covering *The State of the European Wind Energy Supply Chain*, we argued that the supply chain was lagging despite an aggressive demand outlook for wind. Specifically, many suppliers found it challenging to expand their operations in a high-inflation, low-margin environment, which were coupled with the uncertainty and associated risks around the speed of the demand expansion.

We note that the policy framework to incentivize the European wind manufacturing sector and project developers has moved in the right direction since April 2023, somewhat reviving optimism about European wind energy prospects. Still, a lot more can be done in the policy spectrum to facilitate Europe delivering on its wind energy goals and achieving significant economic savings amid reduced dependency on fossil fuel imports in 2030. The European wind sector currently employs ~320,000 people and provides close to €30 billion in direct contribution to GDP. One of the main findings of our report suggests that the wind sector's workforce can grow to about 560,000 full-time equivalents (FTEs), which will boost the direct contribution to GDP to ~€53 billion by 2030, in real 2023 terms. As such, the wind sector's direct contribution to GDP could be maintained at a level of ~€100,000 per FTE per year, in real 2023 terms, if Europe plays it right.

While much of our analysis is focused on the isolated impact of wind energy on various performance indicators, we note that in many cases, wind energy growth cannot be easily substituted by other renewable energy alternatives. For example, solar power needs to be scaled up a lot too, but we cannot compensate for theoretical wind outperformance with additional solar capacity due to very different profiles of solar and wind capacity factors throughout the year in most European locations. Replacing wind with incremental nuclear and hydro generation capacity in the next 5-10 years is unrealistic due to typical project timelines (time from decision to the start of operations) for these other baseload non-fossil sources and the cost of production for new initiatives. There are also some limits on the adoption of biomass in the power sector, as well as scalability concerns for geothermal energy. As such, we argue that the wind sector is critical for European energy autonomy, climate goals, economic growth and job creation. This report provides an in-depth assessment of potential losses for Europe if the continent fails to deliver on its wind targets.

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Additional fossil fuel imports of 64 Bcm avoided in 2030 in the Targets scenario

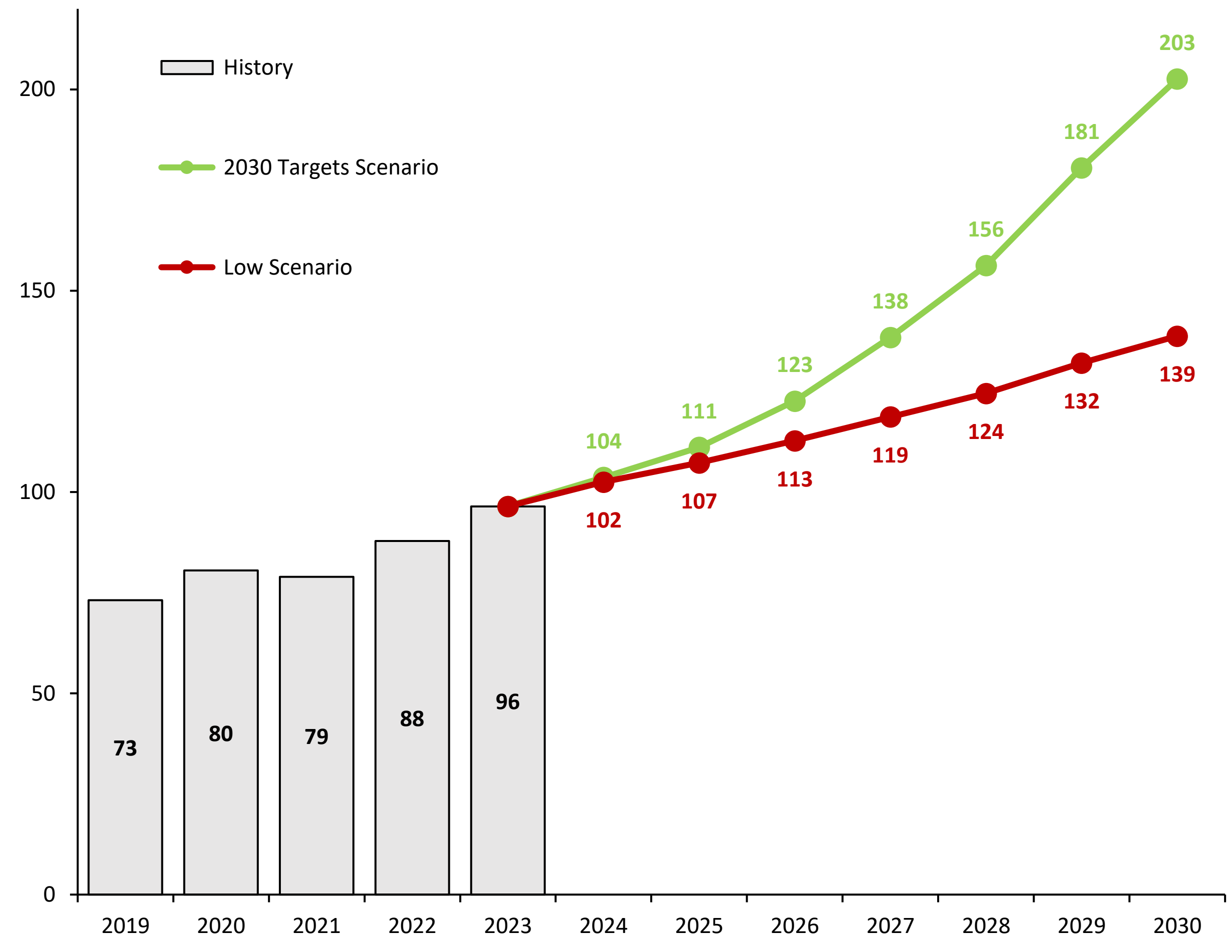
Wind generation allowed Europe to avoid nearly 100 Bcm of fossil fuel imports in 2023 (predominantly a mix of coal and natural gas). Annual avoidance of fossil fuel imports stood at about 73 Bcm in 2019 and has grown steadily alongside the increase in the amount of power generated by wind.

Considering the significant increase in average natural gas and coal prices in 2021-2023 compared to historical levels, the value of economic savings due to avoided fossil fuel imports increased from around €12 billion - €13 billion per year in 2019-2020 to a peak of more than €80 billion in 2022. The average annual economic savings stood at about €39 billion in 2019-2023.

The 2030 Targets scenario is accompanied by an increase in annual avoidance of fossil fuel imports to 200 Bcm by 2030, whereas the Low case will only allow for about 140 Bcm avoidance in 2030. Using average natural gas and coal prices for European customers from 2023 for the remainder of the decade, we estimate annual economic savings due to fossil fuel import avoidance at approximately €76 billion per year in the 2030 Targets Scenario. The economic savings are reduced to €63 billion per year in the Low case.

Hence, in the Low scenario, Europe might need to spend an additional €90 billion on fossil fuel imports in 2024-2030 compared to the spending requirements under the 2030 Targets Scenario. We note that this assumes average natural gas and coal prices from 2023 to be representative of the rest of the decade. In reality, the continent might find it difficult to secure the needed supply of fossil fuels in the Low scenario, with such a development inevitably resulting in another shock in commodity markets (i.e. highly volatile prices for end consumers) in the next few years.

Figure 1: Avoided fossil fuel imports due to wind energy generation
Billion cubic meters per year



Source: Rystad Energy research and analysis

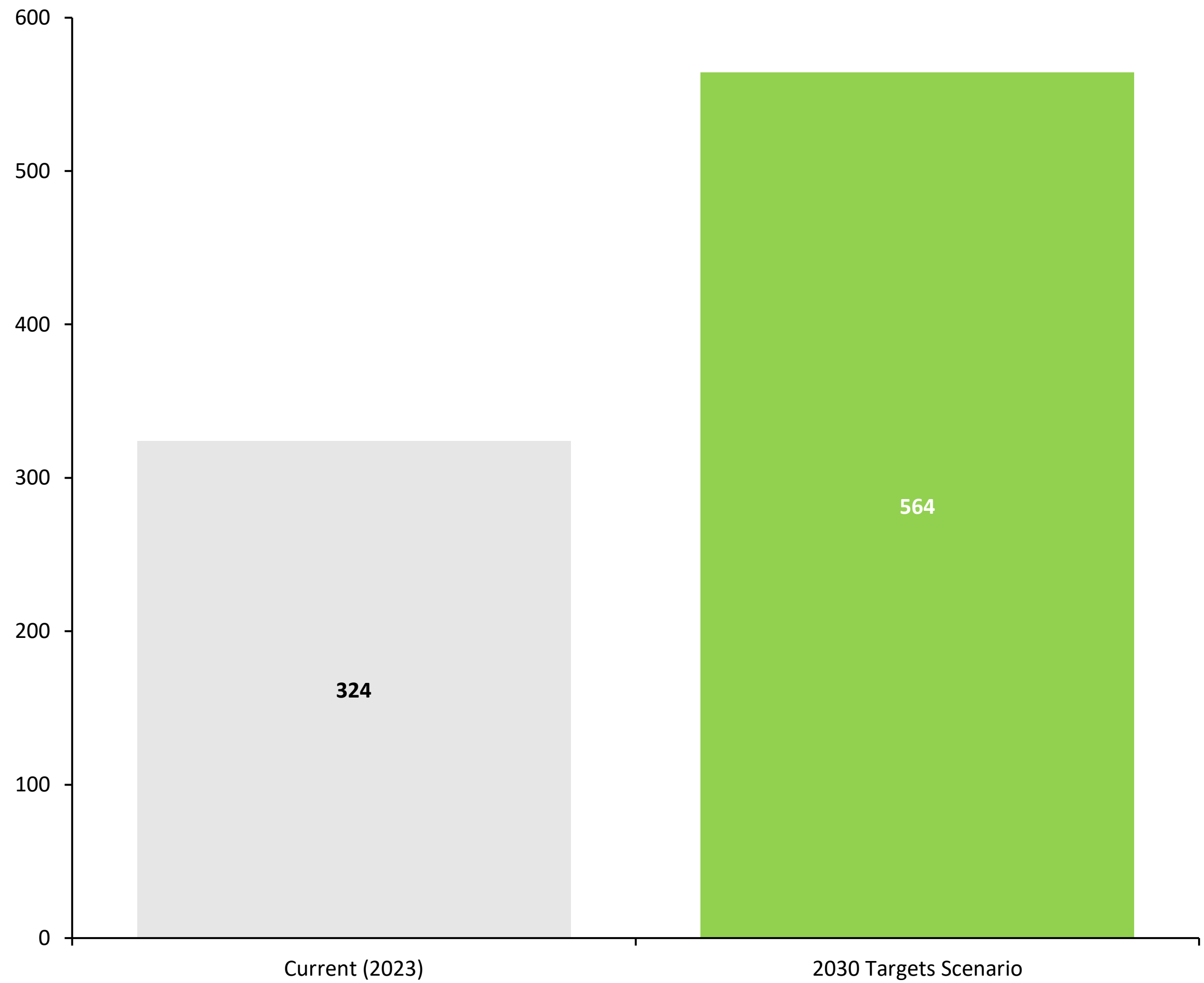
Additional 240,000 full-time wind sector jobs in 2030

European wind sector employment stood at ~324,000 full-time employees in 2023. We estimate that under the WindEurope 2030 Targets scenario, wind energy will be responsible for about 564,000 full-time employees by the end of the decade.

As the 2030 Targets scenario assumes a quick ramp-up of onshore wind, the majority of job creation will be linked to this sector. Hence, 2030 Targets scenario will create 240,000 of additional jobs linked to the sector by the end of this decade.

Additionally, the 2030 Targets scenario still sees a three-fold increase of offshore wind capacity between 2024 and 2030, with capacity ramping up more rapidly from 2026 onwards. Consequently, offshore wind will start to contribute more towards the total jobs in Europe as more and more offshore capacity comes online.

Figure 2: Full time equivalent (FTE) jobs by scenario, Europe
Thousand FTEs



Source: Rystad Energy research and analysis

More than €20 billion of additional GDP contribution in 2030

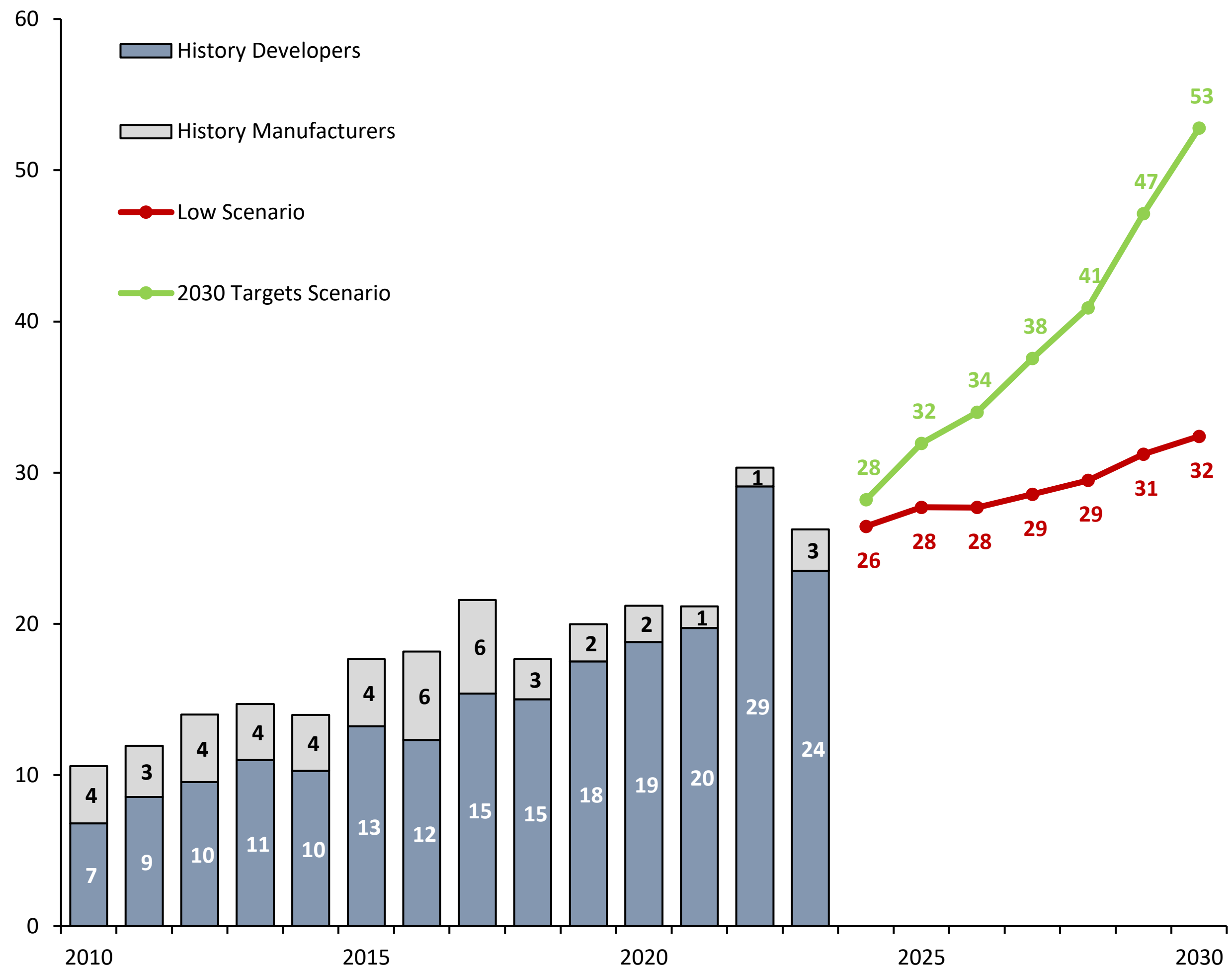
As wind power generation becomes a major source of electricity supply in Europe, the contribution from the wind industry is playing an increasingly important role in the European economy. Back in 2010, the direct contribution from developers, manufacturers and service providers totaled €10.6 billion (in real 2023 terms), with around two-thirds originating from electricity sales from developers. This represented only 0.05% of the European GDP.

Over the last decade, the contribution has grown significantly in both relative and absolute terms. It is estimated that the total direct contribution from the wind industry reached €26.2 billion in 2023. Most of the growth has been the result of greater wind power generation due to increased capacity. The revenue of developers have also been lifted by higher electricity prices, especially during 2022. As such, the direct contribution from developers, manufacturers and service providers reached 0.11% in 2023. However, the contribution from developers has been increasingly significant, totaling €24 billion (or 85%), compared to €4.2 billion from manufacturers and service providers.

Under the 2030 Targets scenario, it is forecast that the direct contribution from the whole wind energy industry will reach 0.22% of European GDP. This growth will be mostly driven by the expansion in generation capacity, meaning that the role developers play will be increasingly significant for the economy. Higher capacity factors for wind generation and increased exposure to the spot market add further support. By 2030, the contribution from developers is forecast to reach €43.9 billion, with manufacturers and service providers contributing around €8.8 billion.

In the Low scenario, where the development of new projects remains unchanged from the current level, the total contribution to GDP from the wind sector would remain below 0.15%.

Figure 3: Wind energy developers and manufacturers contribution to European GDP
Billion EUR, real (2023)



Source: Rystad Energy research and analysis

Emissions avoided by wind in the Targets scenario are valued at €28 billion per year

We quantify the value of emissions avoided by wind under the EU ETS. EU ETS prices increased from less than €20 per tonne in 2015-2017 to an average of €81- €82 per tonne in 2022-2023.

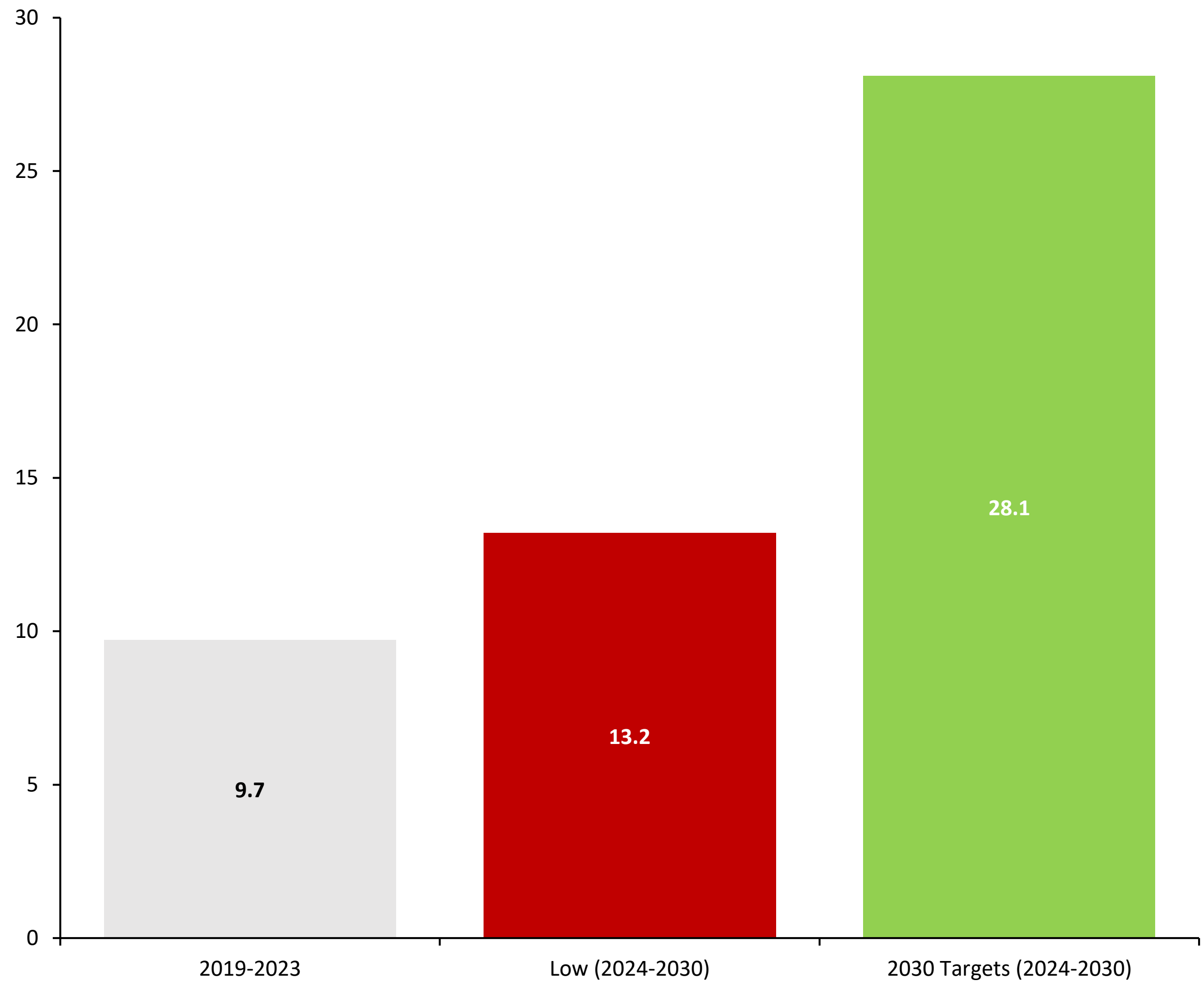
While different factors are currently impacting EU ETS development in different directions, we analyze the value of future CO_2 emissions avoided by wind under the "120 by 2030" scenario, where the EU ETS price gradually increases towards €120 per tonne in 2030.

In the last five years (2019-2023), the annual value of emissions avoided by wind in Europe averaged €9.7 billion. We note that even in the Low scenario, where lifecycle emissions avoidance declines towards 100 million tonnes of CO_2 by 2030, the average annual value of emissions avoided by wind is expected to increase to €13.2 billion in 2024-2030 amid higher EU ETS prices in the forecast period.

The 2030 Targets scenario will allow the continent to further boost the value of emissions avoided by wind, to €28.1 billion per year, in the considered forecast period.

Hence, the magnitude of the difference between the value of emissions avoided by wind under the 2030 Targets and Low scenarios is comparable to the difference between these scenarios on direct contribution to the European economy.

Figure 4: Average annual value of emissions avoided by wind under the "120 by 2030" scenario
Billion EUR



Source: Rystad Energy research and analysis

Up to €50 billion per year difference between 2030 Targets and Low scenarios

Table 1: Assessment of European wind scenarios across energy security, job market, economic growth and nature dimensions in 2024-2030

Performance Dimension	2030 Targets Scenario	Severe Underperformance (Low Scenario)	Cost of Inaction (Difference between Low and 2030 Targets)
Energy Security	• **203 Bcm** of fossil fuel imports avoided due to wind energy generation in 2030 • Expected economic savings of **€76 billion** per year in 2024-2030	• **139 Bcm** of fossil fuel imports avoided due to wind energy generation in 2030 • Expected economic savings of **€63 billion** per year in 2024-2030	• **64 Bcm** of extra fossil fuel imports in 2030 • **€13 billion** per year economic loss in 2024-2030.
Job Market	• **564,000** people employed in the European wind sector in 2030 • **56%** increase in European wind job demand between 2023 and the 2024-2030 average.	• **320,000*** people employed in European wind sector in 2030 • Relatively flat European wind job demand in 2023-2030 period.	• **240,000** European wind jobs lost in 2030 • **Opposite** trend in the labor demand for the sector
Economic Growth	• Wind Energy's direct contribution of **€53 billion** to European GDP in 2030 • **~50%** increase in direct contribution to GDP between 2023 and the 2024-2030 average	• Wind Energy's direct contribution of **€32 billion** to European GDP in 2030 • **~10%** increase in direct contribution to GDP between 2023 and the 2024-2030 average	• Lost direct GDP contribution of **€21 billion** in 2030 • **Stagnation** in GDP contribution rather than a continuous increase from the wind sector
Nature	• **299 million tonnes** of lifecycle carbon dioxide emissions avoided by average annual installation wind vintage in 2024-2030 • Annual value of **€28.1 billion** for avoided emissions.	• **128 million tonnes** of lifecycle carbon dioxide emissions avoided by average annual installation wind vintage in 2024-2030 • Annual value of **€13.2 billion** for avoided emissions.	• **1.2 Gt** of incremental lifecycle emissions due to lower wind activity in 2024-2030. • **€15 billion** per year impact on EU ETS spending in 2024-2030.

*Job market modeling for Low Scenario is based on WindEurope's independent assessment

Source: Rystad Energy research and analysis

Implications for Europe if the continent fails to deliver on wind energy ambitions

This report aims to provide an update on the outlook for the European wind energy sector and understand potential implications for energy security, job market, economic growth and the nature (environment) if the continent falls short of its ambitious wind energy targets for 2030.

The outset of the report is based on WindEurope's capacity outlook for wind power in Europe in its latest 2030 Targets scenario for wind capacity additions and implied generation through 2030. In addition to the 2030 Targets scenario, Central (most likely) and conservative Low scenarios are considered in the report.

Part 1 of the report describes the current status of the European wind energy sector. We start with a recap of the traditional energy trilemma that is frequently used by policymakers as a guiding principle to find a balance between the often-conflicting challenges: ensuring energy reliability, affordability and sustainability. We describe how European policymakers have approached the energy trilemma in recent years and what kind of role wind energy plays in this discussion.

We present the latest fact-based statistics on the development of the European power mix and progress with wind energy supply chain development on the continent. Further, we summarize the evolution of the main challenges and bottlenecks for the European wind sector: inflationary environment and implications for recent auction prices, high interest rates, dependency on turbine imports from China, and overall spending profile for European onshore and offshore wind. We conclude the first section of the report with an in-depth assessment of recent policy announcements that are relevant to the wind sector and identify the areas where further policy progress might be needed.

Part 2 of the report is dedicated to the in-depth assessment of three wind energy scenarios across four different performance dimensions: energy security, job market, economic growth and nature.

At the start of the second part, we present the aforementioned scenarios, which are used as input into the model's underlying cost of inaction assessment across four performance dimensions.

In the **energy security** section, we highlight the potential increase in European power demand between 2023 and 2030 driven by accelerated electrification of the commercial and industrial (C&I) sector and green hydrogen development. Therefore, significant growth in wind and other renewable energy is critical to maintaining fossil fuel demand from the power sector at current levels, even before we consider continuous displacement requirements. Due to the nature of seasonal generation peaks and troughs for solar energy, it is unlikely that the underperformance of wind generation can be compensated by other variable renewable sources in 2030. In turn, non-variable baseload non-fossil generation sources, such as hydro and nuclear, are also unlikely to provide incremental generation in 2030 compared to the current base case outlook amid long cycle times for greenfield and expansion projects. As a result, we argue that the underperformance of wind energy will inevitably increase fossil fuel imports in Europe in 2030. We estimate incremental fossil fuel imports of 64 billion cubic meters (Bcm) in 2030 for the Low Scenario compared to the 2030 Targets scenario, where wind energy helps reduce 203 Bcm of fossil fuel imports. This difference translates into a €13 billion per year economic loss over the 2024-2030 period.

Under the 2030 Targets Scenario, wind energy will be responsible for ~336,000 **jobs** in Europe by the end of 2024, which could increase to ~564,000 full-time equivalent (FTE) employees by the end of the decade. For comparison, the Low Scenario is associated with job demand staying ~320,000 FTEs throughout 2030 revealing a staggering 240,000 jobs difference between the two boundary scenarios in the report.

When discussing the **nature**, we examine annual lifecycle CO_2 avoidance by wind energy in different scenarios. In the 2030 Targets scenario, annual lifecycle CO_2 avoidance is expected to increase to 330 million - 370 million tonnes by the late 2020s. The Central Scenario will also be accompanied by a comparable increase in annual CO_2 avoidance, while the Low Scenario will be accompanied by a gradual decline in annual lifecycle CO_2 avoidance towards 100 million tonnes in 2030 as the rest of the European power mix becomes less carbon intensive. Hence, in the Low Scenario, 1.2 gigatonnes (Gt) of incremental lifecycle emissions are expected due to lower wind activity in 2024-2030. This translates into a €15 billion per year impact on European Union Emissions Trading System (EU ETS) spending over 2024-2030.

Source: Rystad Energy research and analysis

The trilemma between autonomy, affordability and sustainability

The energy trilemma refers to finding a balance between the often-conflicting challenges: ensuring energy reliability, affordability and sustainability.

Reliability refers to whether a country or entity has an uninterrupted availability of energy supply to satisfy its domestic needs. In the short-term, such a system should deliver energy despite sudden changes in demand or part of the supply. In the long-term, this means energy security in terms of energy resources. Affordability means affordable energy that is accessible to everyone. Sustainability refers to energy production that does not have a negative effect on the planet for future generations, both in terms of emissions and human encroachment. The elements in the energy trilemma are universal and will be relevant for the development of other commodities as well.

Historically, the focus between the elements of affordability, sustainability and reliability has shifted depending on the energy climate. After the oil market downturn in 2014, the focus was on cutting costs in the corrected energy market. After this, the focus on energy transition and decarbonization of energy gained momentum. The energy industry is still undergoing fundamental change with an increased emphasis on renewable energy sources, efficiency and emission reduction. The Covid-19 pandemic accelerated this trend, as policymakers saw an opportunity to use the energy transition as a means to reboot the economy after lockdowns.

Russia's invasion of Ukraine served as a reminder of the importance of reliable sources of energy supply. In Europe, this has accelerated the energy transition and led the region to become independent of Russian gas and EU leaders have sharpened their focus towards energy reliability. Moreover, the entire reliability dimension was split into two pillars: energy autonomy and energy security. The focus today is not only on the resiliency of the energy system in its conventional sense (legacy definition of reliability) but also on achieving it predominantly through domestic efforts strengthening local supply chains and the energy project development landscape.

Figure 5: Evolution of the energy trilemma in Europe

Source: Rystad Energy research and analysis

Renewable power generation overtakes fossil fuels with major contribution from wind

For the last two decades, the share of renewable power generation has been growing steadily across Europe mainly driven by onshore wind power. Up to 2010, fossil fuels supplied more than 50% of Europe's total electricity. However, the closure of coal plants across the continent and a strong growth in solar and wind capacity have helped shift the balance in favor of renewable energy.

Coal power generation has been in a sharp decline since 2007, which has continued to date. Several countries including the UK, Spain, Italy and France decided to begin the decommissioning of their coal generation fleet, helping gradually reduce generation from the source that has the largest carbon footprint. However, gas power generation has continued to play a key role in helping meet demand and back up the intermittency of renewable power generation. As such, gas power has remained relatively stable over the last decade despite supply issues and high prices.

Renewable power generation overtook fossil fuels for the first time in 2020 when there was a strong decline in the utilization of gas and coal plants because of lower electricity demand due to the pandemic. At the same time, wind and solar PV capacity continued to grow, helping drive the share of renewable generation to 41% in the same year. Wind power generation has now become the largest source of renewable energy in Europe. In 2023, onshore wind power generation reached 468 terawatt-hours (TWh) and offshore wind generation 110 TWh, taking the total supply from wind to 17% of total generation. Hydropower continues to be the second largest source of renewable energy with approximately 560 TWh of generation in 2023.

Renewable power generation has also overtaken nuclear power supply. Nuclear power used to be the second-largest source of electricity in Europe, with generation peaking at 1,121 TWh in 2004. The closure of nuclear reactors across the continent due to safety concerns has led to a steady decline in generation from nuclear power.

Figure 6: Europe power generation mix by energy source
Terawatt-hours (TWh) per year

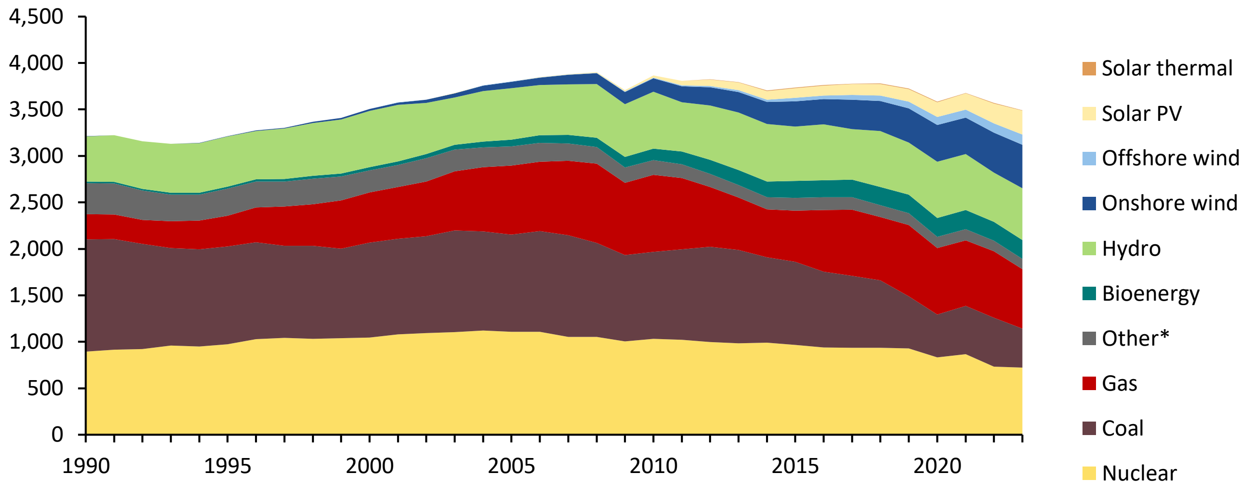
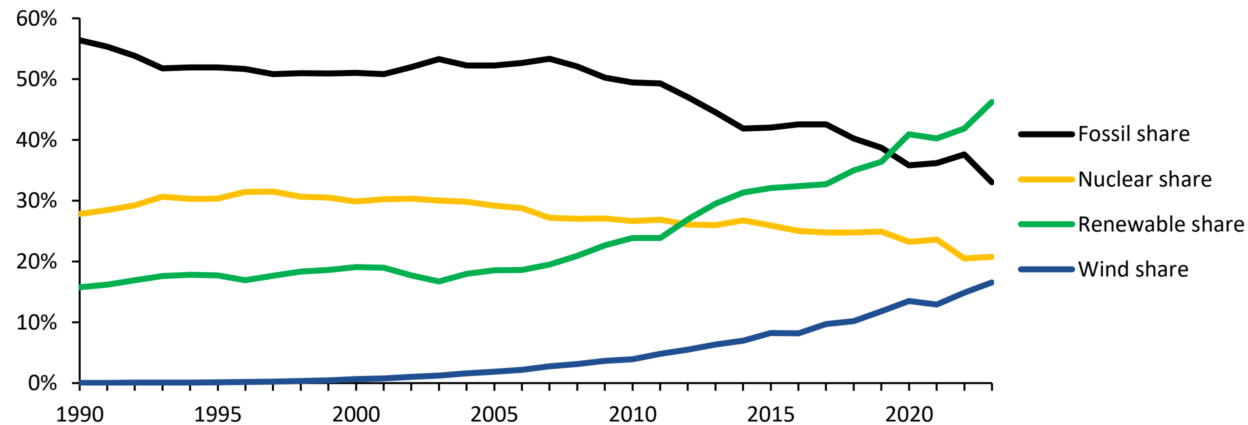


Figure 7: Share of different primary energy sources
Percentage (%)



*Other includes geothermal, liquids, marine, hydrogen mixed and non-renewable waste
Source: Rystad Energy PowerCube

Wind manufacturing facilities in Europe

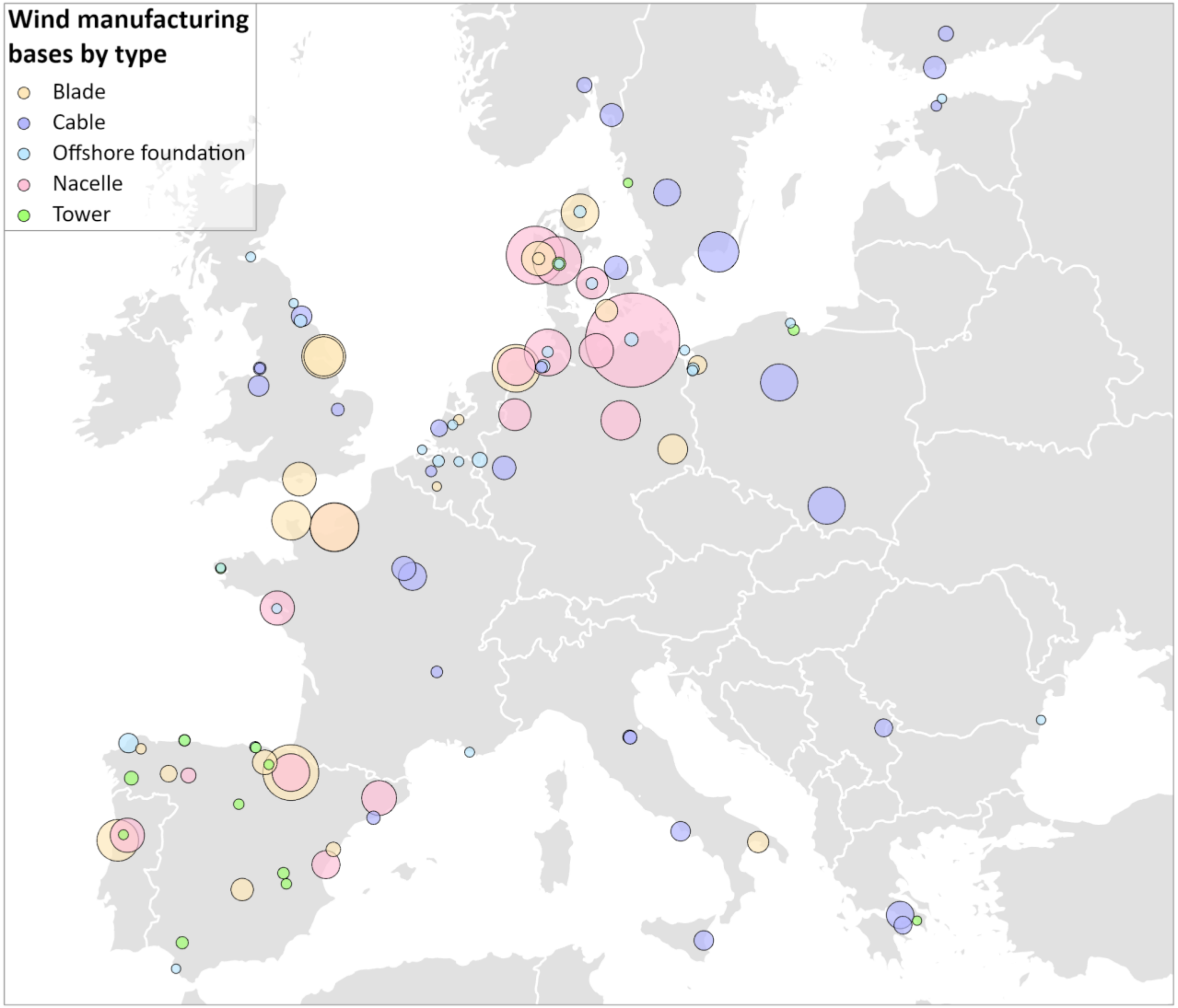
Europe is one of the largest regions in terms of manufacturing capacity for wind power components. Europe has an interconnected supply chain, as the European Union Free Trade Agreement helps the movement of goods across member states' borders.

Noteworthy European countries in the wind supply chain include Germany, Spain and Denmark, all of which have significant activity linked to producing the main components of wind turbines – blades, nacelles, and towers. In recent years, France has also emerged as a key country, with new blade and nacelle manufacturing plants. For offshore wind foundations, key producers include the Netherlands, Germany and Denmark. Unsurprisingly, these countries are also among the leaders in terms of installed capacity for offshore wind in Europe.

Most of these facilities are in port cities, facilitating sea transport. We expect this trend to continue as more manufacturing facilities producing offshore wind components will be added. For cable manufacturing – medium voltage and (extra) high voltage – activity is quite distributed, with contributing countries including Italy, France, the UK, Poland, Norway and Sweden. Notably, the cable production facilities illustrated in the chart to the right may also produce cables for high-voltage direct current (HVDC) interconnectors and oil and gas electrification.

The focus on energy autonomy/security in Europe also has consequences for the supply chain of components and services related to the build-out and operations of the European wind capacity. This is expected to drive the need for further expansion of manufacturing sites, ports and related services. In turn, this will lead to a growing demand for labor. The European wind workforce has remained stable at around 300,000 FTEs from 2019-2022, but this number is expected to rise with the planned scale-up.

Figure 8: Operational manufacturing sites for main wind power components in Europe, as of 2023 year-end*



*Bubble sizes indicate relative manufacturing capacities within each category, based on MW for blades and nacelles, tonnes for towers and offshore wind foundations, and km for cables.
Source: Rystad Energy research and analysis

Cost inflation and interest rates have resulted in developers bidding for higher prices

The recent escalation in auction prices for onshore wind developers is a response to the pressures of escalating costs and rising interest rates. These challenges have led to diminished margins for suppliers and, consequently, shifted financial pressures onto developers, compelling them to increase their auction bid prices to counterbalance these rising expenses. The pace at which bid prices have climbed surpasses the rate of inflation in project costs, marking a shift from historical trends partly due to the significant uptick in interest rates. Although a temporary reduction in component costs is anticipated, a longer-term increase is expected by 2027 due to tightening supply chain constraints, underscoring the need for flexible bidding mechanisms to address unforeseen cost increases and avoid project cancellations.

France's auction scheme for onshore wind, which had a cap set at €70 per MWh to avert speculative bidding, has seen this limit adjusted upwards in response to inflation, although the exact new cap remains undisclosed. This adjustment aims to allow bids to reflect actual costs more accurately while ensuring that developers are not excessively inflating future subsidy costs. Interestingly, Germany has also experienced an upward trend in auction prices for onshore wind projects, albeit to a lesser extent than France. This variance can be attributed to France's more pressing need to accelerate its progress towards renewable energy targets, necessitating more aggressive bidding strategies to catalyze project development and catch up with its objectives.

For offshore wind, the slower pace of capacity awarding does not allow for a similar trend. However, the UK's 2023 offshore wind auctions faced a setback as developers abstained from bidding, citing that the government-offered prices set at £44 ($55.50) per MWh (2012 reference prices) failed to match the escalating costs. In response, the UK government has acknowledged these issues and increased the maximum Administrative Strike Price for offshore wind projects by 66%, to £73 per MWh, and by 52% for floating offshore wind projects, to £176 per MWh, for the upcoming AR6 auction.

Figure 9: Onshore wind auctions awarded prices in selected markets
EUR per megawatt-hour (MWh)

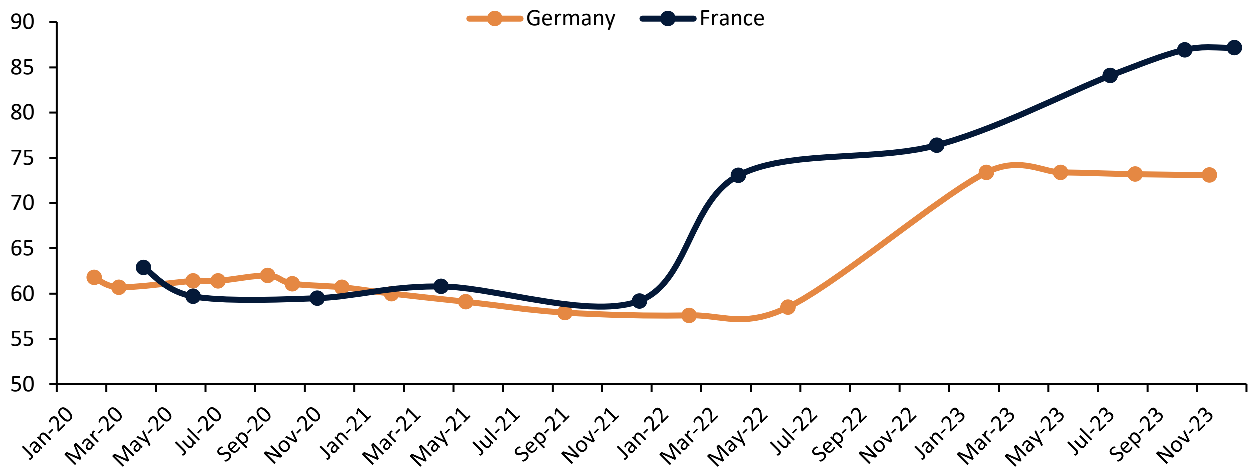
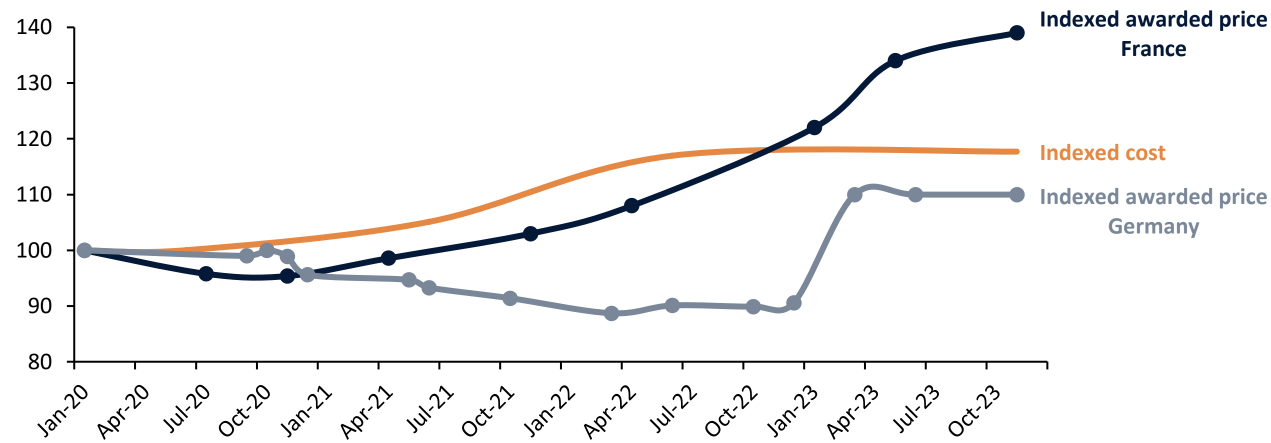


Figure 10: Indexed onshore wind project cost compared to indexed awarded prices in selected markets*
January 2020 = 100, EUR per MWh



*Indexed cost includes equipment, project development, engineering, installation, maintenance and operation costs
Sources: Rystad Energy PowerCube

Higher interest rates eat into gearing potential, reducing share of project finance

Rebooting economies and supply chain disruptions led to rapidly increasing inflationary pressure across industries, pushing prices up for key raw materials and manufactured components. To remedy this, central banks raised interest rates, and Figure 14, to the right, shows how the European Central Bank lifted its fixed rates from 0% in July 2022 to 4.5% by September 2023.

While the soaring inflation itself posed a threat to the European wind targets, the remedial interest rate hikes created a “double whammy” for wind developers and expanding supply chain players. Increased financing costs put pressure on project profitability. Furthermore, the increased capital costs for suppliers looking to increase their capacity to accommodate growing demand may as well be lifted onto developers in terms of higher costs of components and services.

When the Central Bank started lifting its fixed rate interest rates in July 2022, it was the first change since March 2016, when it was lowered from 0.5% to 0%, where it stayed for more than 6 years. During this period, Europe saw a growing share of project-financed offshore wind farms, shown in Figure 15. Many of these projects were highly leveraged in pursuit of higher returns, a strategy that has become decreasingly appealing to developers as interest rates have come back to higher levels.

While the potential for gearing up is diminishing, the situation may favor companies with large balance sheets. 2023 was a strong year for projects backed by corporate finance, with more than 5.5 GW (~65%) of the capacity reaching financial close opting for this strategy.

Despite the market headwinds and uncertainty, 2023 was a record year for offshore projects reaching a final investment decision, reaching nearly 9 GW – a positive comeback for the European offshore wind sector after a low in 2022 of less than 200 MW.

Figure 11: European Central Bank interest rates

Fixed rate interest rate (%)

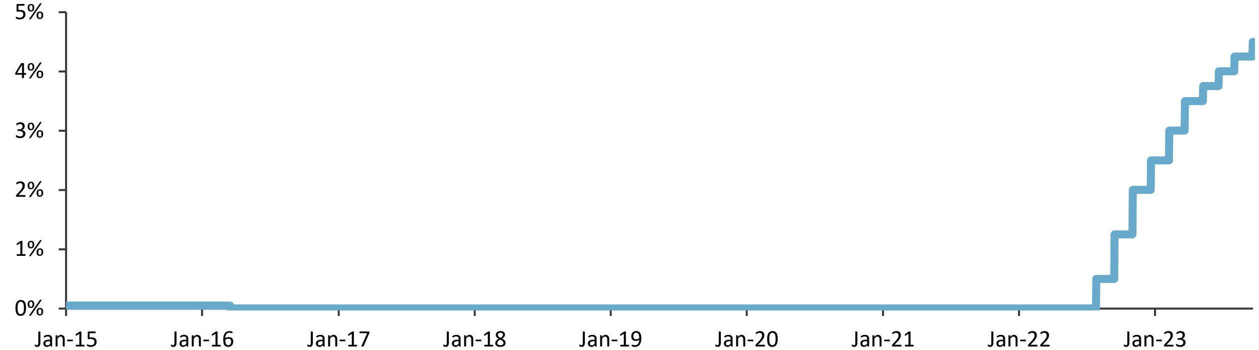
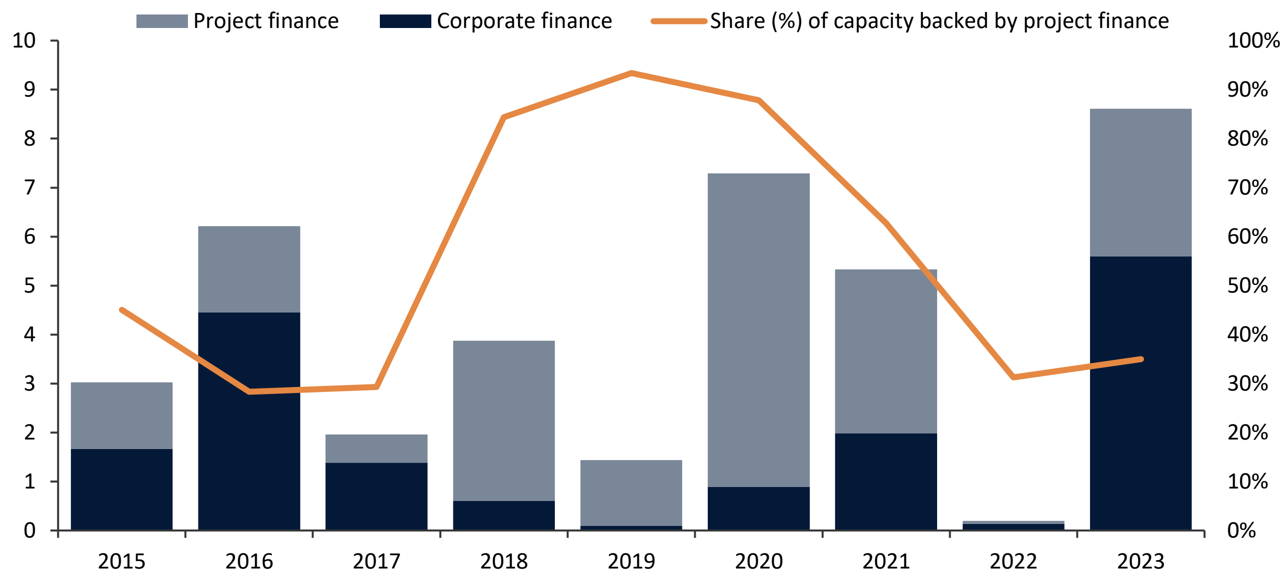


Figure 12: Financially closed offshore wind capacity in Europe per year, by type of financing

Capacity financed (GW_{AC}) Share (%) of capacity backed by project finance



Source: Rystad Energy research and analysis

Significant turbine-related imports to EU, with majority coming from China

Following Russia's invasion of Ukraine, European policymakers have increased their focus on energy security, autonomy and sovereignty. This has been expanded to include not only the supply of energy itself but an increased independence across the supply chain and sourcing of key raw materials.

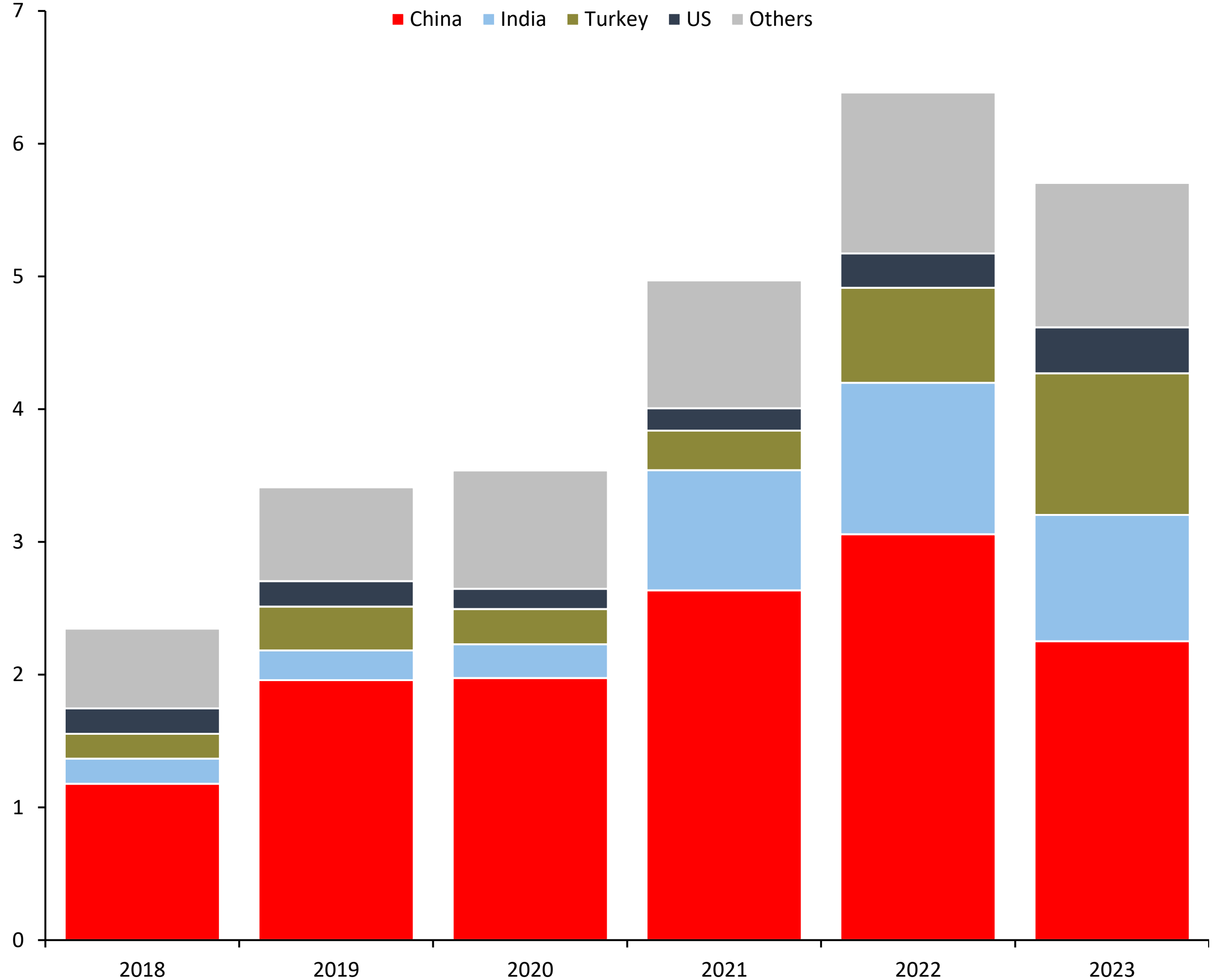
One of the areas receiving the most attention in the wind industry has been the turbine market, where European and Western manufacturers have struggled financially in recent years. This has challenged their prospects of ramping up their capacities at the scale and pace that is needed for Europe to reach its ambitious targets.

Figure 16, to the right, shows that turbine-related imports to the European Union have been growing in recent years, reaching approximately $6.4 billion in 2022. This includes main components such as nacelles, blades and towers, in addition to sub-components.

The main exporter to the EU in terms of trade value is China, which has contributed more than 50% of the import value from 2018 to 2022, on average. India, Turkey and the US follow as other large exporters of turbine-related components to the EU.

While it is too early to conclude with a trend shift, 2023 saw a slight decline in the import value, estimated to decline by about 11% year-on-year. While imports from China and India are estimated to have declined in 2023, Turkish turbine-related exports to the EU grew significantly. It should be noted that the inflationary pressure in recent years has pushed up the trade value of EU imports. In 2023 inflation started to flatten out, which could partly explain the slowdown.

Figure 13: Annual wind turbine component import value to EU from non-EU countries
Billion USD, nominal



Source: Rystad Energy research and analysis

European wind spending at $55 billion in 2023, EU contributes about $42 billion

Expenditures related to the development and operations of onshore and offshore wind farms in Europe have grown from around $35 billion in 2015 to more than $55 billion in 2023, as shown in Figure 17. Most of this spending is directed towards capital expenditures (capex), with operational expenditures (opex) growing more steadily with the increasing installed base of capacity.

Capex remained flat between 2021 and 2023. This is partly driven by limited growth in onshore wind capacity additions between 2022 and 2023. In addition, offshore wind capex ramp-up related to projects expected to come online in the 2024-2026 period has been offset by lower commissioning levels during 2022 and 2023 compared to the 2019-2021 period.

Most of the spending has been related to wind farms located in the EU, amounting to approximately $42 billion in 2023, as illustrated in Figure 18. This is dominated by expenditures related to onshore wind, with countries like Germany, France, Sweden and Spain the main contributors in recent years. For offshore wind, Germany and the Netherlands have been the main engines of spending between 2015 and 2023. France has ramped up its investments significantly in recent years, with its first large-scale offshore wind farm completed in 2022, with additional projects to come online during 2024 and 2025.

In European countries outside of the EU, offshore wind dominates spending. This is primarily driven by the UK, which has grown its offshore wind capacity significantly over the last decade, making it the largest offshore wind nation in Europe with around 45% of the region's operational capacity. The UK is also the largest driver of onshore wind expenditures among non-EU nations. Norway had seen growing onshore wind expenditures from 2015 to 2019, but this has declined rapidly towards 2023 following the nation's three-year licensing break imposed by the government in 2019 and uncertainty around tax policies, seeing new investments dry out.

Figure 14: Total European expenditures in offshore and onshore wind
Billion USD, nominal

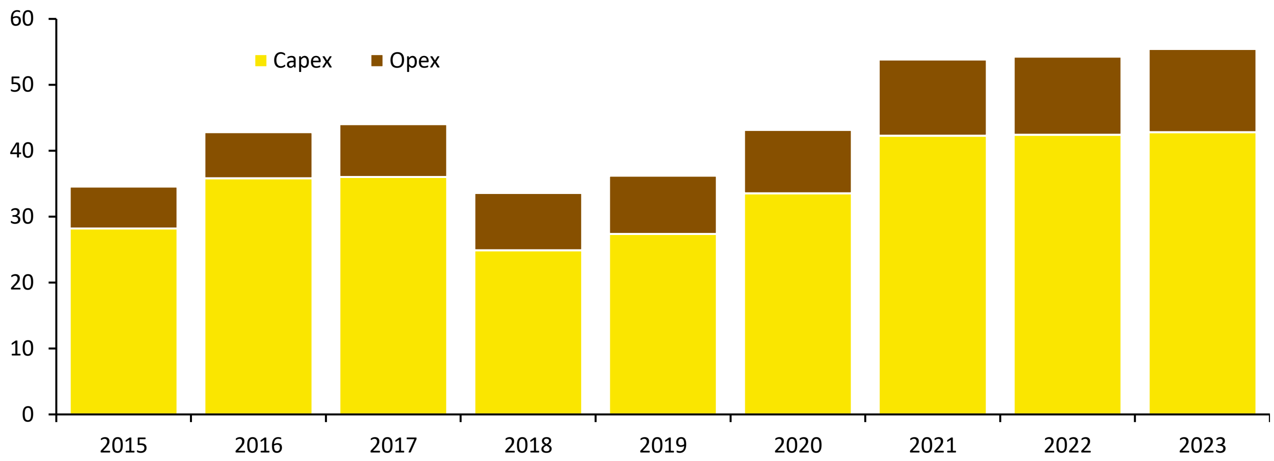
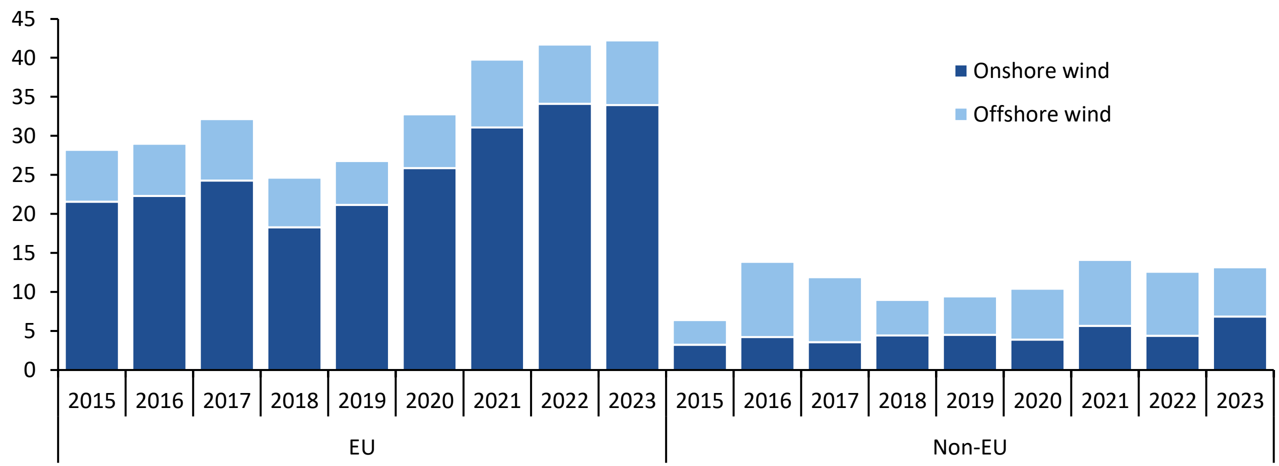


Figure 15: EU and non-EU European expenditures, split by onshore/offshore wind
Billion USD, nominal



Source: Rystad Energy research and analysis

How are European policies tackling the wind energy industry challenges?

European policies		Renewable Energy Directive revision	Technical Support Instrument Regulation	Wind Power Package	Electricity Market Design Reform
Status		*In force*	*In force*	*In force*	*Provisional agreement*
Increase predictability of wind energy development	Defining new long-term targets	✓ (green)			
	Defining medium-term auction schedules on a single platform			✓ (green)	
Accelerate and simplify permitting	Setting caps on permitting procedures	✓ (green)			
	Defining "acceleration areas" and renewable energy projects as "overriding public interest"	✓ (green)			
	Tackling repowering permitting procedures	✓ (green)			
	Facilitating new regulations implementation, digitalizing and centralizing the process		✓ (green)	✓ (green)	
Adapt power market rules and auctions design	Harmonizing the framework for offtake agreements in Europe and promoting two-way Contract-for-Differences and Power Purchase Agreements				✓ (green)
	Indexing auction prices to cost fluctuations and defining non-price criterias that maximise projects execution			✓ (green)	
	Reforming of different electricity markets to facilitate renewable integration and better reflect their variability				✓ (green)
	Disabling a permanent inframarginal revenue cap				✓ (green)
	Enabling compensations for hybrid offshore wind farms				✓ (green)
	Harmonizing revenue models for storage solutions across Europe				✓ (red)

✓ (green) **Announced measures** ✓ (red) **Not announced measures**

Source: Rystad Energy research and analysis

How are European policies tackling the wind energy industry challenges?

The wind energy sector has been high on the agenda of the EU institutions in 2023. The 2022 energy crisis combined with the growing European supply chain reliability on third countries have been catalyzers to the discussions. Below is an updated status on current challenges and how European policies are aiming to tackle it.

Increase wind energy development predictability

The European wind industry has called for greater predictability in the development of wind energy, which would make it easier for industry players to plan and invest in future projects, whether related to the supply chain, project development or infrastructure. The **Renewable Energy Directive (RED) revision** responds to this need by setting new European targets, thereby shaping the long-term prospects for wind energy. It sets a binding target of 42.5% renewable energy in the EU's overall energy consumption by 2030 and is already being translated into national ambitions set out in the **National Energy and Climate Plans (NECPs)**, which are still under revision. In addition, the **Wind Power Package** announced in November 2023 focuses on improving the medium-term predictability of the project pipeline. Member states will be asked to publish medium-term auction schedules on a single EU digital platform and to commit to wind power deployment volumes for at least the period from 2024 to 2026, in addition to their 2030 target.

Accelerate and simplify permitting

The slowness and complexity of permitting procedures in Europe remain one of the main bottlenecks to project development in Europe. As a legacy of the Emergency Regulation on permitting, the **revised RED** has maintained the cap on permitting procedures at two years, including all administrative and grid connection permits and environmental impact assessments. In addition, the EU is introducing "Renewable Energy Acceleration areas" where permits will be issued within one year for new projects and six months for repowering projects. This now requires member states to consider renewable energy projects to be an "overriding public interest" to expedite the resolution of any legal challenges. However, these new rules remain largely dependent on how well member states manage to implement them. The EU is already providing tools to facilitate this implementation, notably through the **Technical Support Instrument (TSI) Regulation**, which offers technical expertise to speed up the granting of wind energy permits. The **Wind Power Package** also announced the launch of the "**Accele-RES**" initiative aimed at effective transposition of the **revised RED**, through the digitalization of permitting processes and training of national authorities.

Adapt power market rules and auction design

While auctions have been an essential tool for developers to cope with recent cost and interest rate inflation, the industry has called for greater consistency in the design of national tenders across the EU. The aim is to limit the risk of non-execution or delay of projects and to support the risk of cost fluctuations. In addition, several concerns required a reform of power market rules to facilitate renewable energy integration and send better investment signals. The **Electricity Market Design (EMD)** reform has recently been provisionally agreed upon and was one of the EU's first strong intentions on standardizing offtakes and updating power market rules. The last version calls for the promotion and harmonization of revenue schemes through long-term contracts for difference (CfDs) and power purchase agreements (PPAs). In addition, it is reforming the power market on a timeframe granularity, aiming to better integrate the renewable variability risk. The **Wind Power Package** effectively addresses the indexation of auction prices on cost fluctuations and aims to launch a dialogue on a new framework of qualitative criteria that would maximize the execution rate of awarded projects.

Source: Rystad Energy research and analysis

How are European policies tackling the wind energy industry challenges?

European policies		Wind Power Package	Critical Raw Materials Act	Net Zero Industry Act	Grid Action Plan
Status		*In force*	*Provisional agreement*	*Provisional agreement*	*Announced*
Support supply chain expansion	Facilitating access to EU funding such as the Innovation fund and to European Investment Bank counter-guarantees mechanisms	✓ Announced			
	Streamlining permitting for supply chain installations			✓ Announced	
	Definining targets for components manufacturing and critical raw materials procurement diversification		✓ Announced	✓ Announced	
	Developing specialized training programs	✓ Announced		✓ Announced	
	Defining auctions criteria on components procurement origin			✓ Announced	
	Implementing targeted financial support mechanisms for investments in the supply chain and tailored to different critical materials and components		✓ Not announced	✓ Not announced	
	Implementing transparent and clear strategies on recyclability and circularity		✓ Not announced	✓ Not announced	
Support grid expansion	Streamlining permitting for cross-border projects and accelerating projects identified as of common interest				✓ Announced
	Improving long-term grid planning in collaboration with the ENTSO-E				✓ Announced
	Introducing regulatory incentives and tailored financing models				✓ Announced
	Implementing flexibility provisions targeting the estimation of grid needs				✓ Announced
	Facilitating access to finance through European Investment Bank counter-guarantees mechanisms				✓ Not announced

✓ (green) **Announced measures** ✓ (red) **Not announced measures**

Source: Rystad Energy research and analysis

How are European policies tackling the wind energy industry challenges?

Support supply chain expansion

The sovereignty of the European energy transition supply chain has been a major topic in 2023. The **Green Deal Industrial Plan** initiated a series of measures and policy packages aimed at securing the local industry for components and raw materials used for renewable energy and technologies, such as hydrogen electrolyzers and carbon capture and storage. Initial discussions were aimed at defining targets for components local manufacturing and critical raw materials procurement. The **Net Zero Industry Act (NZIA)**, having recently reached a provisional agreement, defined a 40% target for domestically produced clean technology components by 2030. The **Critical Raw Materials Act (CRMA)** defined minimum self-reliance targets in terms of the annual consumption of so-called critical raw materials: 10% for extraction, 40% for processing and 25% for domestic recycling. In addition, it states that no more than 65% of the EU annual consumption of each strategic raw material at any relevant stage of processing should rely on a single third country.

Secondly, the measures were oriented towards actions to reach those targets. The **NZIA** introduces a streamlined permitting framework for relevant manufacturing plants, similar to the measures introduced for project development. In addition, the **NZIA** aims to orientate the demand from developers towards the local supply chain by defining auction criteria on components procurement origin. These criteria will have to be used in at least 30% of the volume auctioned every year per member state. Due to the expected growing need for skilled workers, to both support the supply chain and install renewable energy projects, the **NZIA** and the **Wind Power Package** are also introducing European frameworks for specialized training programs. While tailored financial incentives like the one introduced in the US Inflation Reduction Act were expected but not implemented, the EU is proposing to facilitate access to funding. It involves the use of the **EU Innovation Fund** to finance parts of manufacturing plants, as well as leveraging on the **European Investment Bank (EIB)** to provide counter-guarantee mechanisms to facilitate access to private funding.

Support grid expansion

The grid, often referred to as the power system backbone, has been an under-addressed topic in recent years, despite rising concerns about its ability to absorb growing variable power generation. Three main concerns need to be addressed and require significant public support: the modernization of the existing grid to minimize curtailment, the expansion of interconnectors to facilitate supply and demand balancing, and the reduction of grid connection queues for renewable energy new projects.

A long-awaited **Grid Action Plan** was announced by the EU with actional measures to support those challenges but remains to be implemented. The announced measures aim to streamline the permitting for cross-border infrastructures and projects identified as of common interest, to remove any administrative barriers. In collaboration with the ENTSO-E, a long-term planning of the required grid capacity will be defined, to facilitate the introduction of tailored incentives. Also, through the **EMD reform**, the grid operators will be required to implement provisions for flexibility solutions, going beyond the simple use of fossil fuel power plants.

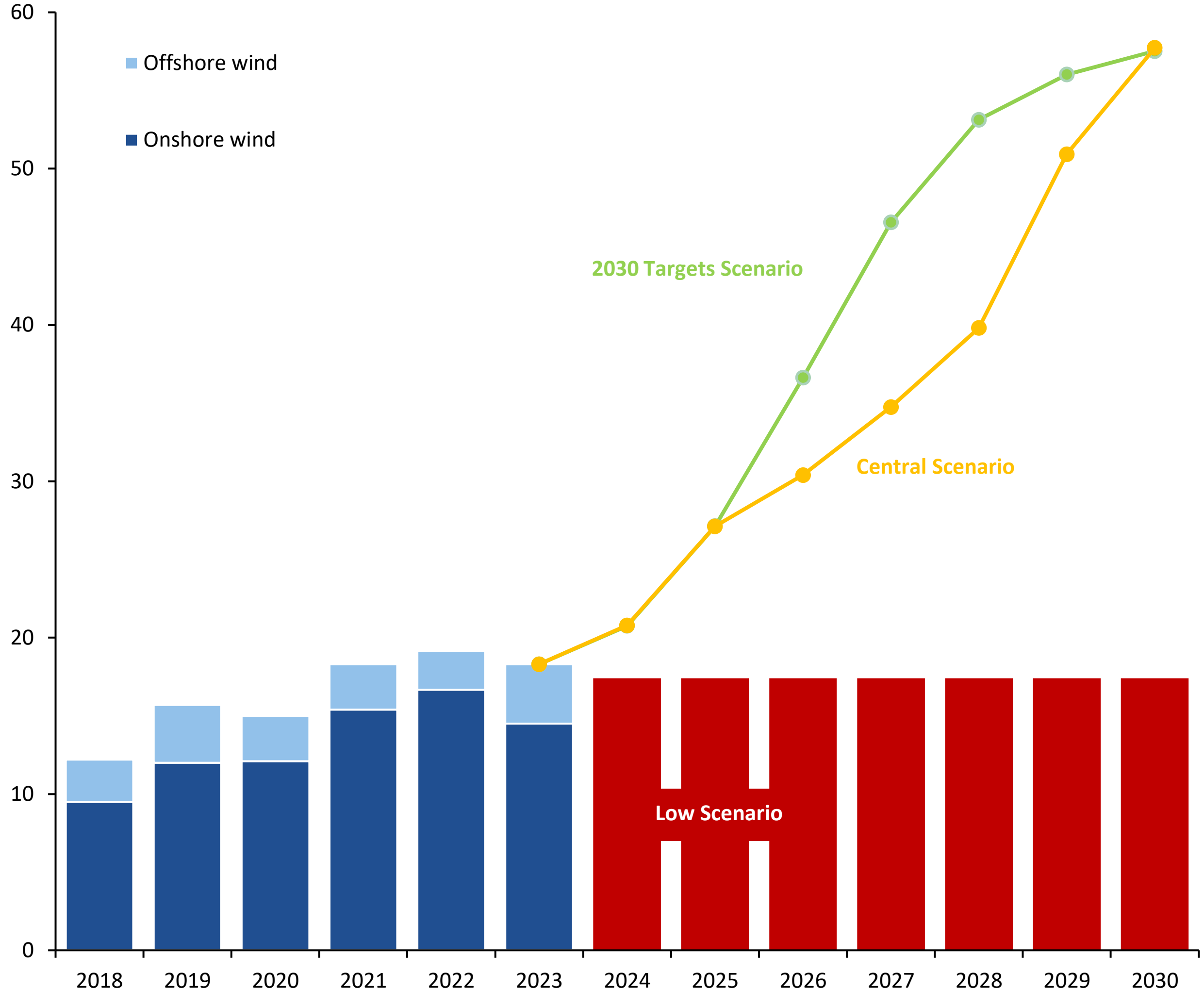
Overall, the EU has been introducing relevant measures to tackle key aspects of the ongoing challenges facing the wind industry. The past year has been pivotal, with permitting, sovereignty and standardization for the renewable energy industry key discussion topics at EU institutions, as well as at the national level. The predictability of the wind sector development is expected to be improved with the finalization of the member states NECPs. The permitting bottleneck has been tackled on paper, but 2024 will have to convert the strong RED revision into successful national measures. The reform of the power market rules has been relevant while avoiding potentially risky major changes. An improvement could be to further involve storage in the discussions, as current divergences in revenue models across countries are leading to competitiveness issues. On the supply chain sovereignty, if key topics have been addressed, the lack of targeted financial support mechanisms combined with non-technology-specific targets remains criticized by the industry.

Scenario introduction and comparison

This report operates with three key scenarios. The high- and mid-case scenarios refers to WindEurope's *2030 Targets scenario* (high) and *Central scenario* (mid). The third is made specifically for this report to illustrate the theoretical downside and has been named the *Low scenario*.

- **WindEurope 2030 Targets scenario**: this is the most optimistic scenario used in this report. It represents a theoretical installation rate required to meet the REPowerEU targets defined in the revised EU Renewable Energy Directive (RED III) and the 2030 targets of non-EU countries - the UK, Turkey, Norway, Switzerland and Serbia. The installation rate begins at the installations level from 2023 and increases to a peak growth rate between 2026 and 2027, showing the expected ramp-up over the next few years. Annual installations continue to grow after 2027, but at a slower rate (including an allowance for expected decommissioning), leading to the 2030 targets being met.
- **WindEurope Central scenario**: this lays out WindEurope's best estimate for installed capacity in Europe towards the end of the decade, including any likely political or economic developments that could affect installations. It considers the latest developments in EU regulation, national policies, announcements of signed power purchase agreements, project development timelines and the ability of wind developers to secure further capacity in upcoming auctions and tenders.
- **Low scenario**: this assumes a zero-growth case, where annual installed capacity stays at 2023 levels from 2024 through 2030. It is a theoretical scenario, ignoring firm, ongoing developments that should ensure growth, especially in the near term, but aims to serve as a reference to the "cost of inaction" through the report.

Figure 16: Annual installed wind capacity in Europe by scenario, 2018-2030
Gigawatts (GW_{AC})



Note: Scenarios do not consider any wind capacity installed in Ukraine, Bosnia and Herzegovina, Montenegro, Kosovo, North Macedonia, Russia and Albania between 2022 and 2030.
Source: WindEurope

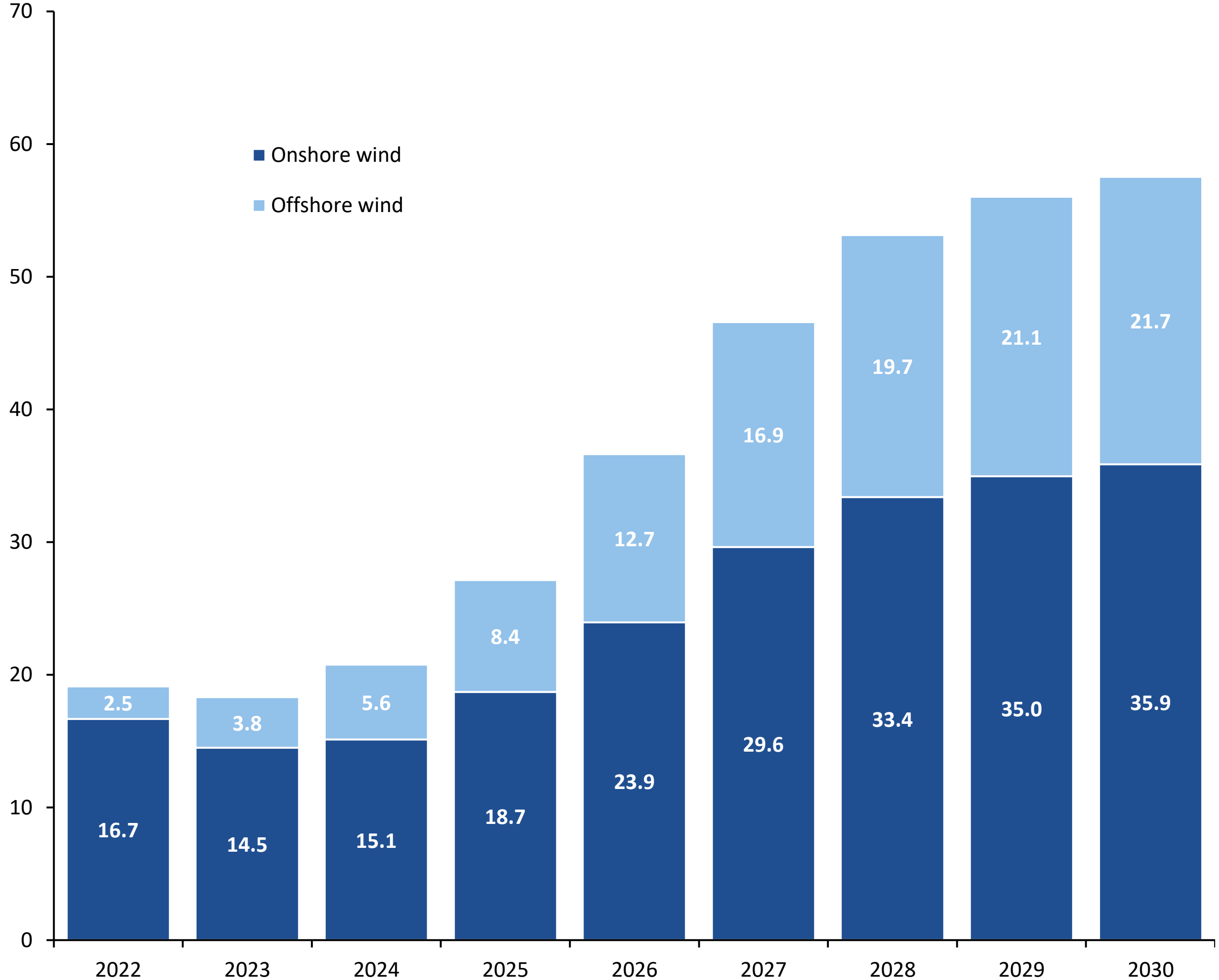
WindEurope 2030 Targets scenario

WindEurope reports about 274 GW of installed wind power capacity in Europe at the end of 2023, including nearly 221 GW in the EU.

The WindEurope 2030 Targets scenario combines both the ambitions set in REPowerEU and different national targets for countries outside the EU. The REPowerEU ambitions, set in the face of the 2022 energy crisis, have been revised in the latest EU Renewable Energy Directive. It is now aiming for a binding target of at least 42.5% of renewable energy in the overall consumption, combined with an indicative high target of 45%. According to the European Commission's assessments, the 45% high target would mean a cumulative installed capacity of 510 GW of wind power by 2030. However, WindEurope estimates that 440 GW would be sufficient for the EU to meet its target. While the Commission's assessment is based on capacity factors reflecting currently operating wind farms (27% for onshore wind and 32% for offshore wind), WindEurope uses capacity factors reflecting recent technological improvements (35% for onshore and 45% for offshore wind). In the 2030 Targets Scenario, WindEurope applies the same methodology to the binding target of 42.5%. This translates the ambition into an installed capacity of just above 420 GW, met by installing on average more than 25 GW per year towards 2030.

Regarding the rest of Europe, the scenario considers the other European countries having made 2030 commitments for wind energy. This includes the UK, which has a 2030 target of 50 GW for offshore wind and 22 GW for onshore wind. Turkey has also set a wind energy target of 18.1 GW by 2030, assumed to be only onshore. While Norway has not yet set a 2030 target, WindEurope estimates 12 GW of installed capacity by 2030. Serbia has set a target to increase installed wind power capacity tenfold by 2030, which would suggest a target of 3.5 GW, according to WindEurope. Finally, WindEurope estimates that Switzerland would need to have reached 240 MW of installed capacity by 2030 to be on track with its 2035 target of 1.2 TWh generated by wind.

Figure 17: Annual installed wind capacity in Europe, WindEurope 2030 Targets scenario
Gigawatts (GW_{AC})



Note: Excludes Ukraine, Bosnia and Herzegovina, Montenegro, Kosovo, North Macedonia, Russia and Albania.
Source: WindEurope

WindEurope Central scenario

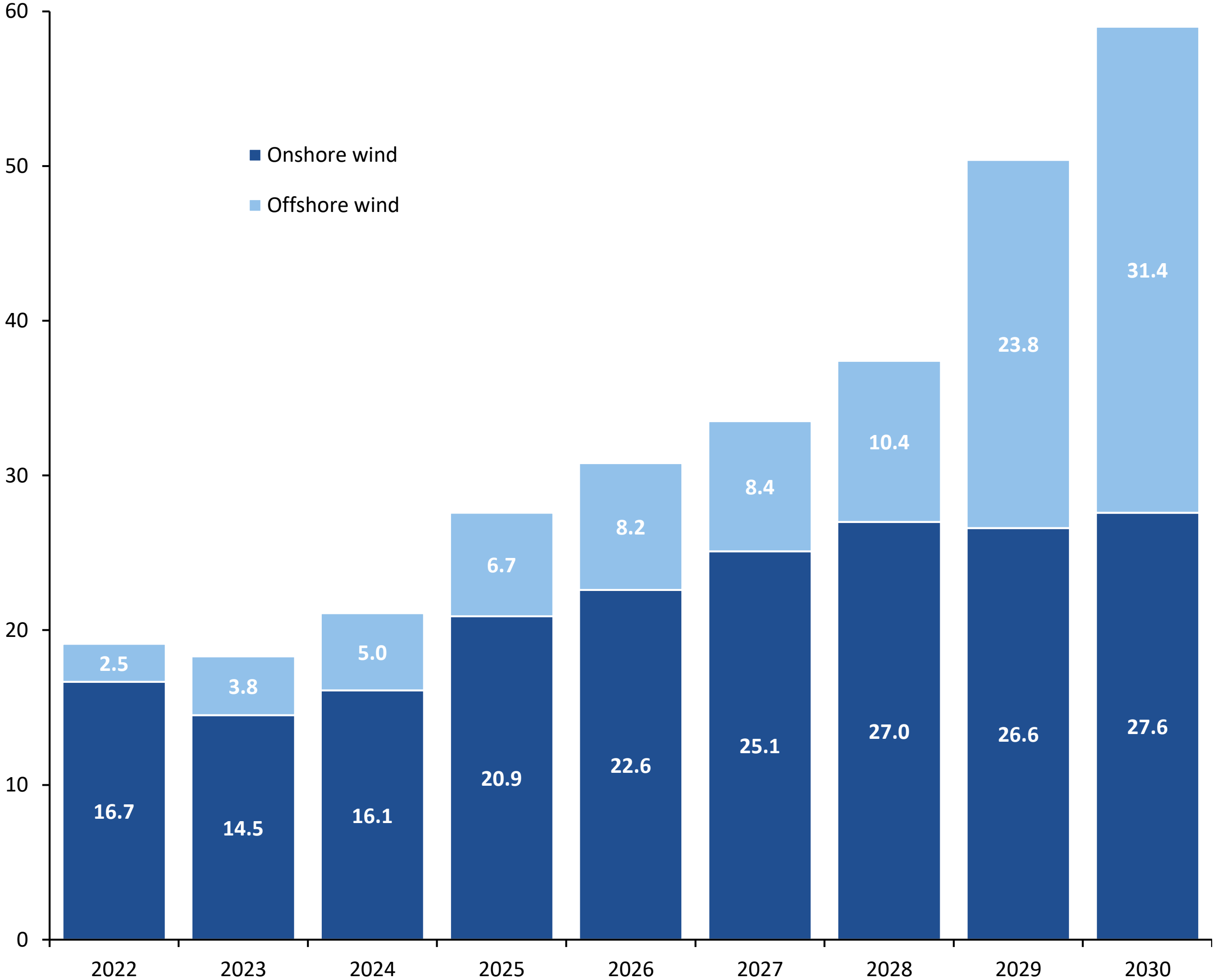
Contrary to the Targets scenario, its Central scenario represents the most likely or expected outlook for European wind capacity build-up through 2030. In the Central scenario, WindEurope also anticipates wind installation in Europe (offshore and onshore combined) to surpass 50 GW per year by the late 2020s, although the build-up in the annual market size is expected to be slower in the next five years.

The difference between the 2030 Targets and the Central scenario is particularly large in the 2027-2028 period when annual wind capacity additions average 37 GW per year in the Central scenario and 50 GW per year in the 2030 Targets scenario. On a cumulative capacity basis, the Central scenario is associated with 260 GW of wind capacity additions in 2024-2030, which is ~12% lower than the cumulative capacity requirements of the 298 GW imposed by the 2030 Targets Scenario for the same period.

We note that in relative terms, the Central scenario features a more conservative outlook for onshore than for offshore wind. For onshore wind, cumulative capacity additions over the 2024-2030 period are 166 GW, versus 191.5 GW in the 2030 Targets scenario. In turn, for offshore wind, the difference between the 2030 Targets and Central scenarios is only 10%: 106 GW installed in the 2030 Targets scenario and 95 GW installed in the Central scenario (2024-2030).

Throughout the remainder of the report, we analyze the impact of the European wind sector performing on the Central scenario rather than the 2030 Targets scenario across various economic, job market, energy security and environmental performance indicators. It is reasonable that certain negative implications are anticipated, but the significance of these implications is sometimes immaterial as the Central and 2030 Targets scenarios are not that far apart. Hence, we frequently reference the hypothetical Low Scenario with a much more conservative wind market outlook to illustrate the severity of negative implications for Europe if the wind outlook degrades considerably.

Figure 18: Annual installed wind capacity in Europe, WindEurope Central scenario
Gigawatts (GW_{AC})



Note: Excludes Ukraine, Bosnia and Herzegovina, Montenegro, Kosovo, North Macedonia, Russia and Albania.
Source: WindEurope

Up to €50 billion per year difference between 2030 Targets and Low scenarios

Table 2: Assessment of European wind scenarios across energy security, job market, economic growth and nature dimensions in 2024-2030

Performance Dimension	2030 Targets Scenario	Slight Underperformance (Central Scenario)	Severe Underperformance (Low Scenario)	Cost of Inaction (Difference between Low and 2030 Targets)
Energy Security	• **203 Bcm** of fossil fuel imports avoided due to wind energy generation in 2030 • Expected economic savings of **€76 billion EUR** per year in 2024-2030	• **190 Bcm** of fossil fuel imports avoided due to wind energy generation in 2030 • Expected economic savings of **€73 billion** per year in 2024-2030	• **139 Bcm** of fossil fuel imports avoided due to wind energy generation in 2030 • Expected economic savings of **€63 billion** per year in 2024-2030	• **64 Bcm** of extra fossil fuel imports in 2030 • **€13 billion** per year economic loss in 2024-2030.
Job Market	• **564,000** people employed in European wind sector in 2030 • **56%** increase in European wind job demand between 2023 and the 2024-2030 average.	• **532,000** people employed in European wind sector in 2030 • **41%** increase in European wind job demand between 2023 and the 2024-2030 average.	• **320,000*** people employed in European wind sector in 2030 • Relatively flat European wind job demand in 2023-2030 period.	• **240,000** European wind jobs lost in 2030 • **Opposite** trend in the labor demand for the sector
Economic Growth	• Wind Energy's direct contribution of **€53 billion** to European GDP in 2030 • **~50%** increase in direct contribution to GDP between 2023 and the 2024-2030 average	• Wind Energy's direct contribution of **€49 billion** to European GDP in 2030 • **~46%** increase in direct contribution to GDP between 2023 and the 2024-2030 average	• Wind Energy's direct contribution of **€32 billion** to European GDP in 2030 • **~10%** increase in direct contribution to GDP between 2023 and the 2024-2030 average	• Lost direct GDP contribution of **€21 billion** in 2030 • **Stagnation** in GDP contribution rather than the continuous increase from the wind sector
Nature	• **299 million tonnes** of lifecycle carbon dioxide emissions avoided by average annual installation wind vintage in 2024-2030 • Annual value of **€28.1 billion** for avoided emissions.	• **262 million tonnes** of lifecycle carbon dioxide emissions avoided by average annual installation wind vintage in 2024-2030 • Annual value of **€24.1 billion** for avoided emissions.	• **128 million tonnes** of lifecycle carbon dioxide emissions avoided by average annual installation wind vintage in 2024-2030 • Annual value of **€13.2 billion** for avoided emissions.	• **1.2 Gt** of incremental lifecycle emissions due to lower wind activity in 2024-2030. • **€15 billion** per year impact on EU ETS spending in 2024-2030.

*Job market modeling for Low Scenario is based on WindEurope's independent assessment
Source: Rystad Energy research and analysis

European power consumption could increase by up to 850 TWh by 2030

European power demand has experienced stagnation at around 2,900-3,100 TWh per year since 2010 as energy efficiency and deindustrialization trends have offset increased penetration of electrification in the residential and C&I sectors, along with an early increase in electricity demand from electric vehicles.

As of 2023, C&I becomes the dominant consumption sector accounting for approximately 2,000 TWh of annual use on the continent. The residential sector consumes about 800 TWh per year, while transportation accounts for the remaining 95 TWh.

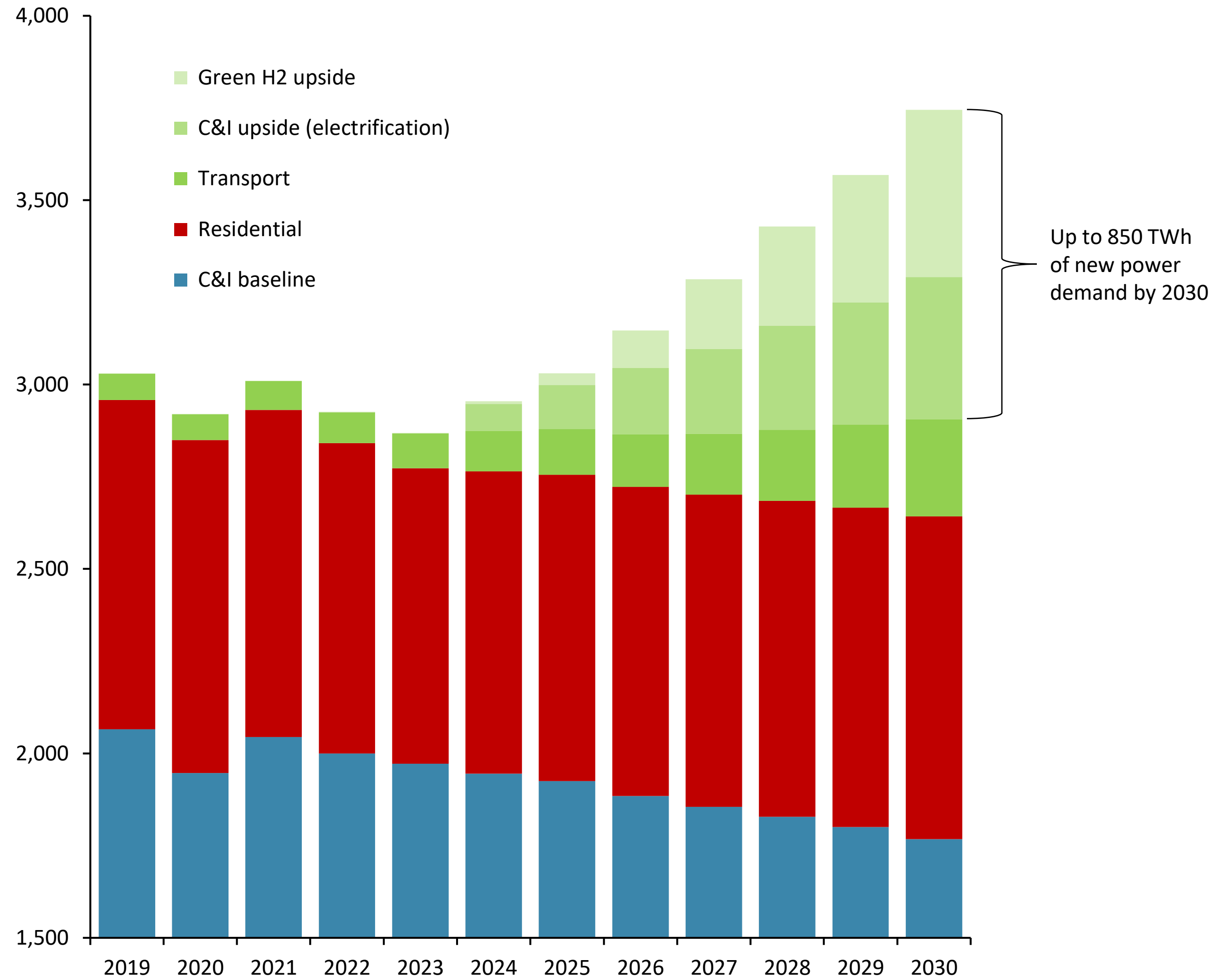
Looking at the three major established sectors, we anticipate baseline European power consumption to remain relatively flat at approximately 2,900 TWh per year through 2030. Energy efficiency and deindustrialization trends are expected to remain prevailing factors pushing C&I electricity consumption down by about 6% between 2023 and 2030. Nevertheless, increases in residential consumption from 800 to 875 TWh per year and power use by transport (from 95 to 260 TWh) are expected to offset the C&I decline.

In addition to the baseline established consumption sectors, two new sources of electricity demand in Europe might emerge by 2030:

- Accelerated electrification and rooftop solar penetration in C&I.
- Electricity demand from green hydrogen production on the continent (10 million tonnes per annum domestic production target for 2030).

While both upside segments remain highly uncertain, we note that each of them can generate a staggering 380-450 TWh per year of additional demand in 2030. The magnitude of green hydrogen upside is directly correlated with wind capacity additions, as a significant portion of European green H2 projects assume hydrogen production during wind curtailment periods. The significance of green hydrogen for future electricity demand, if Europe pursues its targets consistently, comes as a shock. Hence, we provide additional details and outlook for this new sector on the next page.

Figure 19: European power demand outlook
Terawatt-hours (Twh)



Source: Rystad Energy PowerCube

Understanding significance of green hydrogen ramp-up on European power demand

Among power demand sectors presented on the previous page, green hydrogen production is the least certain and often the least understood. Based on pilot and commercial-scale electrolysis hydrogen projects announced in recent years, European green hydrogen production capacity might reach ~8.7 million tonnes per annum (tpa) by 2030. More projects with realistic startup dates before 2030 will likely be announced in 2024-2025.

On the other hand, it is also likely that many of the already announced projects will face delays or complete cancelations and the actual European production capacity for green hydrogen will end up lower than 8.7 million tpa.

Nevertheless, REPowerEU includes an ambitious target of 20 million tpa of green hydrogen consumption by 2030, of which 50%, or 10 million tpa, should be produced domestically in Europe. European policymakers took major steps in 2023 to introduce an appropriate policy framework that incentivizes project developers to pursue green hydrogen initiatives. The maturation of policies and overall business case for green hydrogen in Europe is expected to continue in 2024-2025.

Many green hydrogen projects aim to rely directly on wind power during peak generation hours, while other project developers plan to leverage solar or hybrid solar and wind generation sources.

Based on the current project pipeline and expected average electrolyzer efficiency of 52 kilowatt hours (kWh) per kilogram (kg) in 2030, we estimate that green hydrogen production might require a staggering 450 TWh of electricity in 2030. Based on the current project pipeline and expected improvements in electrolyzer efficiency towards 45 kWh per kg by 2050, we estimate electricity demand of at least 700-800 TWh from green hydrogen production in 2050.

Figure 20: Current green hydrogen pipeline in Europe and REPowerEU targets for 2030
Million tonnes per annum (Mtpa)

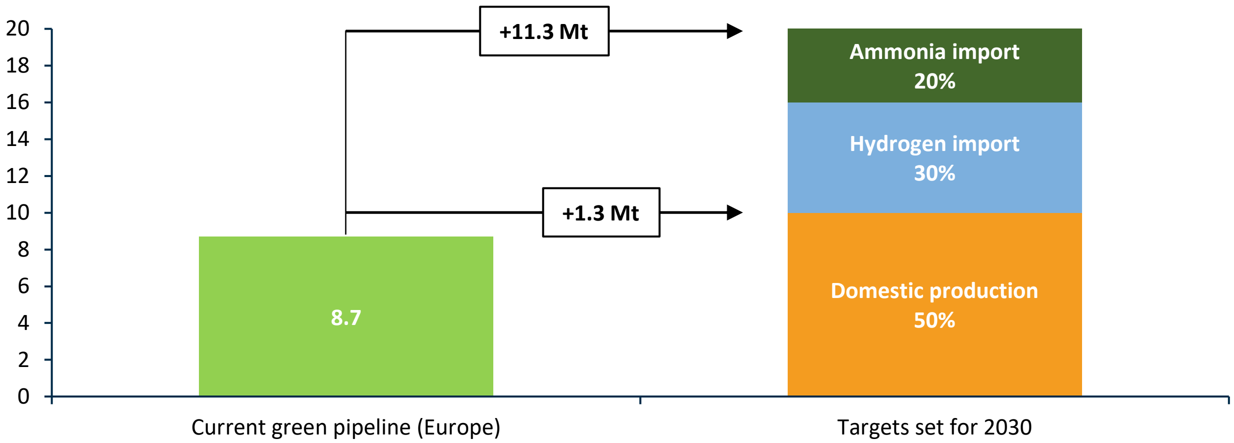
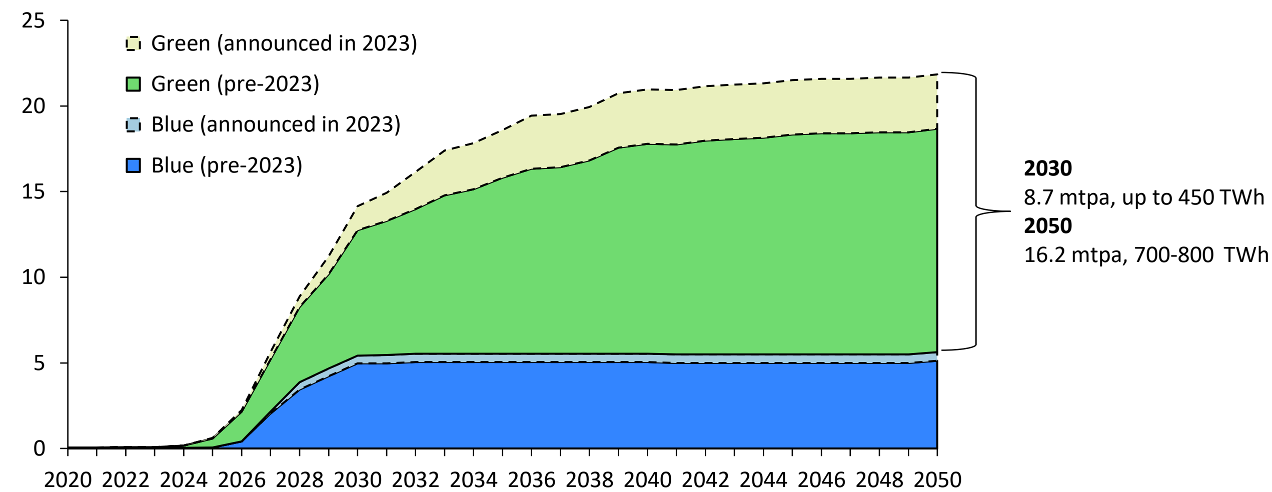


Figure 21: Clean hydrogen supply project pipeline in Europe by production method
Million tonnes per annum (Mtpa)



Source: Rystad Energy research and analysis

Wind to account for 35% of European power mix in the 2030 Targets scenario

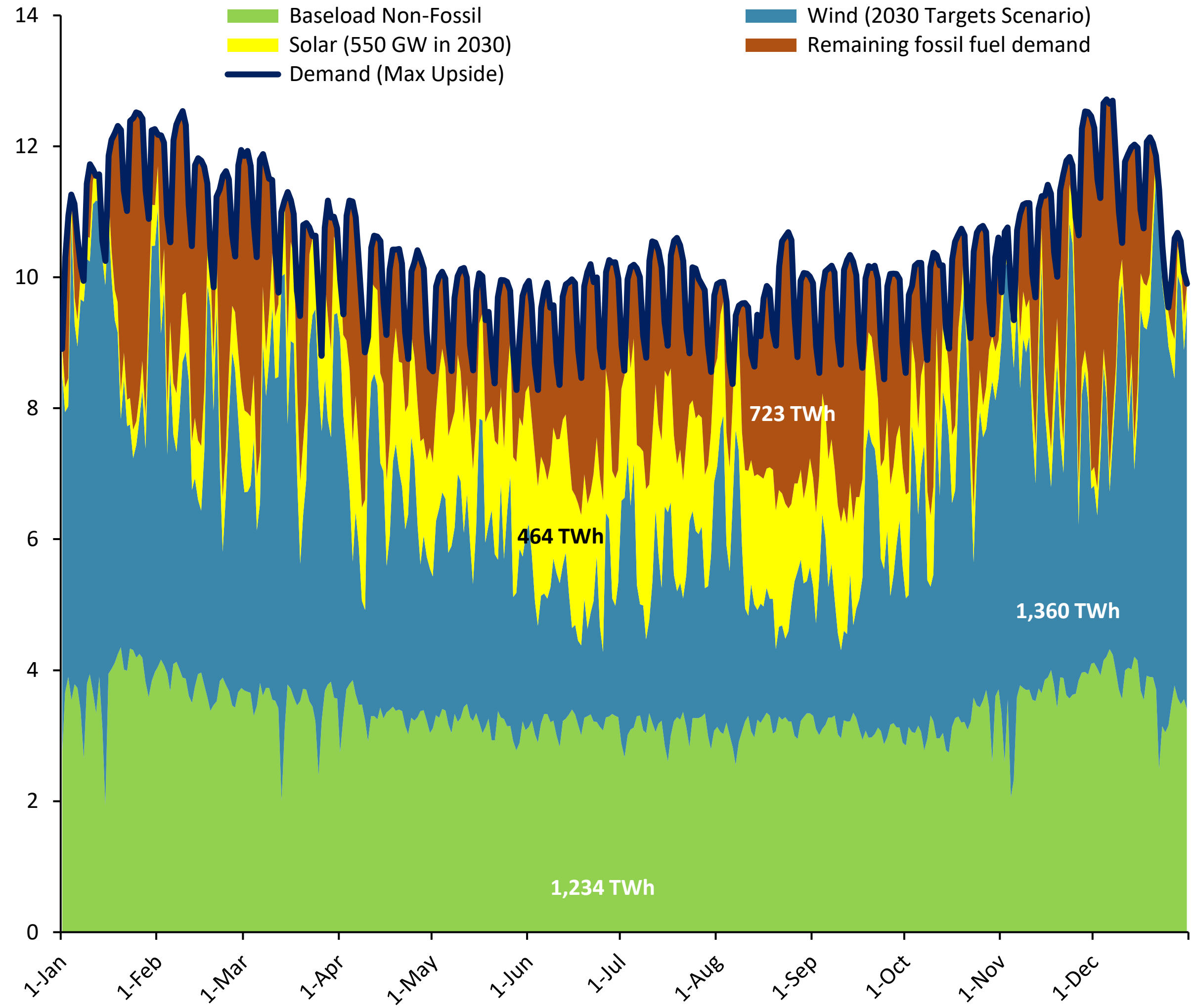
In the maximum upside scenario (with contributions from accelerated C&I electrification and green hydrogen production), European electricity demand might surpass 3,750 TWh per year in 2030. In terms of seasonal fluctuations, this will translate into a typical 10-12 TWh per day range in the first and fourth quarters of the year and a 9-10 TWh range for most of the summer months (in a typical year without material weather anomalies).

For non-variable non-fossil power generation sources (predominantly, hydro, nuclear and bioenergy), we anticipate a maximum 5% growth in installed capacity between 2023 and 2030. With such growth, these sources can generate a stable baseload of 3-4 TWh per day covering ~33% of European power demand in 2030 (~1,234 TWh per year).

If the wind industry delivers on the 2030 Targets scenario and brings the total (onshore and offshore) European installed capacity to ~500 GW by 2030, wind energy is expected to generate approximately 1,360 TWh in a typical year. Daily wind generation spikes above 5 TWh will not be unusual in 1Q and 4Q, while daily wind generation in the summer months is unlikely to surpass 3 TWh in 2030. The solar industry (centralized and distributed combined) is forecast to reach about 550 GW_{AC} of installed capacity by 2030 in the most optimistic scenario (almost delivering on REPowerEU target). Coupled with wind contributions, solar will compensate for undergeneration in the summer months, resulting in a fairly stable baseload of at least 3.5 TWh per day from solar and wind combined.

In the target scenario and maximum upside on the demand side, about 1,000 TWh of electricity in Europe will still have to come from fossil sources. More optimistic capacity additions for non-fossil baseload sources are unlikely on a 7–8-year horizon, while potential outperformance of solar installations will have a limited impact on incremental generation in the first and fourth quarter of each year. As such, the potential underperformance of the target scenario by wind will inevitably result in increased fossil fuel consumption in 2030.

Figure 22: European power consumption and power mix in 2030 (typical year)
TWh per day



Source: Rystad Energy research and analysis

Significant gap in fossil fuel imports between Low and Targets scenario in 2030

Wind generation allowed Europe to avoid nearly 100 Bcm of fossil fuel imports in 2023 (predominantly a mix of coal and natural gas). Annual avoidance of fossil fuel imports stood at approximately 73 Bcm in 2019 and has been growing steadily alongside the increase in power generated by wind.

Considering the significant increase in average natural gas and coal prices in 2021-2023 compared to historical levels, the value of economic savings due to avoided fossil fuel imports increased from around €12 billion - €13 billion per year in 2019-2020 to a peak of more than €80 billion in 2022. The average annual economic savings stood at about €39 billion in 2019-2023.

The 2030 Targets scenario is accompanied by an increase in annual avoidance of fossil fuel imports to 200 Bcm by 2030, whereas the conservative Low case will only allow for about 140 Bcm avoidance in 2030. Using average natural gas and coal prices for European customers from 2023 for the remainder of the decade, we estimate annual economic savings due to fossil fuel import avoidance at approximately €76 billion per year in the 2030 Targets scenario. The savings are reduced to €63 billion per year in the Low case.

Hence, in the Low scenario, Europe might need to spend an additional €90 billion on fossil fuel imports in 2024-2030 compared to the spending requirements under the 2030 Targets scenario. We note that this assumes average natural gas and coal prices from 2023 to be representative of the rest of the decade. In reality, the continent might find it difficult to secure the needed supply of fossil fuels in the Low scenario, with such a development inevitably resulting in another shock in commodity markets (i.e. highly volatile prices for end consumers) in the next few years.

Figure 23: Avoided fossil fuel imports due to wind energy generation
Billion cubic meters per year

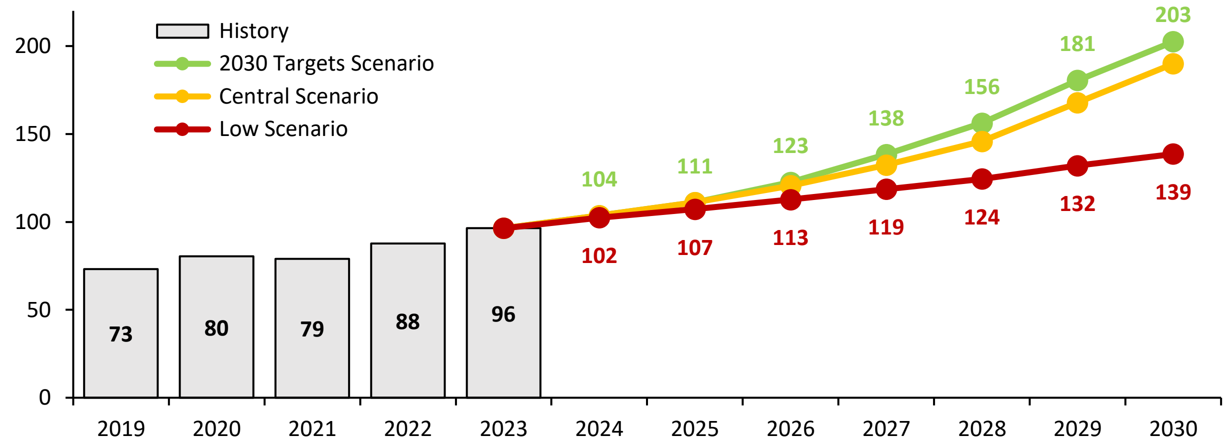
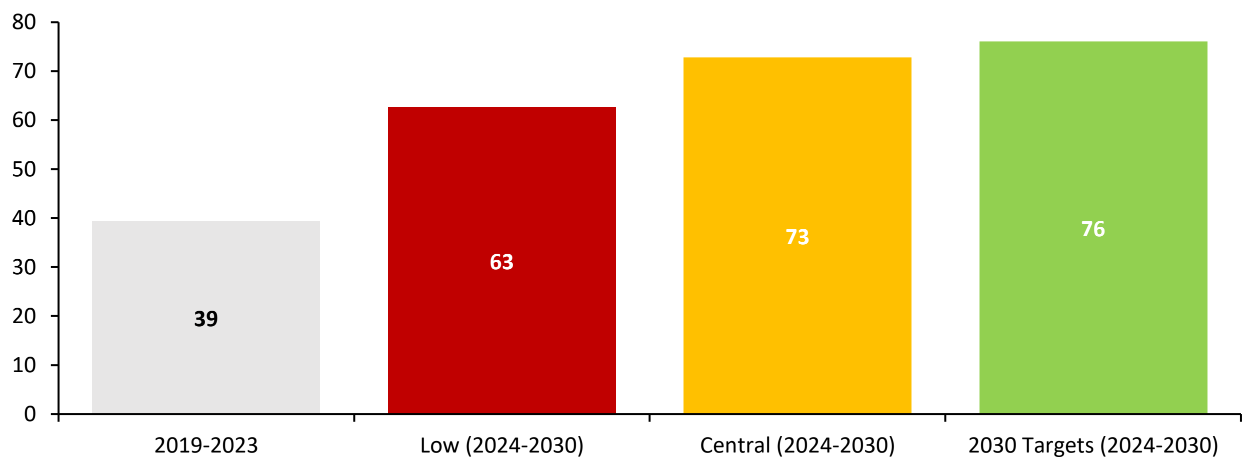


Figure 24: Expected economic savings due to avoided fossil fuel imports
Billion EUR per year



Source: Rystad Energy research and analysis

European natural gas balance to remain stretched through 2030

Any disruptions or shock cycles that result in increased demand for natural gas in continental Europe in the future are likely to cause new periods of significant spikes in commodity prices for end consumers (i.e. similar to the disruption experienced in 2022).

Combined domestic natural gas production in the EU and the UK is on a gradual yet persistent decline and is expected to slow down from ~77 Bcm in 2023 to ~55 Bcm in 2030. The current investment climate and policy direction are unlikely to result in any meaningful upside for domestic production.

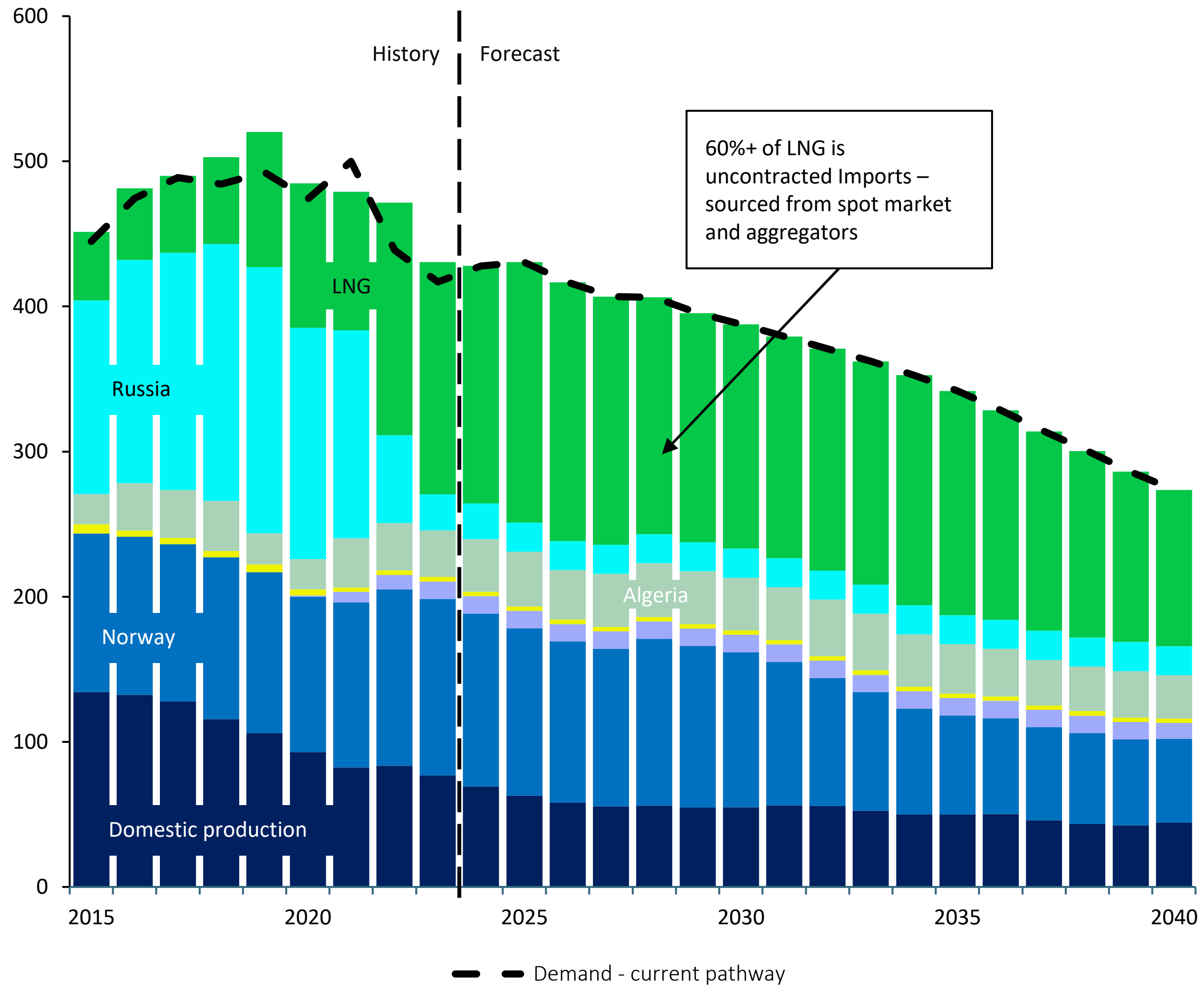
Norway is expected to remain a critical supplier of natural gas for continental Europe until the end of the decade delivering 110-120 Bcm per year. Similar to the outlook for continental Europe, a significant upside to these supply contributions is unlikely due to limited pipeline capacity and the outlook for natural gas production in Norway.

Algeria, Libya and Azerbaijan are set to keep delivering a flat 50 Bcm into the European market (combined).

Hence, based on the current pathway for natural gas demand, Europe is expected to remain dependent on liquefied natural gas (LNG) imports, which increased from 95 Bcm in 2021 to 160 Bcm per year in 2022-2023. The current pathway involves a further increase to ~180 Bcm in 2025-2026 with a gradual decline towards ~150-160 Bcm by 2030.

In the scenario where wind energy fails to deliver on the target case, increased fossil fuel imports will most likely lead specifically to the increase in LNG imports.

Figure 25: EU27+UK gas supply mix by source and demand
Billion cubic meters



Source: Rystad Energy research and analysis

Future growth potential of the biggest LNG swing producer is at risk

When it comes to LNG imports, the US has emerged as the most important strategic partner of Europe and a “swing” producer of LNG since 2022. The US exports of LNG to Europe increased from 19 million tpa in 2021 to 49 million tpa in 2022 and edged higher in 2023 at 53 million tpa. The flows were partially redirected from Asian markets amid short-term market disruptions, though this transformation could also be viewed as structural optimization of global LNG flows with more US LNG flowing to the epicenter of demand with the lowest transportation costs from the US.

Significant regasification capacity has been added in Europe since 2022, potentially allowing for an even higher level of US LNG imports should such a need emerge in the future. Having said that, in the next European natural gas shock cycle, it is the supply side of the equation that might become a bottleneck (rather than import capacity). The recent announcement by the Biden administration to impose a temporary halt on approving new US LNG projects has stunned both domestic and global markets, especially as shipments of the fuel have begun playing an oversized role in feeding demand in Europe and elsewhere.

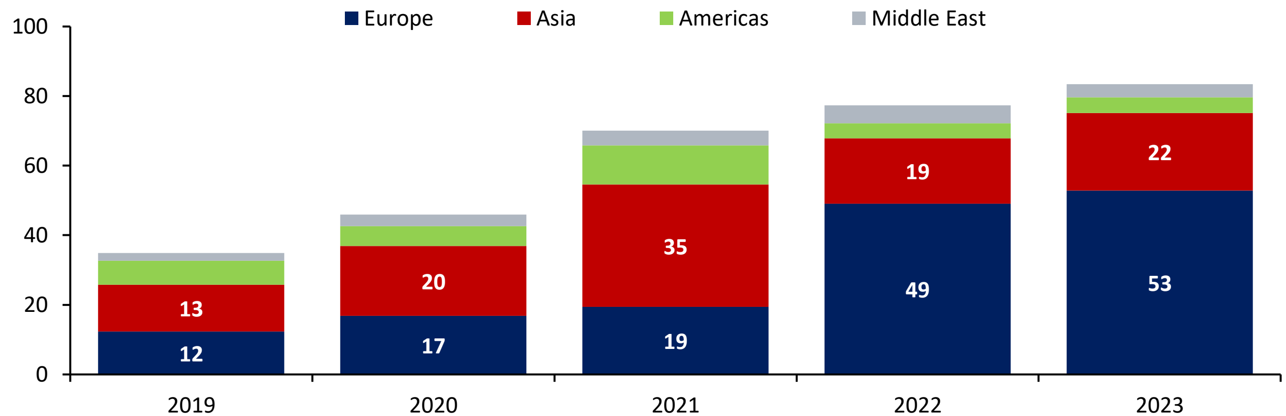
In the short term, the pause disrupts project timelines and investor confidence, potentially delaying FIDs for facilities such as US developer Venture Global LNG’s CP2 project in Cameron Parish, Louisiana. Yet, the long-term consequences loom larger, with ripple effects expected to resonate through global LNG supplies well beyond 2028. The Biden administration's decision has induced nervousness among future LNG customers.

US LNG has been vital to European energy security, as the continent rushed to phase down Russian pipeline supplies. With that said, accelerated wind energy deployment is critical for European energy security and autonomy as it reduces its dependence on US LNG imports and lowers natural gas demand in general.

Figure 26: US Planned LNG projects subjected to non-free trade agreement license approval

Status	Project	Operator	Capacity (million tpa)	Original Approval Expiry	Extension Expiry	FID Approval Year (Estimate)
Pre-FID	Cameron Train 4	Sempra Energy	6	15 Jul 2016	5 May 2026	2025
	Commonwealth LNG	Commonwealth LNG	8.4	Under Review		2026
	CP2	Venture Global	19.8	Under Review		2024 (T1-9) 2027 (T10-18)
	Corpus Christi Midscale T8-9	Cheniere Energy	3.0	Under Review		2024
	Delfin FLNG	Delfin LNG	6.5	1 Jun 2024		2024 (T1) 2026 (T2)
	Fast LNG	New Fortress Energy	1.4	Under Review		2027
	Freeport Train 4	Freeport LNG	5.1	28 May 2019	28 May 2026	2025
	Lake Charles LNG	Energy Transfer	10	16 Dec 2025	16 Dec 2025	2027
	Sabine Pass Expansion	Cheniere Energy	19.5	N/A		2026 (T1), 2028 (T2), 2030 (T3)
	Port Arthur Phase II	Sempra Energy	13.5	Under Review		2025

Figure 27: Global LNG import volume from the US
Million tonnes per annum (Mtpa)



Source: Rystad Energy research and analysis

Cost of fossil-fueled power generation remains the main driver for power prices

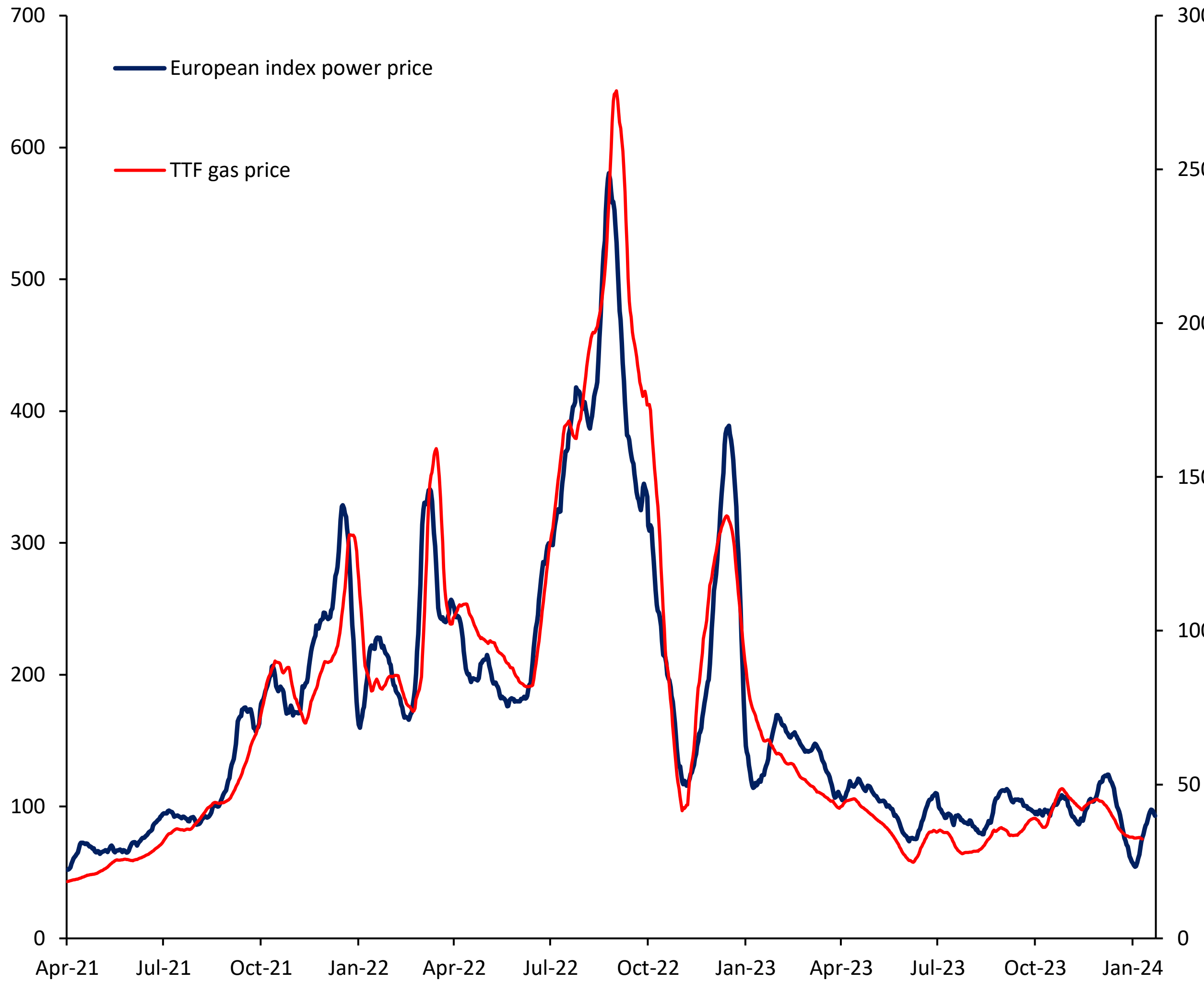
Natural gas power generation has played a key role in the European power mix and is expected to remain a major source of energy supply in the medium term. The growth in wind and solar generation across Europe will gradually start displacing fossil-fueled power generation, but as long as gas, and to some extent coal, remain in the mix it will continue to have a strong impact on the power market in general, and prices in particular.

Renewable power in Europe has grown strongly over the past decade currently representing more than 45% of the total supply when including sources like hydro, geothermal and biofuels. Renewable energy sources normally have a lower operational cost than conventional sources of supply meaning that they are on the lower end of the merit order.

Despite the growing share of lower-cost renewable sources, gas and coal power generation continue to supply close to 30% of Europe's electricity. In 2023, gas power supplied around 18% of Europe's electricity and coal 12%. Fossil-fueled power generation has much higher operational costs than other sources of electricity due to the high cost of fuels and carbon in Europe, making gas and coal generation the marginal sources of supply throughout the year. As a result, the operational expenditure of gas and coal power generation continues to be the main price setter for power prices across the continent. This is clearly visible when plotting average European power prices with Title Transfer Facility (TTF) prices, which is the main benchmark for natural gas prices in the region.

During the energy crisis of 2022, the shortage of natural gas supplies in Europe made prices increase to a record level of more than €270 per MWh. Despite this, gas power generation continued to be needed to meet energy demand and, therefore, power plant operators (and consumers) had to pay the high price to ensure enough supply. As Europe has diversified its natural gas and LNG supply, prices for both gas and power have gradually declined to more normal levels.

Figure 28: European index power spot price (left)* and Title Transfer Facility (TTF) gas spot price (right)
EUR per megawatt-hour (MWh)



*European power index is a simple average of daily spot prices in Germany, France, the UK and Italy. Data displayed as 15-day floating average for both series
Sources: Rystad Energy PowerCube

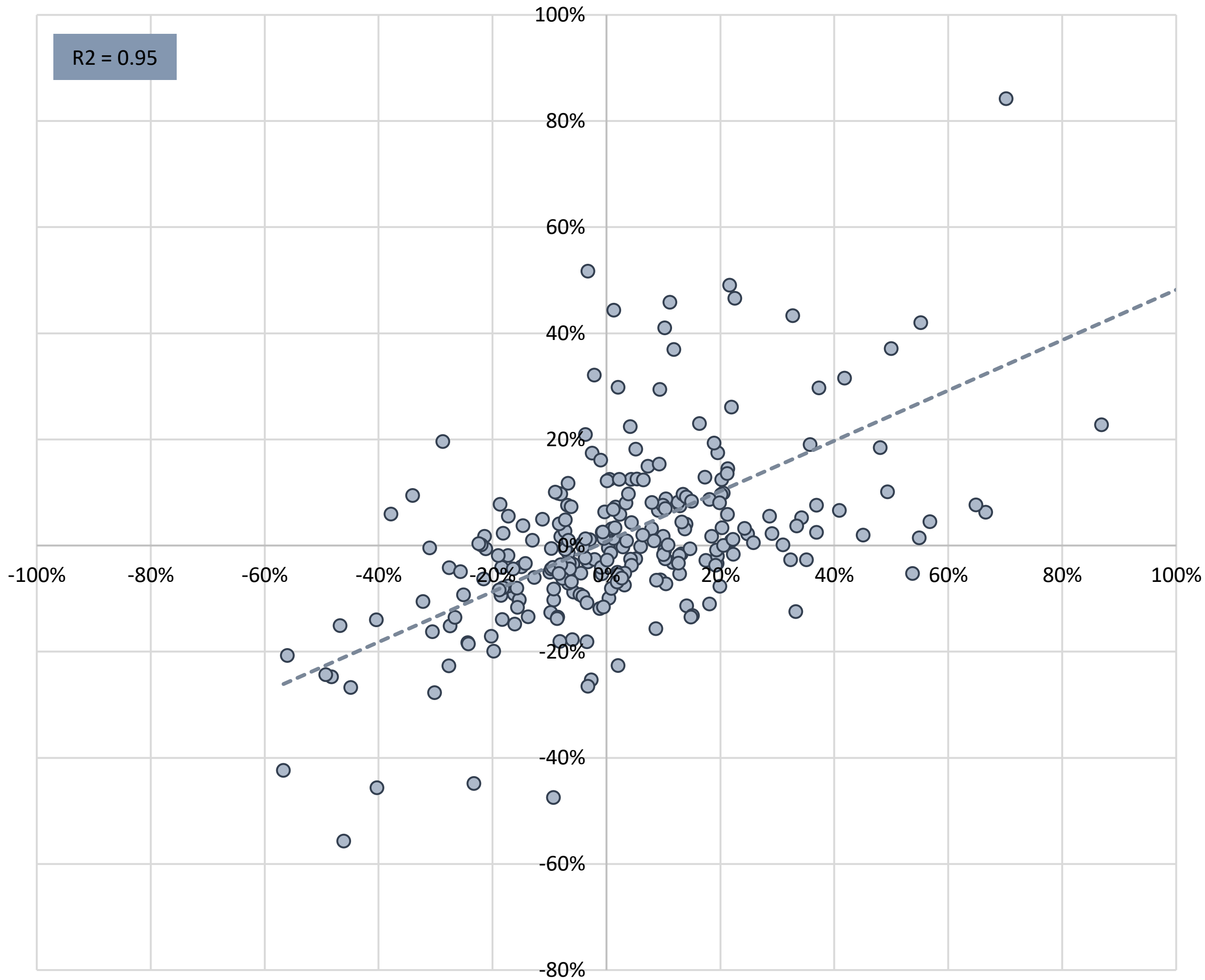
Volatility in gas prices has a strong effect on power prices

European power and gas prices have been extremely volatile over the past three years driven by fuel supply shortages and geopolitical tensions. Natural gas and power prices in Europe traded at normal levels of €20 per MWh and €60 per MWh, respectively, at the start of 2021. A steady increase in prices was initiated when Russia diminished gas pipeline exports to Europe from the end of 2021. The situation became even more extreme after Russia's full-scale invasion of Ukraine in 2022 causing major disruptions in both gas and coal exports from Russia to the continent. European utilities had to replace pipeline gas with LNG, creating strong competition with Asian markets for the fuel. This led gas prices to reach a historical high of more than €270 per MWh in the second half of 2022. Electricity prices followed the same trend, averaging almost €600 per MWh at the end of August.

In 2023, the situation improved significantly as Europe quickly diversified its gas supplies and accumulated enough in storage for the winter season. This helped gas prices normalize through the year and helped power prices across the region decline towards a more normal level of €100 per MWh. In 2024, the situation continues to look stable.

Figure 32, to the right, displays the strong correlation that exists between changes in gas prices and power prices in Europe. However, power prices tend to be more volatile than gas prices due to the strong intermittency of renewable energy sources, specifically wind power. With strong wind generation changes throughout the day, it will generally be gas power plants providing flexibility to ensure a well-balanced system. In the medium term, gas power is likely to remain the main source of flexibility across Europe, playing a key role in providing energy security. The region already has a large gas power generation fleet and gas importing storage and distribution network. However, with the increasing availability of alternative sources, such as batteries and pumped hydro, the use of gas will decline in the longer term, and the volatility in power prices should also be reduced.

Figure 29: Weekly changes in power (X-axis) and gas prices (Y-axis) in 2023
Percentage (%)



Sources: Rystad Energy PowerCube

European power prices could stabilize as the gas market balances

The winter of 2023-2024 served as a stress test for the European energy sector, with significant uncertainty remaining around the continent's ability to meet its energy demand. TTF natural gas prices have been hovering well below €50 per MWh since the start of 2024, thanks to ample global LNG supplies and healthy underground gas storage levels. With Europe now better equipped with increased LNG import terminal capacity and long-term supply contracts, the outlook for natural gas prices is to trend towards a level below €30 per MWh by 2030. This is the general level required to cover the costs of importing LNG from the US which is likely to remain the main source of LNG supply beyond 2030.

Despite a general expectation of a well-balanced market, Europe will continue to be exposed to natural gas price volatility. The increased dependence on LNG imports means that Europe will need to compete globally, mostly with Asian buyers, to ensure enough gas supplies. This competition is likely to lead to periods of higher prices, especially during winter and in the event of market shocks, such as extreme weather or supply disruptions.

Natural gas power generation will continue playing an important role in the European energy mix, providing base load supply and backing up the intermittency of wind power. Consequently, the cost of gas power generation will remain one of the main power price drivers. Assuming a gas price below €30 per MWh, average European power prices could trend towards a range of €40- €80 per MWh in 2030. As the share of renewable energy continues to grow in Europe, the effect that gas prices have on the power market will gradually be diluted. During peak renewable generation hours, gas generation could decline significantly reducing the number of hours where gas generation will set the price. However, during peak demand hours, gas power plants will play an important role and will continue to be the main price setters.

Figure 30: Historical monthly and forecasted yearly TTF natural gas prices
Euros per megawatt-hour (MWh)

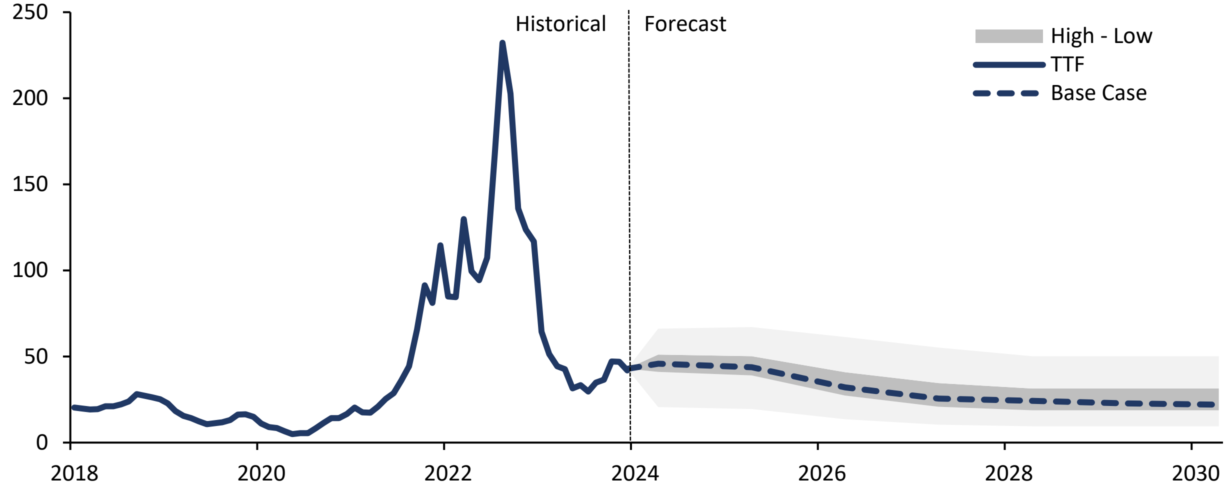
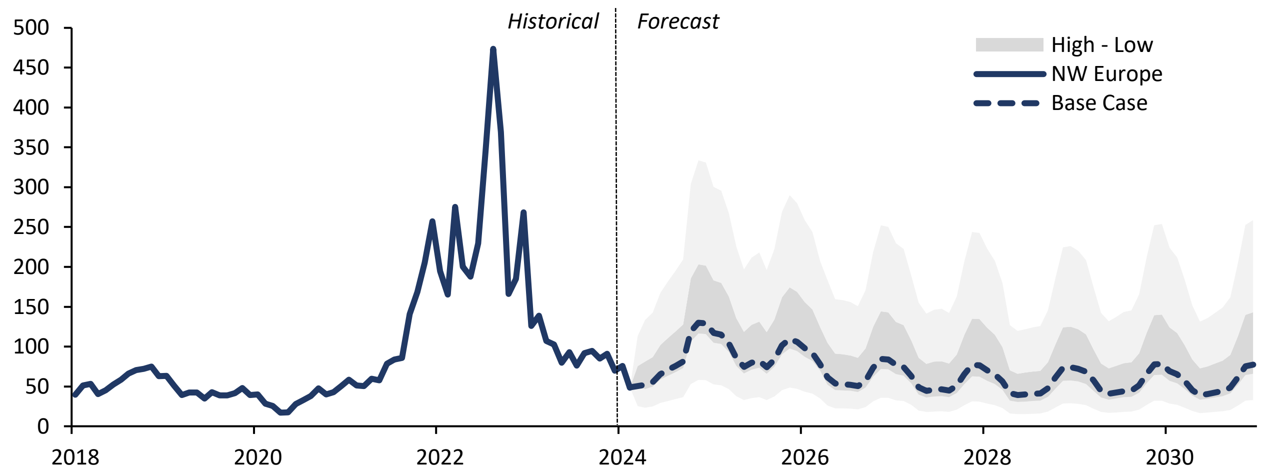


Figure 31: Historical and forecasted monthly NW Europe power prices
Euros per megawatt-hour (MWh)



Sources: Rystad Energy PowerCube

The European wind job market could reach 564,000 FTEs by 2030

Under the WindEurope 2030 Targets scenario, wind energy will be responsible for around 336,000 jobs in Europe by the end of 2024, which could increase to about 564,000 full-time employees by the end of the decade. As the 2030 Targets scenario assumes a quick ramp-up of onshore wind, most of the job creation will be linked to this sector. Additionally, the 2030 Targets scenario still sees a three-fold increase of offshore wind capacity between 2024 and 2030, ramping up more rapidly from 2026 onwards. Consequently, offshore wind will start to contribute more towards the total jobs in Europe as more and more offshore capacity comes online.

The WindEurope Central scenario assumes 532,000 full-time employees by the end of the decade. As offshore capacity is expected to ramp up more quickly in the Central scenario, the average jobs required per GW across onshore and offshore wind start to converge towards the 2030 Targets Scenario from 2026. The Central scenario represents an overall risk of 30,000 jobs compared to the 2030 Targets scenario, but when comparing onshore and offshore wind, the Central scenario results in an additional 20,000 offshore FTEs, whereas onshore results in a reduction of 50,000 onshore FTEs.

Figure 32: Full time equivalent (FTE) by scenario, Europe
Thousand FTEs

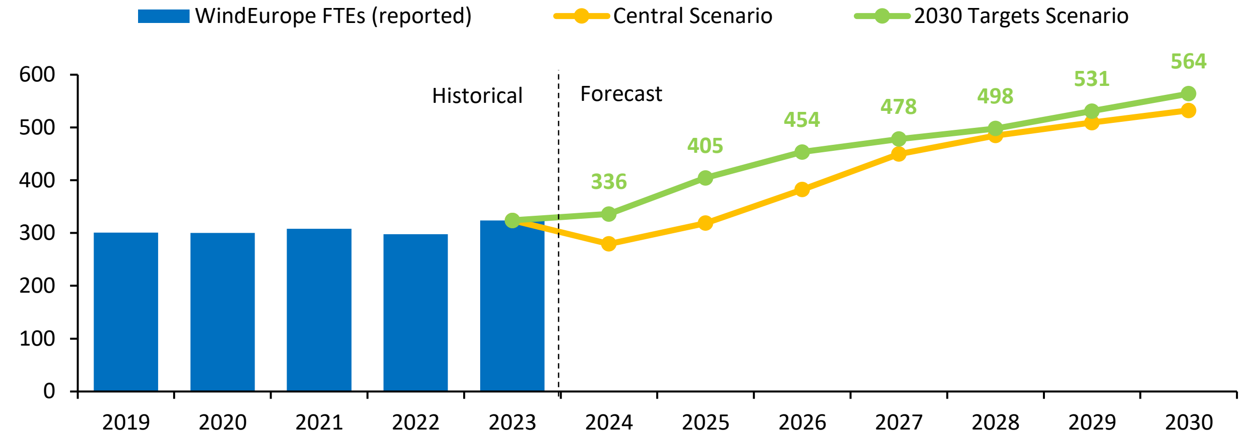
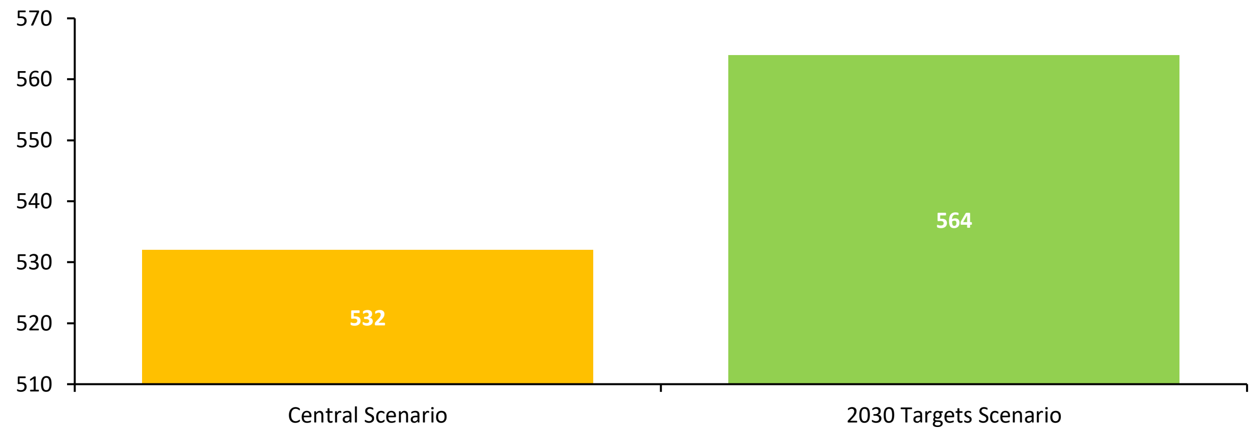


Figure 33: Full time equivalent (FTE) in Europe in 2030 by scenario
Thousand FTEs



Source: Rystad Energy research and analysis, WindEurope - 2030 Wind Energy Jobs Projections (2023); February 2024

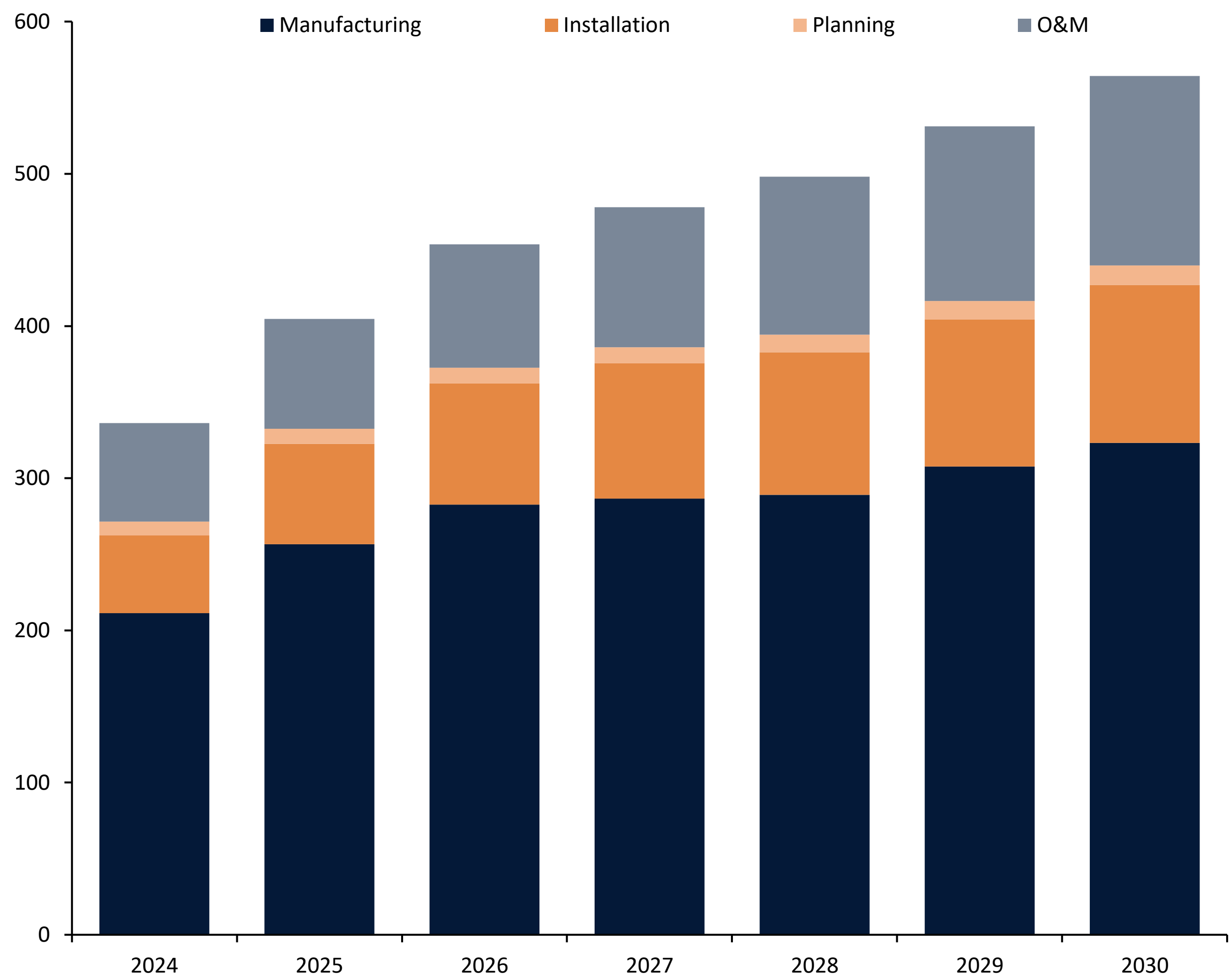
Steep increase in wind job demand is driven by manufacturing

Under the 2030 Targets scenario and the Central scenario, manufacturing and installation emerge as the two key job sectors for onshore and offshore wind. Both the 2030 Targets Scenario and the Central Scenario see annual capacity additions step up significantly by 2026. Thus, manufacturing will see job demand step up quickly from 2024 onwards to meet the needed additions from mid-decade and beyond.

To meet the targets for capacity additions, the manufacturing capacity must be commercially available before the capacity additions are installed, representing a risk for job creation under both the Central and 2030 Targets scenarios. The average installed turbine sizes for onshore and offshore wind are set to increase significantly towards 2030, representing a risk to manufacturing capabilities and job creation. Larger turbines come with larger tower heights and rotor blades, creating problems for the manufacturing facilities that were set up previously to manufacture much smaller turbines. Thus, existing manufacturing capacity might struggle to meet the demands of larger turbine sizes as they have not been built to support such size increases. As turbine manufacturing represents more than 70% of the demand for wind manufacturing jobs in 2025 already, decommissioning of turbine manufacturing facilities can become a risk to job creation. Although some newer facilities might be able to scale up their manufacturing by increasing facility size, a significant portion of manufacturing capabilities will have to be replaced to meet the demand for larger sizes.

Although both the 2030 Targets scenario and the Central scenario represent demand for upwards of 290,000 FTEs in manufacturing by the middle of the decade, this demand hinges on European manufacturing being able to step up sharply before capacity additions start to ramp up by 2026.

Figure 34: Full time equivalent (FTE) by job type under 2030 Targets scenario, Europe
Thousand FTEs



Source: Rystad Energy research and analysis, WindEurope - 2030 Wind Energy Jobs Projections (2023); February 2024

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Increased sizes and efficiency will drive increased output per worker

Under the WindEurope scenarios, the most important driver of job creation is manufacturing. From early on, the European wind sector has been strong, hosting the manufacturing facilities of leading suppliers such as Vestas, GE and Siemens Gamesa. The WindEurope 2030 Targets scenario will see onshore wind as the main driver of manufacturing jobs through 2030, as annual capacity additions are set to reach 35 GW, whereas offshore wind is expected to contribute with approximately 16 GW. In total, this represents a 185% increase in annual wind capacity additions from 2024 to 2030, resulting in significant increases in manufacturing jobs.

However, as turbine capacity increases both for onshore and offshore wind, the total expected full-time employees required per GW of capacity additions is set to decrease by 6,000 jobs per GW under the 2030 Targets scenario. This is primarily driven by expectations of increased efficiencies associated with lower maintenance requirements, less cabling and corresponding foundations, leading to an expected reduction of 26% in FTEs per doubling of turbine capacity for onshore turbine manufacturing, and an expected 36% reduction for offshore turbine manufacturing. Despite these reductions, turbine manufacturing jobs are still expected to see a 50% increase from 2024 to 2030 under the 2030 Targets Scenario, primarily driven by a steep increase in capacity additions across onshore and offshore wind.

Offshore foundation manufacturing also remains a large driver of jobs in Europe towards 2030. Although monopile foundations remain the leading foundation type, the share of floating foundations is expected to increase towards the end of the decade. Larger turbine capacities also require larger foundations, resulting in longer manufacturing times. This could see jobs resulting from foundation manufacturing increase by 60% from 2024 to 2030 under the WindEurope 2030 Targets Scenario.

Figure 35: Forecasted full time equivalent (FTE) manufacturing jobs in Europe, 2030 Targets Scenario
Thousand FTEs

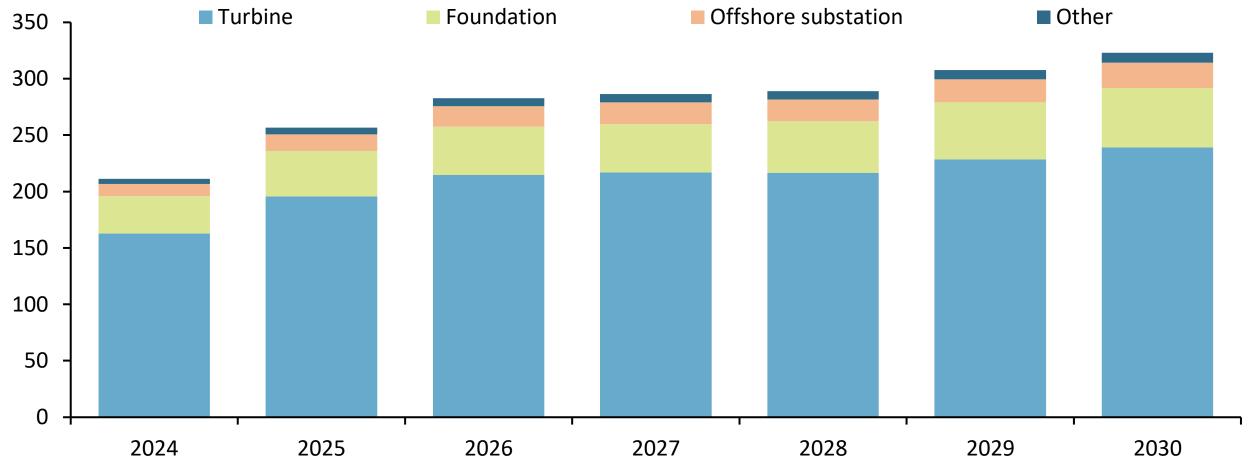
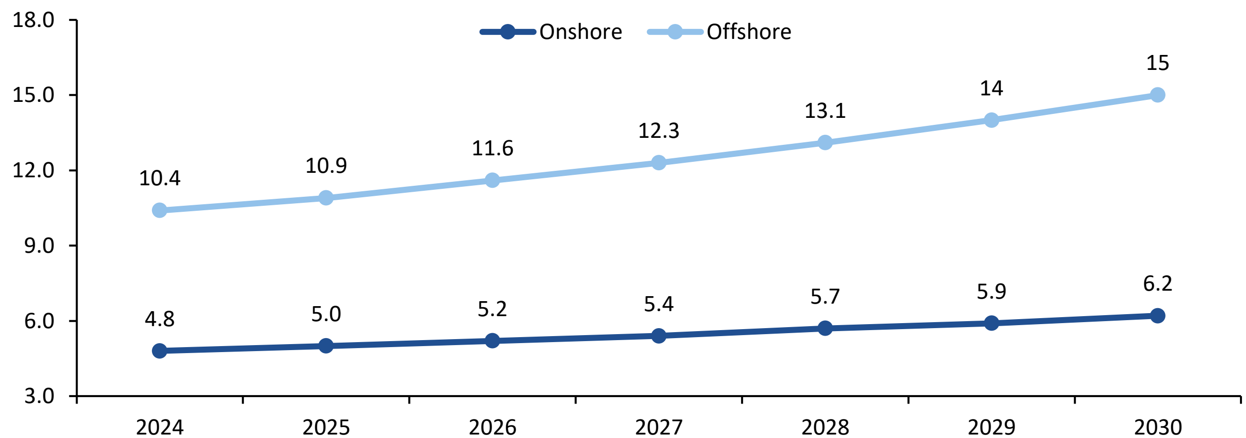


Figure 36: Average turbine sizes by energy source
Megawatts (MW)



Source: Rystad Energy research and analysis, WindEurope - 2030 Wind Energy Jobs Projections (2023); February 2024

Lack of European turbine manufacturing capacity puts job creation at risk

One of the potential bottlenecks to the 2030 Targets and Central scenarios is European turbine manufacturing capacity. The Net Zero Industry Act (NZIA) aims to strengthen European manufacturing and ensure that wind energy is "made in Europe", by establishing pre-qualification and non-price award criteria when selecting winning bids in auction rounds. Although this will incentivize a ramp-up of European wind manufacturing, there is still a long way to go for supply to meet the demand from the WindEurope 2030 Targets scenario and the Central scenario.

As of February 2024, the announced annual manufacturing capacity in Europe for wind is estimated at 26.2 GW for blades and 29.8 GW for nacelles. For offshore wind, nacelle manufacturing capacity needs to ramp up by 13 GW to meet the capacity required for the 2030 target, while blade manufacturing capacity must ramp up by 8 GW. For onshore wind, blade capacity must increase by 23 GW and nacelle capacity by 16 GW. In the case that European auctions require all developers to meet the supply chain resilience criteria around European technology, almost 72% of the job creation resulting from onshore turbine manufacturing and 60% of offshore turbine manufacturing is at risk due to the discrepancy between available turbine capacity and capacity required under the 2030 Targets scenario. Should developers need to meet the same prerequisites under the Central scenario, 63% of job creation resulting from both onshore and offshore turbine manufacturing remain at risk due to the discrepancy between available turbine capacity and capacity required under the Central Scenario*.

Both these projections assume that there are no supply and demand bottlenecks in certain turbine size groups. However, nearly all demand for capacity additions (particularly for offshore wind) represents larger turbine segments, meaning that the risked job creation could widen even further due to a lack of available manufacturing capacity for larger sizes. This highlights the importance of quickly stepping up the European manufacturing capabilities for wind turbines.

Figure 37: Blade manufacturing capacity, Europe
Gigawatts (GW)

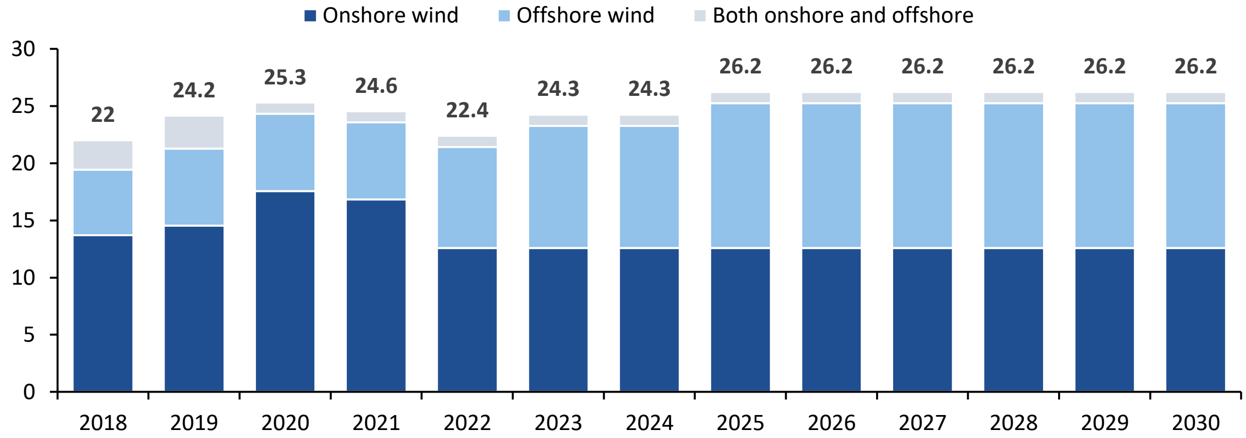
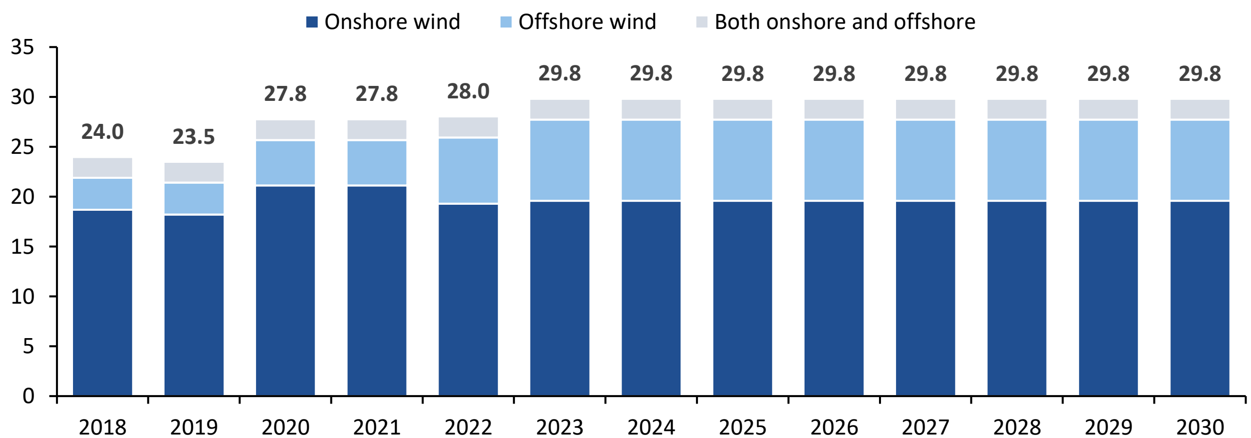


Figure 38: Nacelle manufacturing capacity, Europe
Gigawatts (GW)



*Assumes discrepancy between blade manufacturing and annual capacity additions under WindEurope scenarios
Source: Rystad Energy research and analysis, WindEurope - 2030 Wind Energy Jobs Projections (2023); February 2024

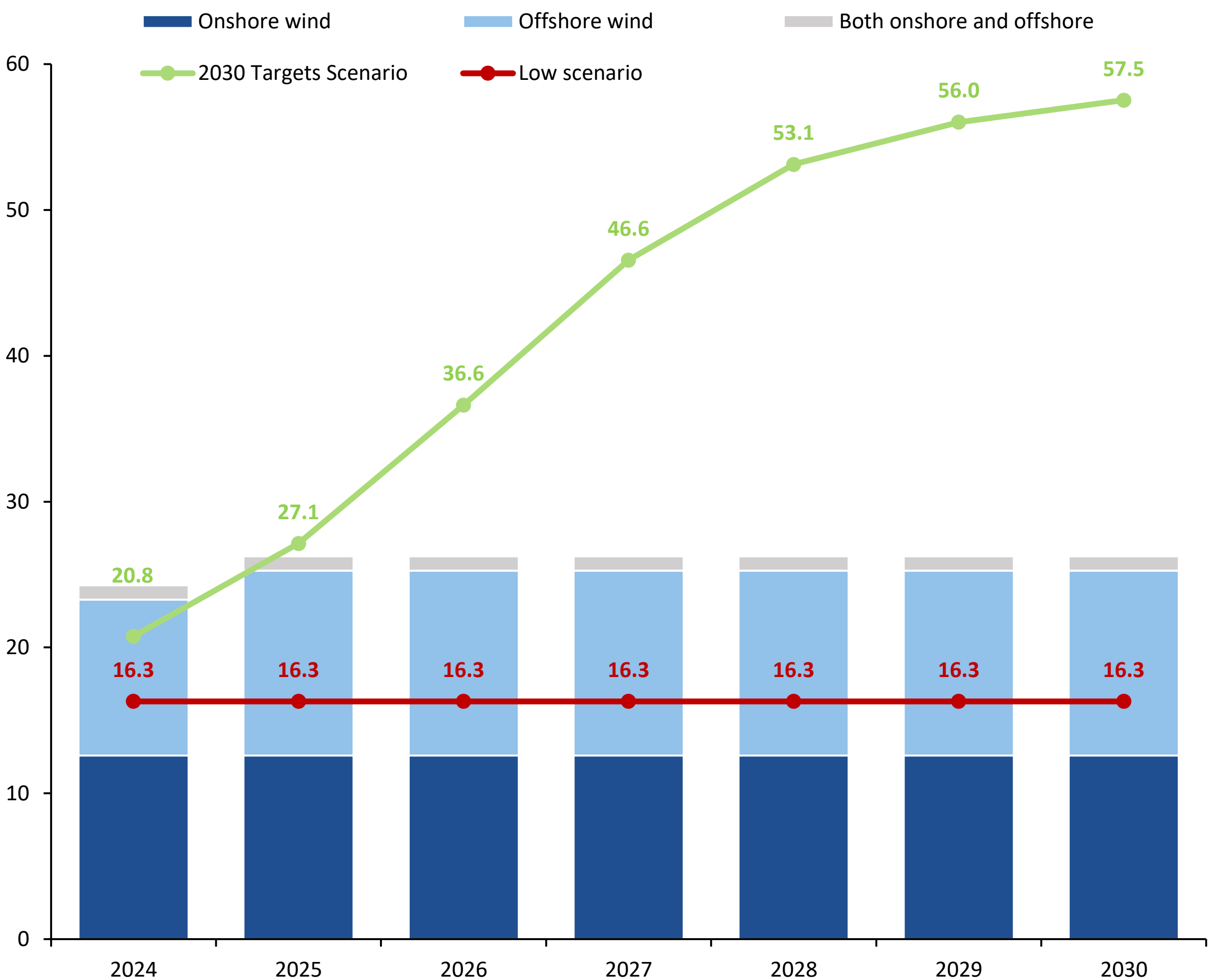
European manufacturing capacity must increase to meet targets

Based on the announced manufacturing capacity for both onshore and offshore wind turbines, blades remain the most significant bottleneck in European wind turbine manufacturing. Currently, up to 90% of commissioned wind projects have installed European-manufactured wind turbines. However, under the 2030 Targets scenario, the announced manufacturing capacity will not be able to meet the demand. The blade manufacturing capacity available for 2025 already lags behind the targeted annual capacity additions. This means that job creation resulting from the 2030 Targets scenario could be at risk from next year if additional manufacturing capacity is not added in time.

By 2030, Europe will lack as much as 30 GW of annual manufacturing capacity compared to the requirements of the 2030 Targets scenario, risking as much as 72% of onshore and 60% of offshore job creation, assuming the share of European versus global wind turbine manufacturing workers stays constant through the decade. To avoid losses in job creation and to step up European manufacturing capacity to meet demand under the 2030 Targets scenario, the announced European turbine manufacturing capacity has to increase by an average of 20% year-on-year between 2024 and 2030, as well as keep up with the demand for increased turbine sizes.

However, the already announced global wind turbine manufacturing capacity will amount to 178 GW by 2030. Thus, sourcing turbines from non-European manufacturers might be one way to meet the demands of the 2030 Targets Scenario, assuming there are no supply and demand issues in acquiring larger turbines. However, depending on the share of demand being met by non-European supply, the outlook for European wind-related jobs would then shift from the 2030 Targets Scenario trajectory towards the Low Scenario, as job creation would move outside of Europe.

Figure 39: Turbine manufacturing capacity, annual capacity additions, Europe
Gigawatts (GW)



Source: Rystad Energy research and analysis, WindEurope - 2030 Wind Energy Jobs Projections (2023); February 2024

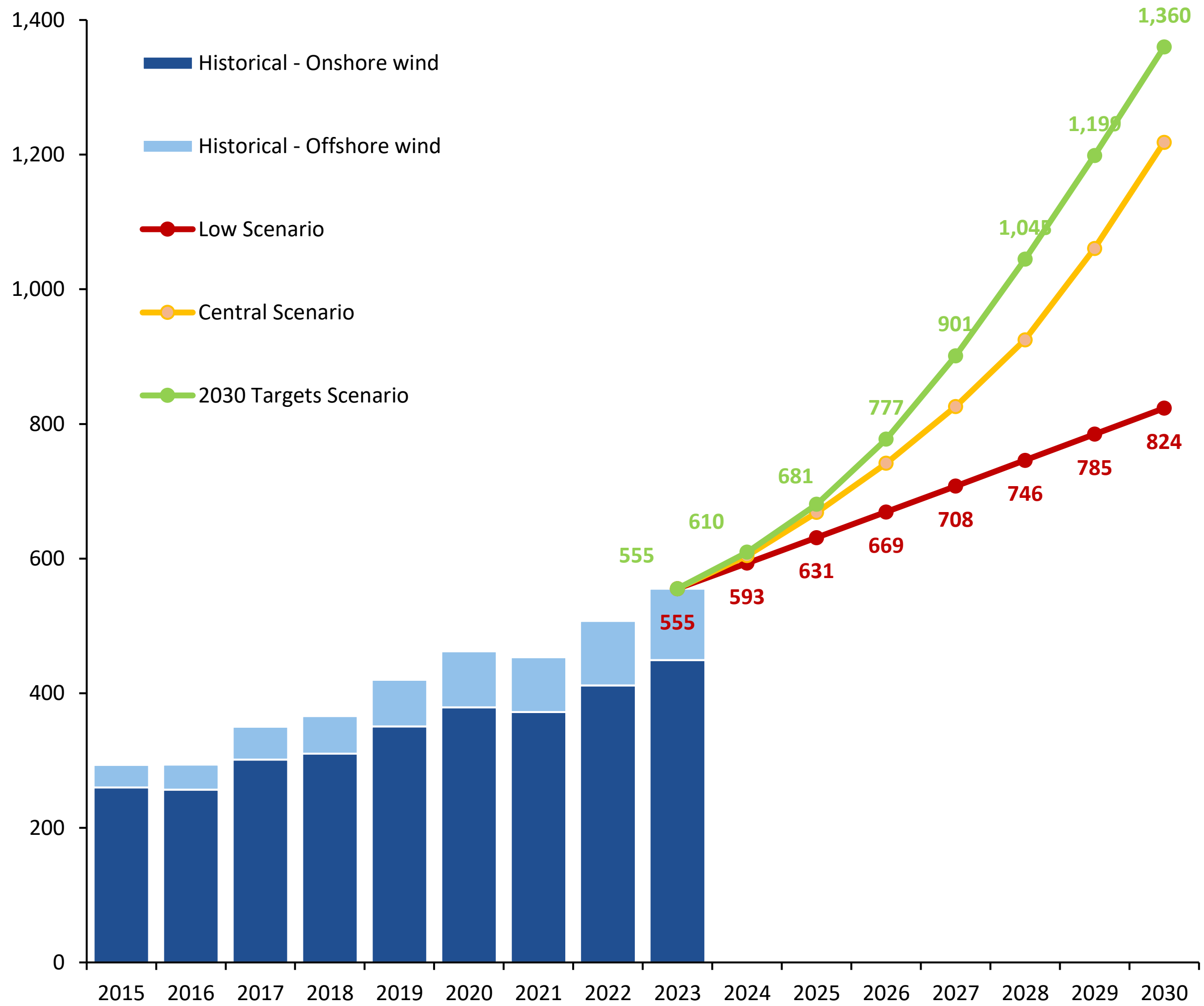
Wind power generation set to more than double by 2030, if targets are reached

The EU target defined in the Renewable Energy Directive aims for a contribution from renewable energy of at least 42.5% of overall energy consumption. This would be achieved by significant capacity additions outlined in the 2030 Targets Scenario, but also by gains of efficiency in the output of newly commissioned turbines. In Europe, the average capacity factors for onshore wind generation reached an average of 22% in 2023, compared to an average of 38% for offshore wind. Due to larger and more efficient turbines, those European figures are expected to reach about 25% by 2030 for onshore wind and 40% for offshore wind. Over the decade, these capacity factors are expected to gradually increase, not only due to the learning curve of turbine performance but also because the marginal effect of low generation in the first year of a newly commissioned plant will become less and less significant.

In the 2030 Targets scenario, this leads to a forecast overall wind generation of 1,360 TWh in 2030, about 2.5 times the generation of 2023. While onshore wind is expected to remain the largest share of the generation, offshore wind will see a stronger increase, especially from the second part of the decade when the offshore wind output is expected to more than triple.

In the Low scenario, the yearly capacity additions will remain at the conservative level of what was recorded in 2023. This not only means a lower amount of capacity but also a less productive turbine fleet, on average. Capacity factors are also expected to remain conservative, with limited growth from 2023 levels. Therefore, by 2030, the overall wind generation in the Low Scenario is not expected to exceed 1,000 TWh, with a forecast 825 TWh. In such a scenario, Europe would face a dilemma between limiting its power demand growth in favor of limiting emissions or feeding growing power demand with more fossil-fuel generation.

Figure 40: Europe, onshore and offshore wind net generation by year and by scenario
Terawatt-hours (TWh)



Source: Rystad Energy research and analysis

Onshore wind developers to reach over €30 billion direct GDP contribution by 2030

At the end of 2023, revenue from onshore wind power generation reached an estimated €29 billion. The revenue was mainly based on offtake agreements contracted with government entities through auction processes, balanced with a relatively low share of merchant exposure. The trend for bidding prices started with high feed-in-tariffs in the early 2010s to incentivize and boost the first years of the onshore wind industry. This was followed by a drop in contracted prices from 2015 as governments assessed those agreements as too lucrative for developers compared with decreased costs. As discussed in the first section of this report, the recent inflation in component and financial costs has led to an uptick in the auction prices in 2023.

These offtake contracts are generally designed to last between 10 and 20 years and are indexed to inflation depending on the country. This means that over time, as wind power generation increases, revenue per output becomes increasingly stable because of the weighting of the historical selling price. Thus, this metric reflects less and less the granular cost trends that can be reflected in auction prices. From another perspective, this means that as early as 2023, a significant proportion of onshore wind developers' revenues in 2030 is already defined based on the year-to-date negotiated prices. In contrast, the increasing penetration of onshore wind generators on the spot market results in revenue volatility to some extent. Typically, the uptick in revenue per generation observed in 2022 is significantly due to the record high power prices that year.

In terms of GDP contribution, the revenue must be lowered by the opex related to the plant operation, which remain marginal. In 2022, onshore wind reached its historical peak in terms of GDP contribution, reaching about €25 billion due to the high power prices. Looking ahead, power prices remain uncertain but are not expected to reach such high levels. Based on the 2030 Targets scenario, GDP contribution is expected to reach the same level as in 2022 only from 2027 and to reach €34 billion by the end of the decade.

Figure 41: Europe 2030 Targets scenario, onshore wind generation gross revenue and revenue per generation
Billion EUR, real (2023) EUR per megawatt-hour (MWh)

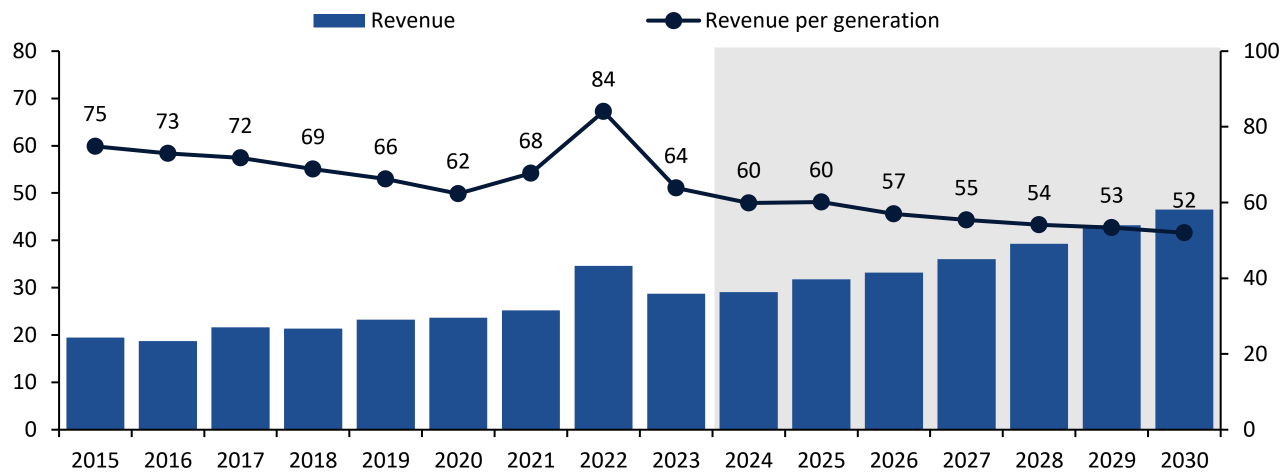
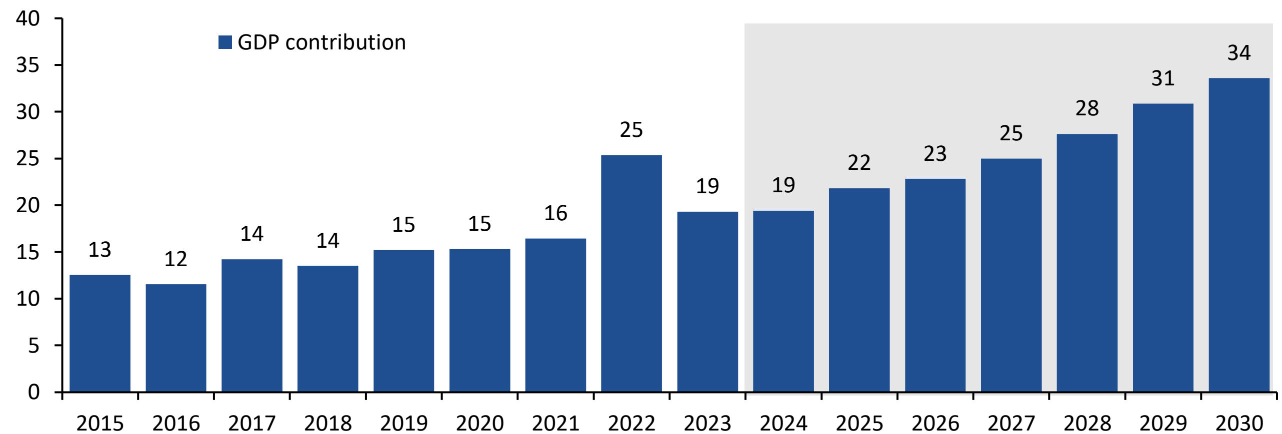


Figure 42: Europe 2030 Targets scenario, onshore wind GDP direct contribution
Billion EUR, real (2023)



Source: Rystad Energy research and analysis

The end of the decade will be pivotal for the offshore wind developers' contribution

Revenue from offshore wind generation has experienced steady growth, reaching a record in 2023 at €12.5 billion. Revenue sources from existing plants are largely tied to historical auctions, with limited spot market exposure. Going forward, this exposure is expected to remain limited, combined with a higher share of corporate PPAs. Historical offshore wind offtake agreements were significantly higher than those for onshore wind, aligned with the capex differences. Initially, bidding prices were closing at over €100 per MWh. Following a steep learning curve and strong expectations of higher capacity factors from new turbines, weighted average bidding prices started to decrease below €70 per MWh from 2016. Bidding prices have been challenged, however, in the face of the component cost inflation observed in the last two years.

The evolution of offshore wind revenue is less impacted than onshore wind by the weight of past agreements due to relatively lower commissioning in the last 10 years, compared to what is expected in the coming years. However, there is a significant lag between the auction year and the commissioning date, explaining the delayed decrease in the revenue per generation. In the 2030 Target Scenario, revenue is expected to strongly increase due to the significant offshore wind capacity additions required to reach Europe's ambitions. However, in terms of revenue per generation, there is a decreasing trend leading to less than €100 per MWh from 2025. This is due to the auctions led in the late 2010s, where bidding prices reached levels averaging €60 per MWh. In terms of GDP contribution, opex is significantly higher for offshore wind plant operation than for onshore wind, despite an ongoing decreasing trend. While the offshore wind power generation led to about €4 billion of GDP contribution in 2023, it is expected to more than double by 2030. The stronger increase is expected in the last two years of the decade, driven by over 20 GW of newly installed capacity each year in the 2030 Targets Scenario and an uptick in the associated offtake prices.

Figure 43: Europe 2030 Targets scenario, offshore wind generation gross revenue and revenue per generation
Billion EUR, real (2023) — EUR per megawatt-hour (MWh)

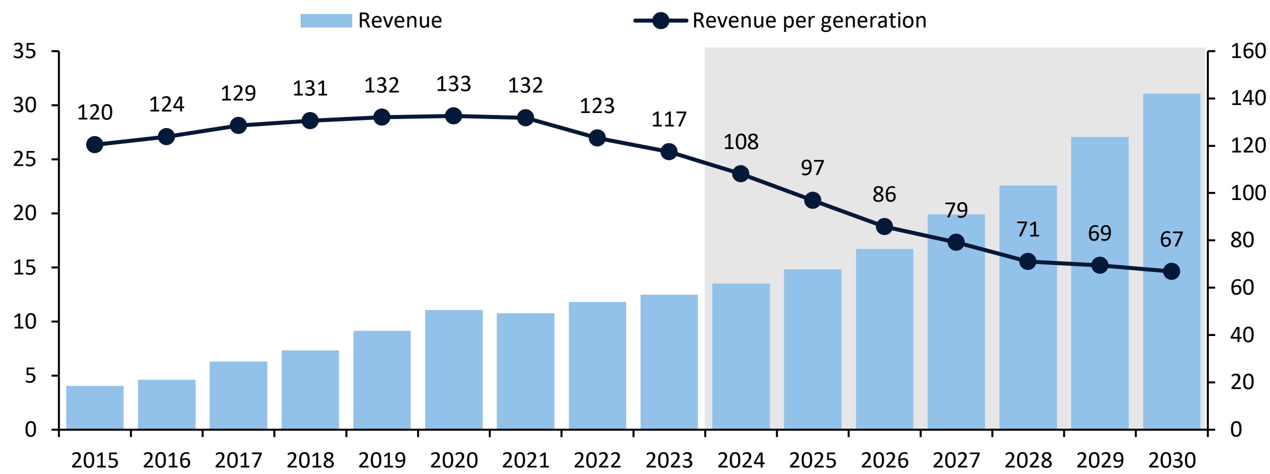
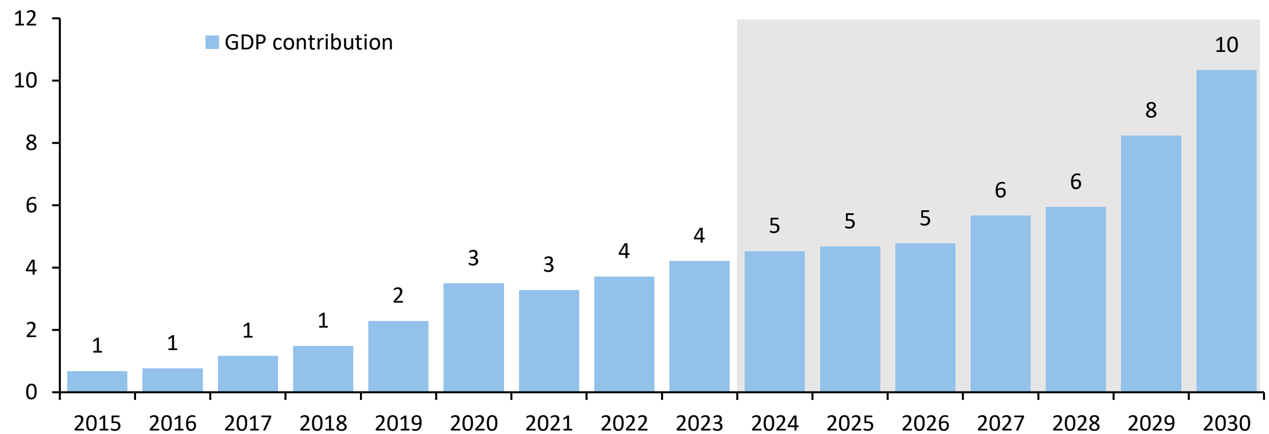


Figure 44: Europe 2030 Targets scenario, offshore wind GDP direct contribution
Billion EUR, real (2023)



Source: Rystad Energy research and analysis

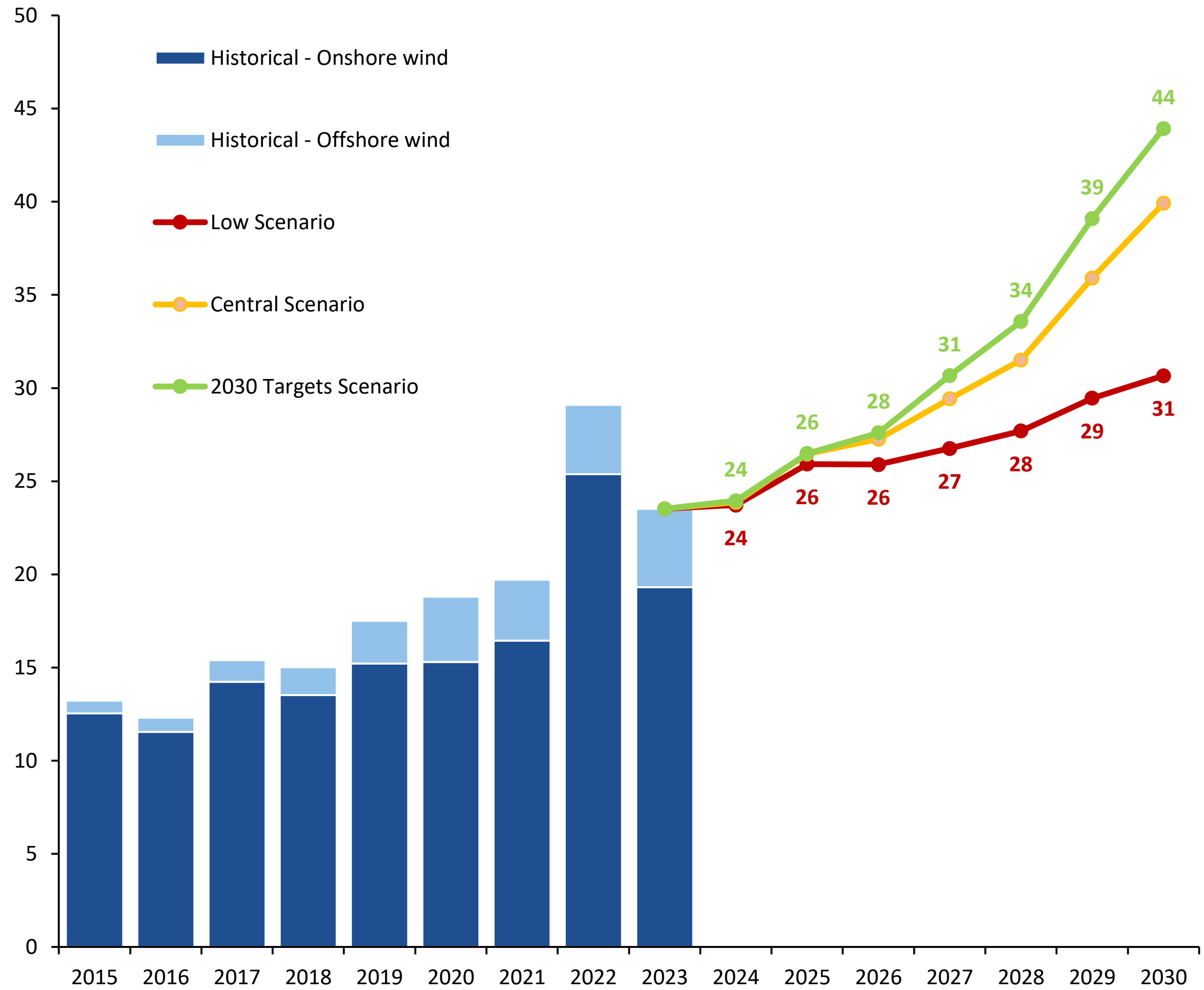
Wind developers GDP contribution to grow by 60% in the second part of the decade

The overall GDP contribution from wind power developers leads to sensitive variations between the three scenarios for new capacity installations. A slower capacity commissioning will not only reduce the European cumulative wind fleet but also decrease its overall efficiency. In addition, revenue stacking varies between scenarios, leading to different distributions of the revenues between historical auction prices, recent higher auction prices reflecting cost trends, spot market exposure and corporate PPAs.

All three scenarios expect a relatively slow growth of overall generation GDP contribution until 2025, reaching about €26 billion. In the case where Europe is on track with its 2030 targets, a strong growth in GDP contribution is expected from 2026, increasing by over 60%, to reach €44 billion in 2030. A lower pace of commissioning, aligned with WindEurope's Central Scenario, would result in a steadier growth of about 50% to reach €40 billion by 2030. As expected, the Low Scenario reflects the stronger shortfall. By 2030, the GDP contribution would reach a low €30 billion, an 18% growth from 2025 levels. This would result in significant cumulative GDP deficiency over the rest of the decade. In the Low Scenario, the wind power generation sector would see a cumulative €35 billion GDP loss from 2024 to 2030, compared with the 2030 Targets Scenario. Such a loss is comparable to a full year of GDP from the wind generation sector expected from 2028 in the 2030 Targets Scenario.

Those results can also be contrasted with uncertainties related to forecast revenue and received prices. In the Low Scenario, revenue is largely defined by historical auction prices, offering a low level of uncertainty towards the end of the decade. In the 2030 Targets Scenario, the relatively higher share spot market exposure leads to uncertainty in revenue. With conservative assumptions in the spot price forecast, a downside risk for the GDP contribution remains low. On the other hand, an upside risk remains significant, as seen in 2022. In the event of an energy crisis leading to record high power prices, the 2030 Targets Scenario figures could be significantly revised upwards.

Figure 45: Europe wind generation GDP contribution by scenario
Billion EUR, real (2023)



Source: Rystad Energy research and analysis

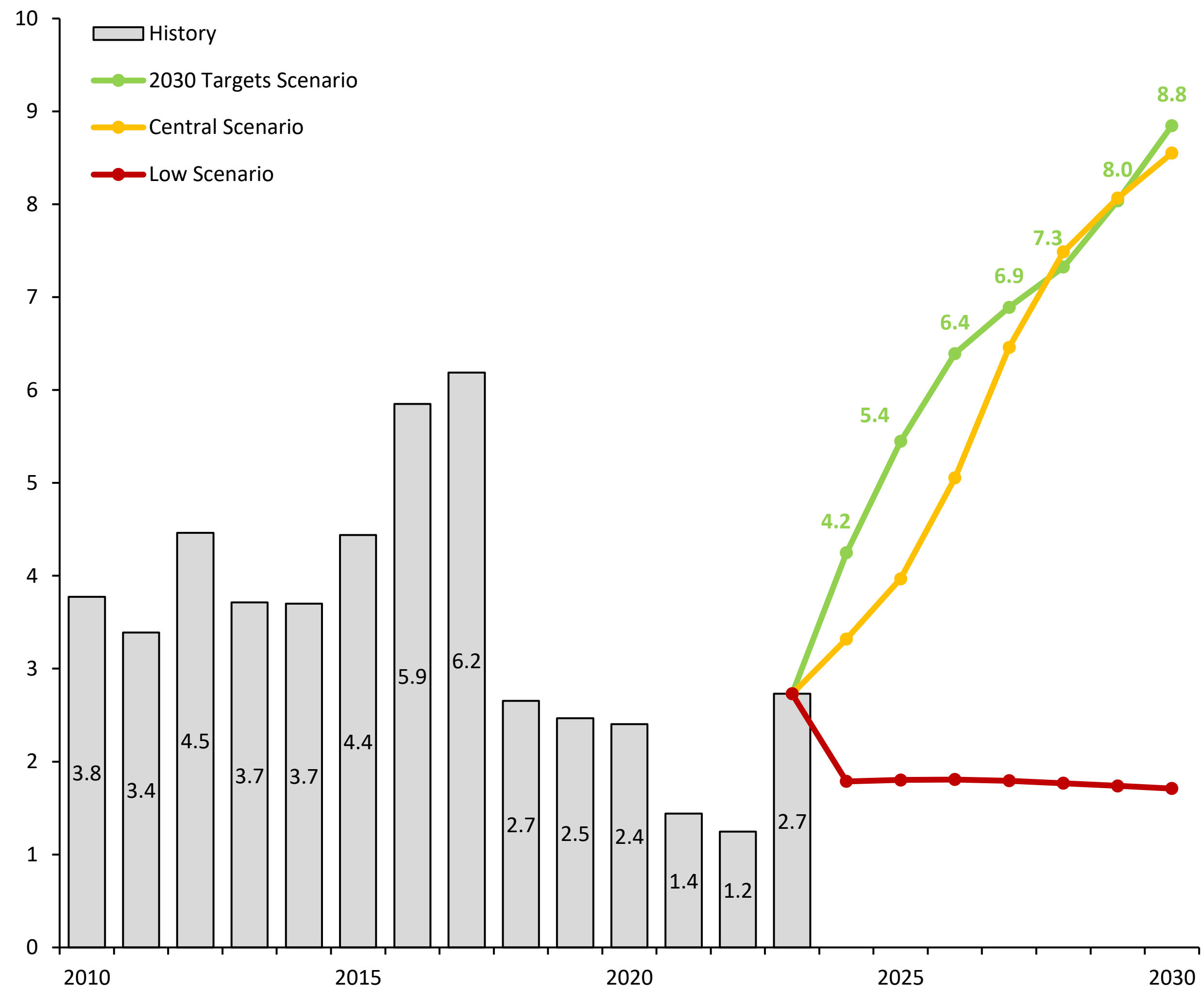
Contribution from wind energy manufacturers to GDP could increase three-fold

European wind energy manufacturers and service providers have been playing an increasingly important role in contributing to European GDP as the number of projects grows across the region. It is estimated that the contribution from this sector grew from €3.8 billion in 2010 to more than €6 billion in 2017 (real 2023 terms). However, the contribution dropped to an estimated average of €2 billion in the period between 2018 and 2023 as a result of lower margins experienced by wind turbine manufacturers. According to Rystad Energy estimates, adjusted earnings before interest, taxes, depreciation and amortization (EBITDA) margins for the sector went from 15% in 2017 to less than 5% by 2022.

Going forward, it is expected that the impact from wind energy manufacturers and service providers will increase as the development of new projects continues to grow and the margins of companies recover. In the 2030 Target Scenario, it is forecast that the total contribution will reach close to €9 billion by 2030. Around half of this contribution will come directly from the profits of the wind turbine manufacturers, with the remaining 50% contributed by component manufacturers, service providers and infrastructure providers. In this forecast, it is estimated that the EBITDA margins will grow back to at least 7%. However, if margins were to reach previous levels of 15%, then the actual contribution could be closer to €18 billion-€19 billion.

In a Low scenario, where the growth in the development of onshore and offshore wind projects remains unchanged from the current level, the contribution from manufacturers and service providers would be well below the average of the last two decades. In this scenario, the contribution would hover below €2 billion between now and 2030.

Figure 46: Wind energy manufacturers contribution to EU GDP
Billion EUR, real (2023)



Source: Rystad Energy research and analysis

Growth in revenue from developers will drive greater contribution to European GDP

As wind power generation becomes a major source of electricity supply in Europe, the contribution from the wind industry is playing an increasingly important role in the European economy. Back in 2010, the direct contribution from developers, manufacturers and service providers totaled €10.6 billion (in real 2023 terms), with around two-thirds originating from electricity sales from developers. This represented only 0.05% of the European GDP.

Over the last decade, the contribution has grown significantly in both relative and absolute terms. It is estimated that the total direct contribution from the wind industry reached €26.2 billion in 2023. Most of the growth has been the result of greater wind power generation due to increased capacity. The revenue of developers has also been lifted by higher electricity prices, especially during 2022. As such, the direct contribution from developers, manufacturers and service providers reached 0.11% in 2023. However, the contribution from developers has been increasingly significant, totaling €24 billion (or 85%), compared to €4.2 billion from manufacturers and service providers.

Under the 2030 Targets scenario, it is forecast that the direct contribution from the whole wind energy industry will reach 0.22% of European GDP. This growth will be mostly driven by the expansion in generation capacity, meaning that the role developers play will be increasingly significant for the economy. Higher capacity factors for wind generation and increased exposure to the spot market add further support. By 2030, the contribution from developers is forecast to reach €43.9 billion, with manufacturers and service providers contributing around €8.8 billion.

In the Low scenario, where the development of new projects remains unchanged from the current level, then the total contribution to GDP from the wind sector would remain below 0.15%.

Figure 47: Wind energy developers and manufacturers contribution to European GDP
Billion EUR, real (2023)

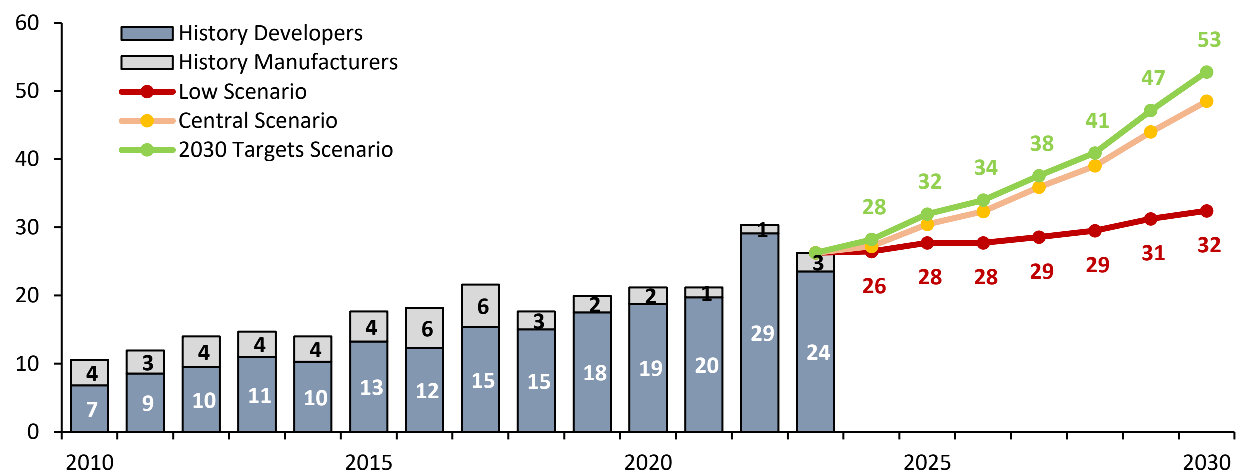
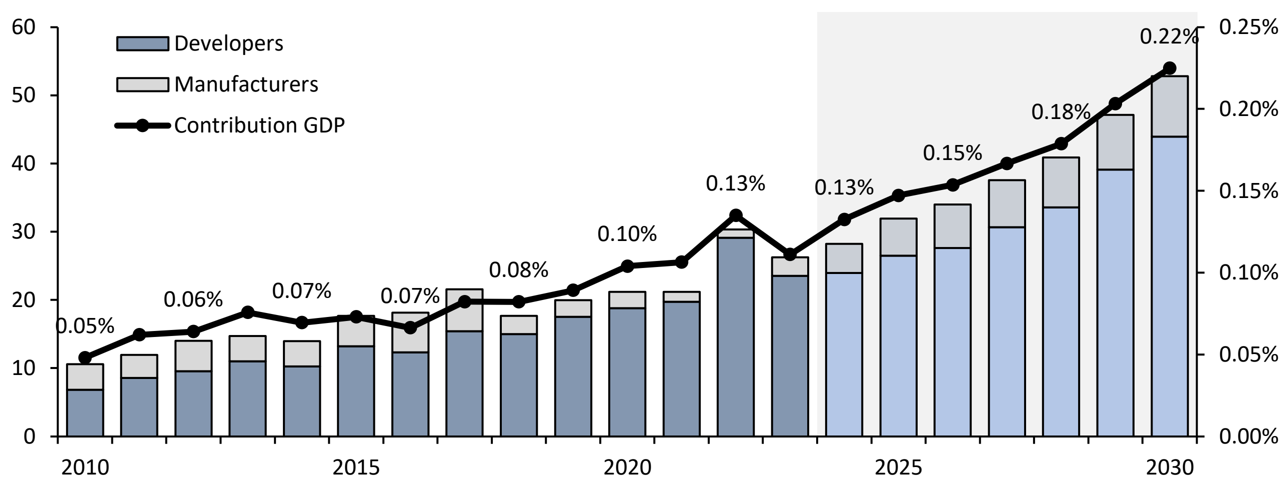


Figure 48: Wind energy developers and manufacturers contribution to European GDP – 2030 Targets scenario
Billion EUR, real (2023)



Source: Rystad Energy research and analysis

European power fossil CO_2 footprint has improved by 50% since 2007

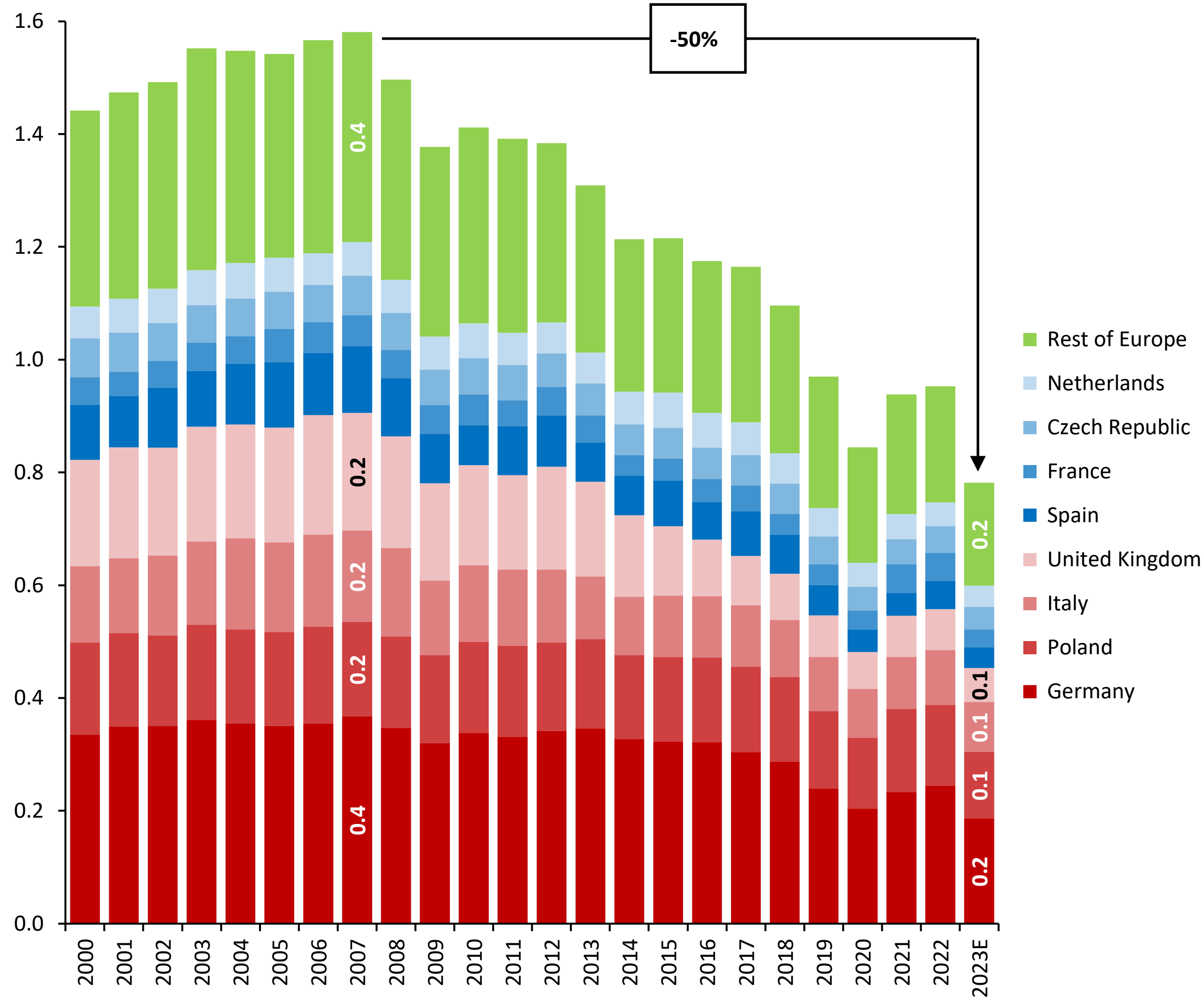
Direct fossil CO_2 emissions from the European power and heat generation sector peaked in 2007, two years after the introduction of the ETS. The peak annual CO_2 footprint was recorded at 1.58 Gtpa, with Germany, Poland, Italy and the UK accounting for 57% of the power CO_2 footprint on the continent. Since 2007, European power CO_2 emissions steadily declined to around 0.84 Gtpa in 2020 before rebounding slightly to about 0.95 Gtpa in 2021-2022 on the back of the energy crisis and reintegration of coal into the European power mix.

In 2023, the European power sector proved its commitment to structural decarbonization as record-high generation from renewable sources significantly impacted demand for both coal and natural gas from the European power mix. As a result, a record-low (in modern history) CO_2 footprint of the European power sector of 0.78 Gtpa was achieved in 2023.

There is no doubt that the European power mix remains on the path towards structural decarbonization as the total CO_2 footprint declined by 50% between 2007 and 2023. Further integration of wind, solar and battery energy storage will certainly allow the continent to achieve consistent reduction in power CO_2 emission levels in the next 10-15 years.

While significant differences in the current power mix are observed across different European countries and grids, we note that the average speed of decarbonization is comparable for the largest and smaller emitters. Germany, Poland, Italy and the UK accounted for the same 57%-58% of European power CO_2 footprint in 2023.

Figure 49: Europe, direct power sector fossil CO_2 emissions by country and year
Gigatonnes of CO_2



Source: EDGAR, Rystad Energy PowerCube

Wind drove 65% of European power carbon intensity improvements in 2007-2023

While the total CO_2 footprint of the European power sector is important, we note that absolute emission levels do not reveal the full picture as European electricity demand and total generation declined between 2007 and 2023.

A more representative metric that reveals the level of structural decarbonization is the carbon intensity of the European power mix, which quantifies the level of direct CO_2 emissions per unit of electricity output (kg of CO_2 per MWh). The carbon intensity of the European power mix peaked at about 450 kg of CO_2 per MWh in the 21st century and declined from ~438 kg per MWh to ~239 kg per MWh between 2007 and 2023.

Analyzing the contribution of different primary energy sources, we quantify the relative impact of each source on the improvement in European carbon intensity. While the improvement story is predominantly about increased renewable generation, it is worth noting that changes in the fossil energy mix (mainly coal-to-gas switching) also contributed with 56 kg per MWh to carbon intensity improvement between 2007 and 2023. Significant expansion in wind, solar and bioenergy generation reduced European carbon intensity by a substantial 230 kg per MWh between 2007 and 2023. However, this improvement was partially offset by retiring nuclear and hydro capacity in selected European countries. These retirements had a negative contribution of 87 kg per MWh to European power carbon intensity between 2007 and 2023.

Overall, wind energy alone accounted for 131 out of 199 kg per MWh improvements in the European carbon intensity of the power mix between 2007 and 2023. In other words, 65% of improvements were driven by the integration of wind into the European power mix, which is the largest contribution across all primary energy sources.

Figure 50: Europe, actual carbon intensity of power mix by year
Kilograms of CO_2 per megawatt-hour (MWh)

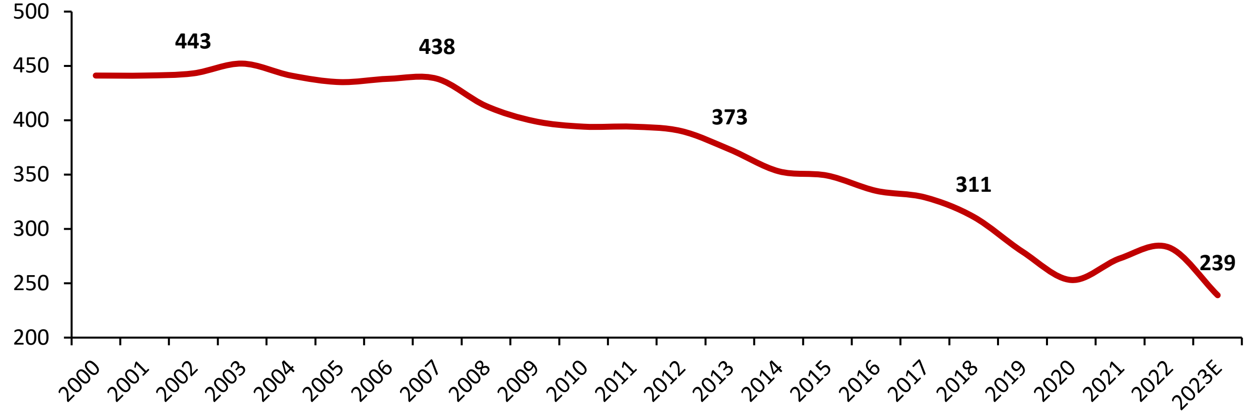
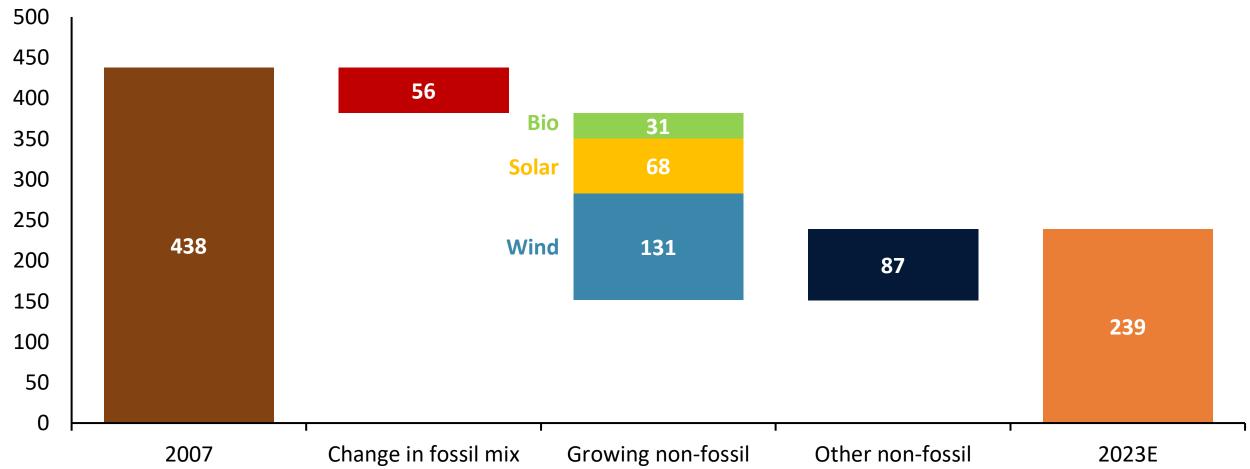


Figure 51: Europe, the contribution of different energy sources to carbon intensity improvements in 2007-2023
Kilograms of CO_2 per megawatt-hour (MWh)



Source: Rystad Energy PowerCube

Wind energy CO_2 avoidance may rise to ~300-350 mt per installation vintage

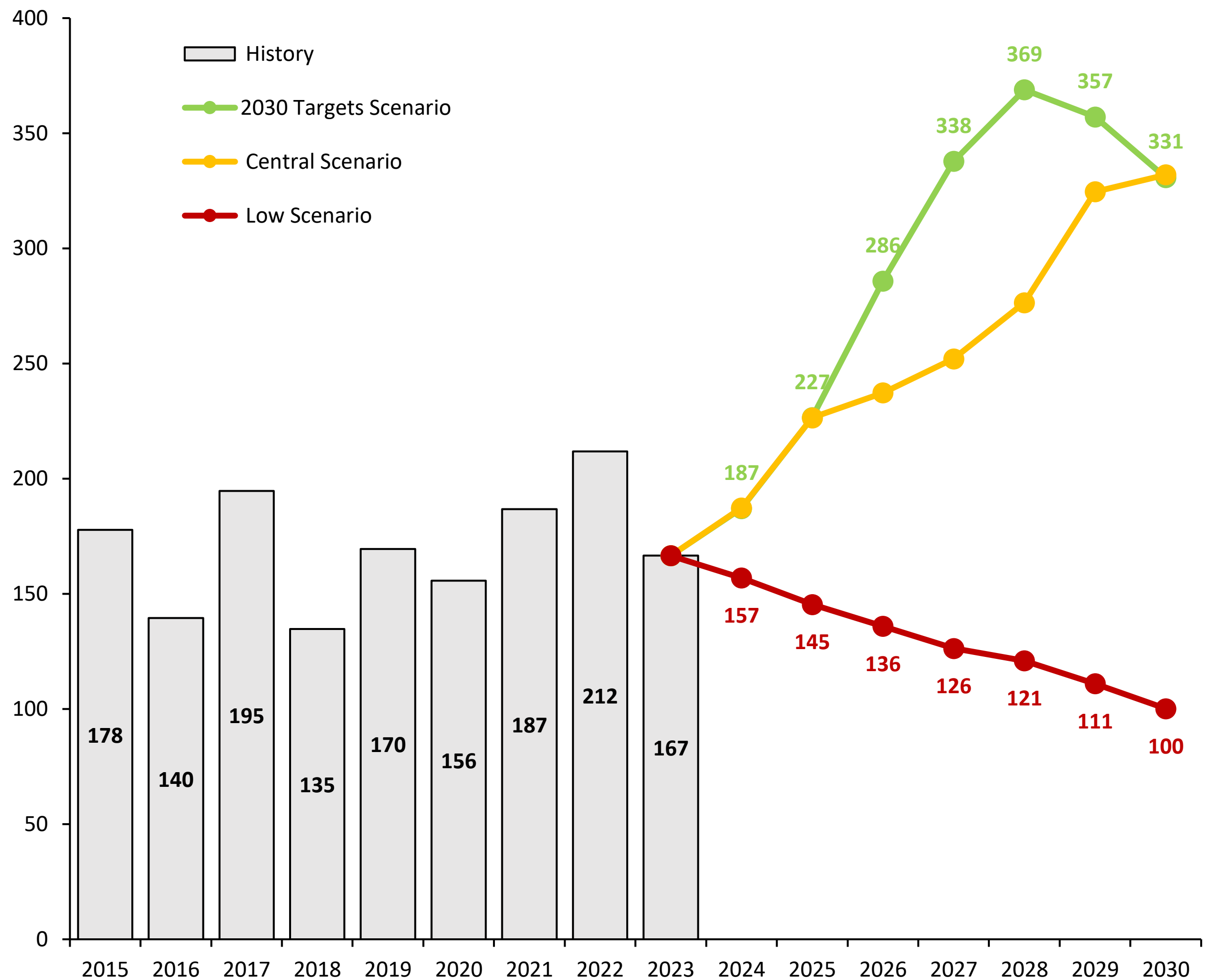
We quantify the amount of CO_2 emissions avoided by wind energy historically and under each scenario considered in this report. There are two conceptually different approaches to the assessment of emission avoidance by renewable sources: current generation and lifecycle basis. For the current generation basis, it typically involves the assessment of the carbon intensity of marginal power sources which must step in at any given point in time if wind generation is not available for the system. As wind generation is expected to increase considerably in 2024-2030, even in the Low scenario, the emission avoidance on a generation basis by wind will increase considerably by 2030 regardless of the considered scenario.

With this in mind, we focus on emission avoidance on a lifecycle basis to illustrate the true significance of the 2030 Targets scenario for wind for long-term decarbonization of the European power mix. For the life-cycle approach, we estimate emission avoidance by each annual vintage of wind capacity additions assuming 25 years lifetime for turbines and future most likely development of other (i.e. non-wind) energy sources. Then, we calculate the avoided CO_2 emissions for each operational year and present cumulative (or lifecycle) emissions for each installation vintage.

In the last 10 years, lifecycle CO_2 emissions avoided per annual installation vintage have generally fluctuated 135 million-212 million tonnes of CO_2, with 2022 being the best and 2016 and 2018 being the worst annual installation vintages from the point of view of life cycle CO_2 avoidance.

In the 2030 Targets scenario, annual lifecycle CO_2 avoidance is expected to increase to 330 million-370 million tonnes by the late 2020s. The Central Scenario will also be accompanied by a comparable increase in annual avoidance, while the Low Scenario will be accompanied by a gradual decline in annual lifecycle avoidance towards 100 million tonnes in 2030 as the rest of the Europe power mix becomes less carbon intensive.

Figure 52: Europe, avoided lifecycle CO_2 emissions by wind capacity installation vintage
Million tonnes of CO_2



Source: Rystad Energy research and analysis

Emissions avoided by wind under the Target scenario are valued at €28 billion per year

We quantify the value of emissions avoided by wind under the EU ETS. EU ETS prices increased from less than €20 per tonne in 2015-2017 to an average of €81- €82 per tonne in 2022-2023. While different factors are currently impacting EU ETS development in different directions, we analyze the value of future CO_2 emissions avoided by wind under the "120 by 2030" scenario, where the EU ETS price gradually increases towards €120 per tonne in 2030.

In the last five years (2019-2023), the annual value of emissions avoided by wind in Europe averaged €9.7 billion. We note that even in the Low Scenario, where lifecycle emissions avoidance declines towards 100 million tonnes of CO_2 by 2030, the average annual value of emissions avoided by wind is expected to increase to €13.2 billion in 2024-2030 amid higher EU ETS prices in the forecast period.

A much larger impact is unlocked when we move from the Low to Central Scenario as the average annual value of emissions avoided in 2024-2030 nearly doubles to €24.1 billion.

Finally, the 2030 Targets scenario will allow the continent to boost the value of emissions avoided by wind further, to €28.1 billion per year, in the considered forecast period.

Hence, the magnitude of the difference between the value of emissions avoided by wind under the 2030 Targets and Low scenarios is comparable to the difference between these scenarios on direct contribution to the European economy.

Figure 53: European Union Emissions Trading System, historical development and "120 by 2030" scenario
EUR per tonne

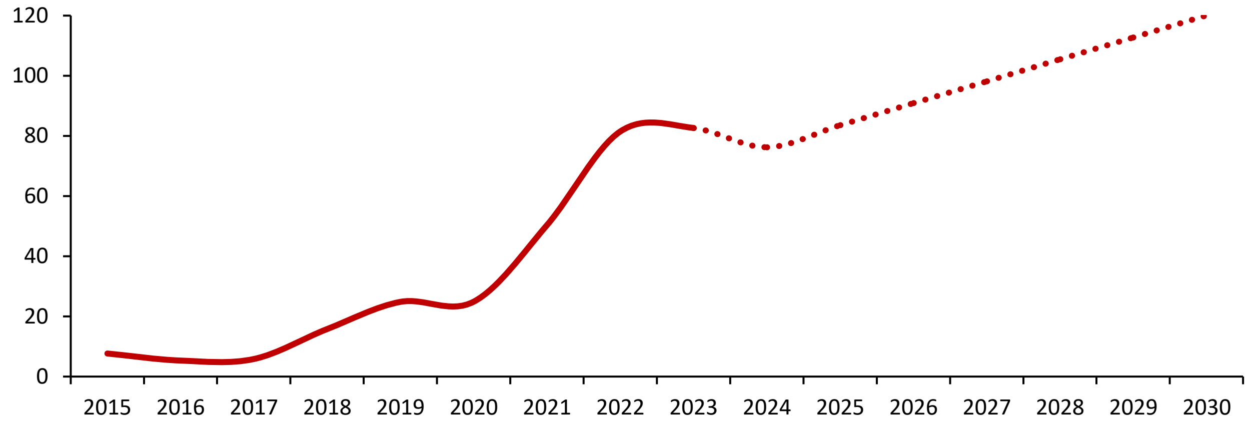
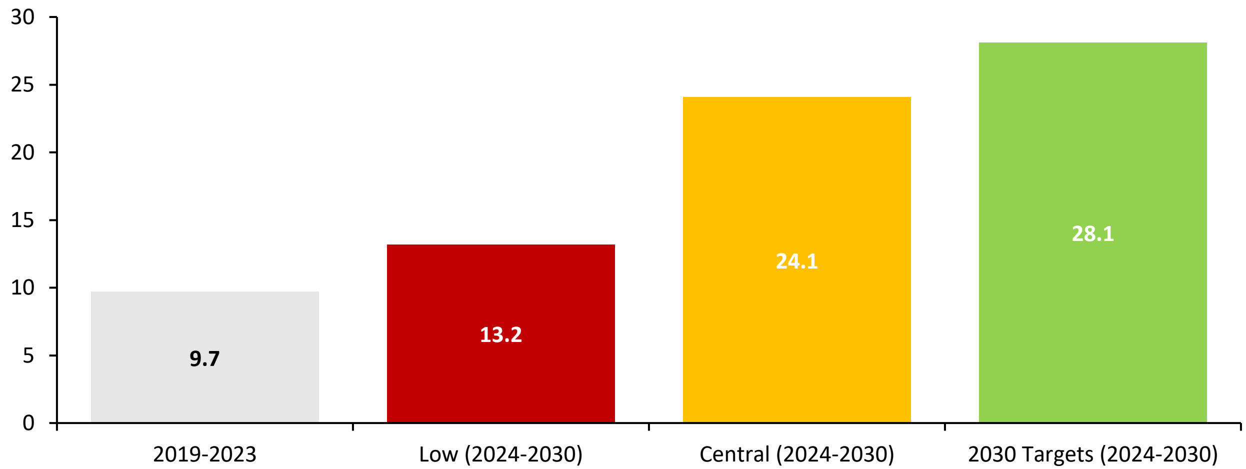


Figure 54: Average annual value of emissions avoided by wind under the "120 by 2030" scenario
Billion EUR



Source: Rystad Energy research and analysis

Policy recommendations (1/2)

Cost of inaction – Policy recommendations

Things have gotten better for the European wind industry in 2023. We've seen improvement of permitting numbers and a rebound in investment. As well as the adoption of important legislative and non-legislative measures that are critical to support wind energy deployment.

The European Commission launched the Wind Power Package – a set of 15 immediate measures to accelerate wind deployment and bolster the competitiveness of European manufacturing. The Package was then endorsed by 26 EU Governments and 300 wind energy companies who signed the European Wind Charter. This commitment signalled a united front in implementing the EU Wind Power Package and is expected to have a positive impact on permitting, finance, and auctioning mechanisms.

The wind energy target for 2030 is now within reach. But Europe must focus on the delivery and on the full and timely implementation by national Governments of the rules set out in the Renewable Energy Directive, the Wind Power Package, and the Net-Zero Industry Act as soon as possible. With less than 7 years to go until 2030, we need these supporting measures to be quickly adopted, to guarantee a viable European wind energy supply chain which can help Europe to reach its 2030 targets.

Permitting

Since 2022, the European Union extensively worked on improving permitting for wind projects. The Emergency Regulation on Permitting and the revision of the Renewable Energy Directive set out new permitting rules that will speed up the permitting of wind projects. It is crucial that Member States implement those rules as soon as possible.

- Member States must transpose the permitting provisions of the Renewable Energy Directive by 1 July 2014, notably the "overriding public interest" principle. Member States should also clearly define steps and timelines within the administrative services involved to ensure that all relevant permits are delivered within the 2-year deadline for onshore wind and 3-year deadline for offshore wind.
- By 1 November 2025, Member States must set up a one-stop-shop and digitalise their permitting procedures.
- Member States must proactively engage in spatial planning and remove constraints to wind deployment with a view of accelerating permitting in all suitable areas. If needed at all, Renewable Acceleration Areas in areas easy to identify where environmental impact is low (harbours, road and rail corridors, industrial sites, or degraded land).

Auction design

The measures set out in the Wind Power Package on auction design are now being enshrined in EU legislation as part of the Net-Zero Industry Act. The Act aims to strengthen Europe's domestic clean technology manufacturing capacity. It mandates pre-qualification criteria (on cybersecurity, responsible business conduct and the ability to deliver a project), factoring in supply chain resilience, and non-price award criteria, for at least 30% of renewable energy auctions to begin with. This to reward social, economic and security benefits wind energy project bring to the European society.

- Member States must prioritise wind auctions when implementing non-price prequalification and award criteria.
- These criteria should be clear, transparent, actionable, and in line with EU guidance to ensure a streamlined implementation across the EU.
- The Commission and Member States must consult the industry when adopting the Implementing Act on auction design within 9 months after entry into force of the Net-Zero Industry Act.

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Policy recommendations (2/2)

Supply Chain

Over the past few years, the European wind energy supply chain has faced rising pressure from a range of factors such as inflation, difficulty in accessing raw materials, competition from non-European manufacturers and a lack of clear project pipelines because of delays in the permitting process.

The sector may be turning a corner as demonstrated by renewed confidence from wind manufacturers. New and expanded factories in Poland, the Netherlands and Germany are already being developed which will add to the existing 250 factories across Europe.

Despite the policy and manufacturing progress, we are still seeing delays in the wider supply chain. This includes waiting periods of 3 - 4 years in some cases for offshore foundations. The availability of cable and installation vessels will also become an issue in the short-term if more are not produced.

- National Governments need to continue support their supply chains using the flexibility of the State aid Guidelines and the Temporary Crisis and Transition Framework.
- Particular attention should be made on boosting Port capacity.
- Innovation funding at EU and national level should focus on scaling up production to support the accelerated deployment of wind energy.

Grids

Governments must also look at their grid development plans with urgency – slow grid expansion and optimisation is quickly becoming the number one bottleneck for wind energy deployment in Europe. Significant volumes of wind power capacity are stuck in grid permitting procedures across Europe, which can last up to 10 years in some countries. The "first come, first served" approach that all countries apply now for connecting new assets to their grids will not deliver the necessary pace.

In 2023 Europe ramped up its political oversight on electricity grids and took promising steps to accelerate the development of network infrastructure that can deliver its climate goals. The European Commission estimates that €584bn will need to be invested in electricity grids this decade. And according to the first Offshore Network Development Plans, €85bn will need to be invested to build more than 11,000 km of new offshore electricity transmission networks by 2030. These announcements have trigged an unprecedented momentum to connect new renewable energy assets and grid equipment supply chains.

- National Authorities should use this opportunity to plan anticipatory investments to expand, reinforce or optimise their transmission and distribution networks so that they can reach the targets in their National Energy and Climate Plans. They will also need to reserve the necessary grid connection capacity for all technologies identified as strategic in their net-zero transition. This will enable Europe to reinforce its grid equipment manufacturing base.
- Governments also need to optimise the use of the existing grid, and proactively managing grid connection queues.
- In terms of offshore network infrastructure, National Authorities must try to find an optimal and fair way to share costs and benefits at sea basin level.
- Finally, curtailment of wind energy is becoming more common right across Europe and is now a serious uncertainty factor for investments in new renewable capacity. Europe will need targeted mechanisms and regulatory adjustments to handle curtailment in a cost-effective manner. With the implementation of the new Electricity Market Design and the provisions for non-fossil flexibility, National Authorities will have the opportunity to deploy their assessments on flexibility needs and targets and prioritise flexibility from non-fossil resources.

Electrification

Finally with only 23% of its energy demand currently being met with electricity, Europe urgently needs to accelerate the pace of electrification. Achieving a climate-neutral continent by 2050 demands an ambitious leap to 58-71% reliance on electricity. The pace of electrification must be accelerated to decarbonise the European Economy

- The new European Commission needs to deliver an electrification plan in its first 100 days setting a 35% electrification target by 2030.
- Member States need to take concrete measures to increase electrification of transport, heating and cooling and industry in their National Energy and Climate Plans

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We are

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We provide

reliable **data, analytics and advisory** to enable our clients to navigate the future of energy

Our goal

is to **provide transparency** in the global energy markets and to **contribute to a responsible energy transition**

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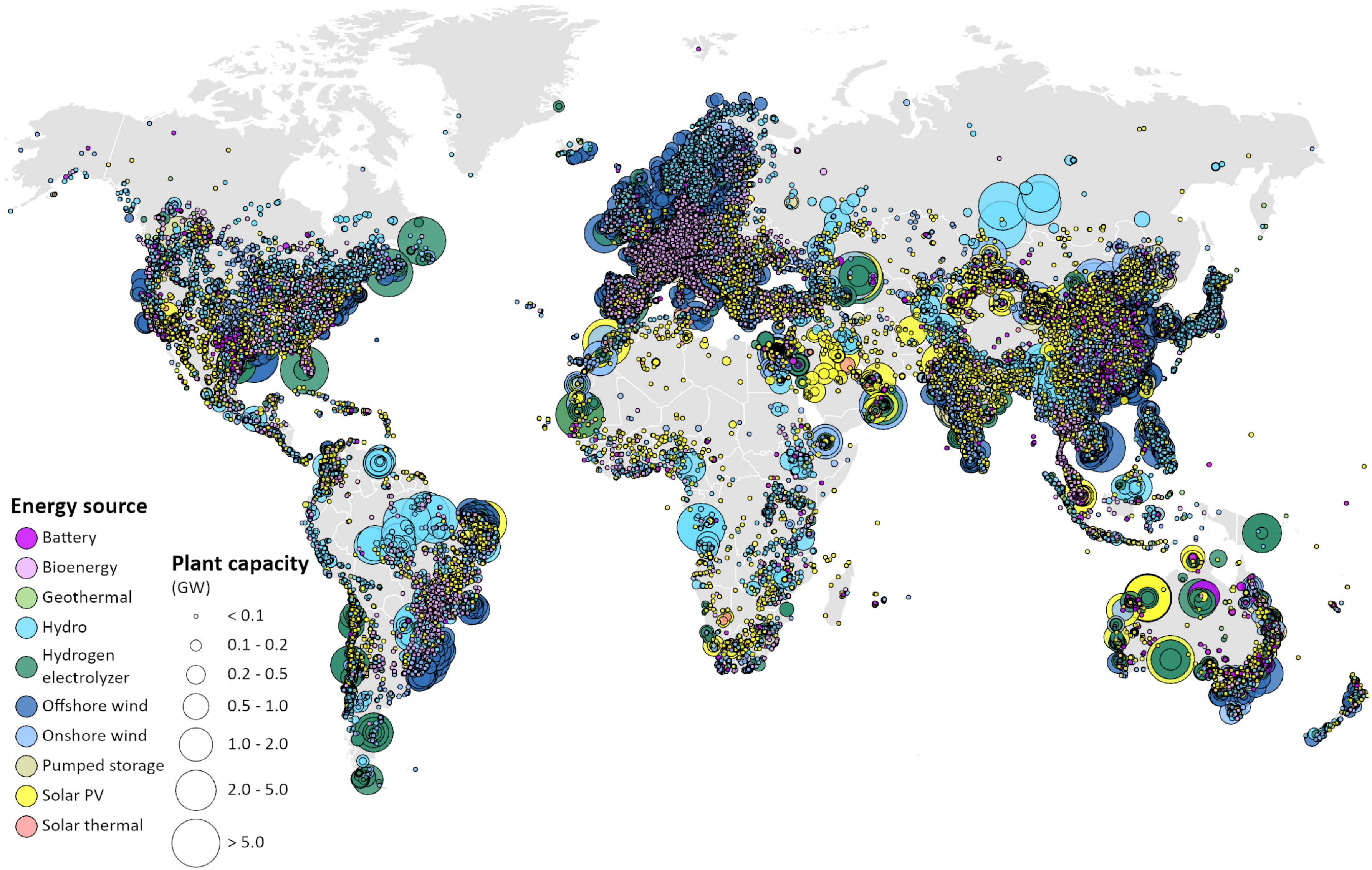
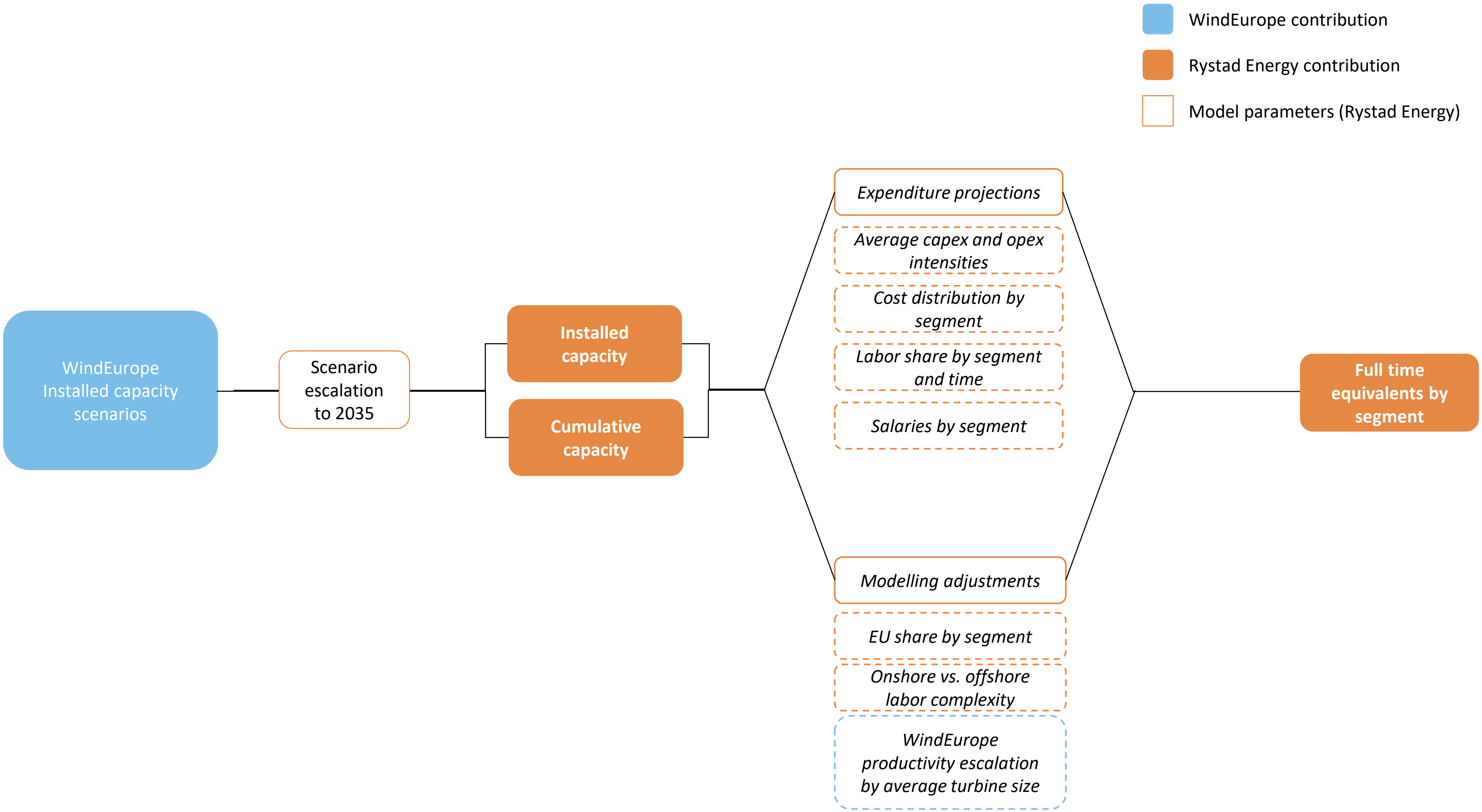
Rystad Energy covers more than 150,000 renewable and energy storage assets globally



Methodology overview

Figure 55: Job model overview



Methodology overview

Figure 56: Wind developers GDP direct contribution model

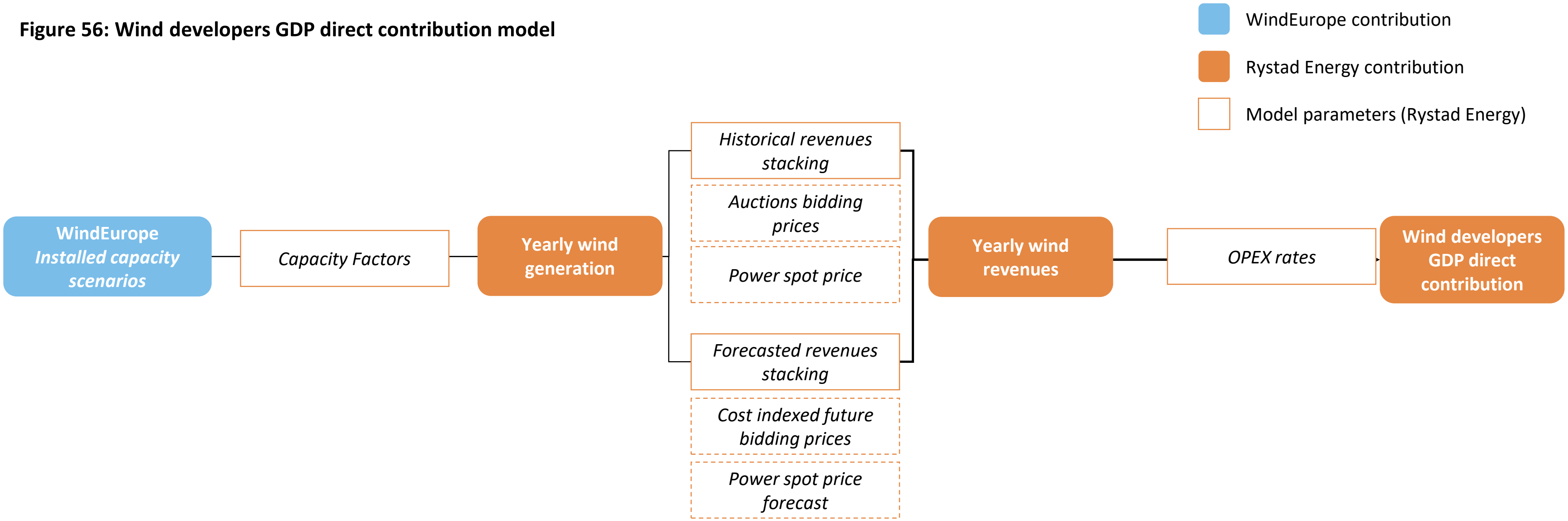
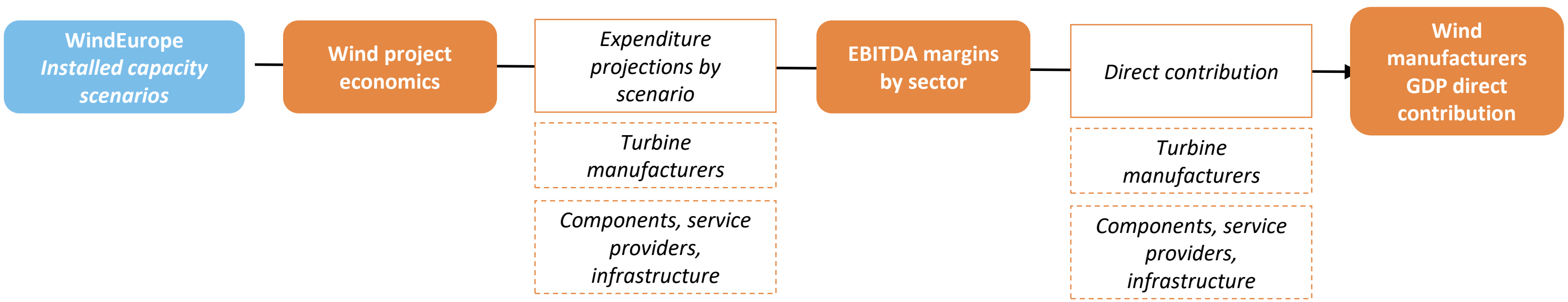


Figure 57: Wind manufactures GDP direct contribution model



*Only used for material modeling purposes

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