The State of the European Wind Energy Supply Chain

A «what-would-it-take» analysis of the European supply chain's ability to support ambitious capacity targets towards 2030

A Rystad Energy report in cooperation with WindEurope

April 2023

About this report

This report has been produced by Rystad Energy in cooperation with WindEurope. It is focused on Europe's wind supply chain and its ability to support ambitious capacity targets for 2030.

The outset of the report is based on **WindEurope's** capacity outlook for wind power in Europe in its *"2030 Targets Scenario"* presented in the *"Wind energy in Europe 2022 – Statistics and the outlook for 2023-2027"* report published in February 2023.

Using this capacity outlook as an exogenous factor, **Rystad Energy** has applied its models and industry knowledge to estimate the resulting demand for components, services and materials along the value chain towards 2030.

Through extensive research on the current and announced supply capacities, Rystad Energy aims to identify potential supply chain risks and bottlenecks as well as assess the urgency of the necessary expansions. 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, in addition to describing the components and materials that are essential for the wind industry.

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

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Foreword

Europe's energy mix is set to see a significant transformation towards 2030 as the climate emergency and the energy crisis in the wake of Russia's invasion of Ukraine are pressuring the region's ability to secure reliable, affordable, and clean energy supply – a challenge set to continue for the years to come.

The energy transition initiatives in Europe were accelerated during the Covid-19 pandemic, as means of rebooting economies while simultaneously taking steps towards reaching climate targets. As the markets gradually recovered post-pandemic from high inflationary pressure, Russia's invasion of Ukraine in February 2022 shifted the focus of European policy makers from energy transition to energy security.

Policy makers responded to the need to reduce dependency on Russian gas by increasing domestic supply, building new import terminals for LNG to shift import routes, and significantly lifting renewable targets. For the latter, wind energy in Europe was identified as a key energy source required to reach European renewable capacity ambitions. The REPowerEU plan was laid out last year, which WindEurope concluded would require 440 GW of operational wind capacity by 2030 and an average installation rate of 30 GW annually towards 2030. In addition, countries established national targets for onshore wind and offshore wind and kicked off cooperation initiatives – such as the Esbjerg and Marienborg Declarations for offshore wind.

Some of the main policy initiatives for wind in 2022 were aimed at raising targets and supporting them by shortening permitting procedures, which was identified as the key bottleneck in reaching new ambitions. In recent months, we have also seen several European nations making new areas available for wind energy, which is aimed at backing the massive build-out needed.

However, focus has now been shifted towards the supply chain's ability to support such a rapid ramp-up in activity levels. Moreover, European energy independence has broadened to include the supply chain and critical raw materials, which adds to the challenge – not only will activity levels spike to new heights, but the growing demand should primarily be met by domestic supply, and not an increase in imports.

For the European wind supply chain, the challenge may seem too large to handle. Wind turbine manufacturers have reported low margins and poor financial results for several years, along with many other companies along the value chain. Also, the more established onshore wind market in Europe needs to grow to reach European ambitions, while the younger offshore wind industry will see activity accelerate this decade.

For offshore wind, cost reductions observed over the past 5-10 years have been driven by the rapid development in turbine sizes. Larger turbines improve total lifecycle economics, and developers' natural affinity towards the largest models in the market led to a race between OEMs to provide the biggest and most efficient turbines. This has come at the cost of significant R&D budgets among the turbine manufacturers.

At the same time, the demand for offshore wind acreage has increased substantially in recent years, exacerbated by legacy oil and gas majors moving into the sector with deep pockets and a high willingness to pay. Higher acreage bids and lower strike prices increased the need for further cost reductions, and the cost cutting pressure has trickled down through the supply chain. On top of this, inflation in the wake of the pandemic and Russia's invasion of Ukraine continue to challenge the already pressured margins.

The turbine trend creates ripple effects for the entire value chain. Other components such as foundations and inter-array cables must be changed to handle the larger turbines, and handling and lifting capabilities must be scaled up to accommodate growing component sizes. This adds to the challenge of the sheer activity growth.

While the demand outlook seems increasingly strong and certain, the supply chain is lagging. One reason is suppliers' ability to expand in a high-inflation, low-margin environment where capital costs are growing. Another source of uncertainty is the pace at which demand is changing. When faced with a potential expansion, suppliers must ask themselves how future-proof this is. The risk of scaling up and quickly becoming obsolete adds uncertainty for decision makers and pushes final investment decisions out in time.

Our analysis shows that *time* may not be something that Europe has in abundance – if ambitious capacity targets are to be met. The rapid activity growth needed to reach targets will in certain segments require large supply chain expansions, and if not, bottlenecks may occur already by 2024/2025. To avoid this, suppliers must make decisions to expand either this year (2023), or the next. This means that for those suppliers, a strong investment signal must be given today, and that the time for action is now. Consequently, European policy makers will face the difficult balancing act of reaching targets and securing a domestic supply.

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What would it take for Europe's supply chain to deliver on wind energy ambitions?

The aim of this report is to assess the state of the European wind supply chain and its ability to support ambitious capacity targets towards 2030. The outset of the analysis is WindEurope's *2030 Targets Scenario* presented in its report "*Wind energy in Europe 2022 – Statistics and the outlook for 2023-2027*" published in February 2023. The scenario describes the necessary European Union wind capacity additions towards 2030 to reach the targets set in the REPowerEU plan, and those required for non-EU European countries to reach their capacity and climate targets. Rystad Energy has used this capacity outlook to estimate the demand for components, services and materials along the wind supply chain and compare this to existing supply capacities in Europe to identify potential bottlenecks, expansion needs, and the urgency of the potentially necessary expansions.

Another important backdrop is the focus on boosting European independence, not only in energy, but also from a supply chain and material sourcing perspective. As such, the focus in this report is primarily on European supply and its ramp-up needs, and to a lesser extent on the need to increase imports. The report introduces a trilemma framework, describing the balance between reliability, affordability and sustainability, and this is referenced where applicable throughout the report.

Part 1 describes the current status of the global and European energy markets and the European wind industry. It provides a summary of the current policies aimed at supporting a shift towards increasing wind energy (and other renewables) in the power mix and increasing European energy, supply chain and raw material independence.

The past year has been marked by a balance of record renewable energy development activity and major challenges for the broader energy transition industry. Russia's invasion of Ukraine led to a global energy crisis that hit consumers hard but underlined the key role of renewable energy in Europe's energy security – and not only sustainability. While the energy crisis and post-Covid-19 recovery spurred renewable energy commissioning, materials and components price inflation has put the wind energy supply chain under severe financial pressure. Although Europe has managed to overcome the winter season and the inflation crisis has started to ease, many challenges remain. Therefore, the energy topic has kept the European Commission busy, with many energy policies announced during the year. The REPowerEU plan set out a European energy roadmap to 2030, and the ongoing Green Deal Industrial Plan aims to provide the highly necessary support to achieve these ambitions.

Part 2 considers the current and future supply capacities in the European wind industry, and the demand for components, services and materials estimated by Rystad Energy, based on WindEurope's *2030 Targets Scenario*. The estimated supply-demand balance shows that for wind energy capacity targets to be met by 2030, there would be a need to rapidly expand capacities across the supply chain unique to wind, including turbines, towers, foundations, wind turbine installation vessels (WTIVs), and more. The key findings of the quantitative assessment of selected parts of the European wind supply chain can be seen in Table A on the next page.

While the ambitious wind energy capacity targets would require nearly all parts of the European wind supply chain to be ramped-up, our analysis shows that those related to offshore wind would be most critical. Compared to onshore wind, where activity levels need to be ramped up from already high levels and with limited growth in turbine sizes, offshore wind is forecast to see a steeper increase towards 2030, with turbine sizes expected to grow rapidly. This is expected to put significant pressure on the manufacturing of turbines larger than 12 MW, large-diameter monopiles, and floating foundations. For the same reason, expansions are expected to be required for next-generation WTIVs. These expansions are extremely time-sensitive as an undersupply is expected around mid-decade, with expansions in need of being initiated as early as 2023-2024 due to lead-times.

Onshore wind is also expected to drive manufacturing expansion needs, especially on the turbine side, driven by the sheer activity increase required to reach targets.

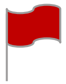
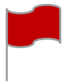
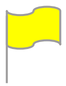
Several other parts of the wider supply chain would be pressured if targets are to be reached: transmission and grid infrastructure is expected to be squeezed by an increase in wind, in addition to a growth in renewables, and a general electrification of the energy system; skilled labor may serve as a bottleneck for specialized parts of the wind supply chain; other vessel segments such as foundation and cable installation, service operation vessels (SOVs) and anchor handling tug supply (AHTS) vessels for floating wind are expected to need fleet expansions; ports need upgrading to support the large-scale build-out of offshore wind and the industrialization of floating wind; and floating wind would require mooring line manufacturing to be ramped up significantly.

Material demand is expected to grow nearly four-fold towards 2030 if targets are to be reached. Assessed according to their relative importance in wind, the expected growth trajectory towards 2030 and relative score on reliability, affordability and sustainability, steel, copper and rare earth minerals are seen as most strategically important. The latter two are assessed as at most risk, due to their rapid demand growth, Europe's relatively high import reliance for these materials, and their critical role in cables and turbines, respectively.

Source: Rystad Energy research and analysis

Key findings

Table A: Key findings summary, selected parts of the supply chain unique to the wind industry

Segment	Industry	Sub-segment	2022-2030 demand growth*	Time to action*	Urgency assessment	Comment
Turbines	Onshore & Offshore wind	Total market	**~3X** *Capacity (MW)*	**2024-2025**		• *High inflation, low margins and an R&D race to supply the largest turbines on the market has put pressure on western OEM's ability to expand manufacturing capacities or repurpose facilities to accommodate a changing demand.* • *While onshore wind turbine size demand is relatively more stable, expansion of manufacturing is needed to match growth in activity levels in the 2030 Targets Scenario.* • *Offshore wind serves as the key challenge, with a large gap between current manufacturing capacity and projected demand for the largest models.* • *Rotor blade manufacturing represents the current bottleneck for European turbine supply, but both need a rapid expansion to meet demand in this scenario.*
	Offshore wind	>12 MW turbines	**0-29 GW**	**2024**		
Towers	Onshore & Offshore wind	All	**~2.5X** *Metric tons*	**2025**		• *Centralized tower supply for a larger range of turbines has enabled the supply chain to expand with growing activity.* • *Tower demand will be driven by a relatively high number of onshore wind turbines (compared to offshore wind) and increasing offshore wind activity and sizes.* • *Growth is expected to accelerate in the second half of the decade, creating an additional need for expansion.*
Foundations	Offshore wind	Monopiles	**~12X** *Metric tons*	**2024-2025**		• *Monopiles will remain the most popular concept in Europe, and with rapid growth in activity and turbine sizes in offshore wind, manufacturing must be scaled up quickly within the largest monopile segments.* • *Jacket manufacturing capacity less constrained thanks to O&G industry.* • *Floating foundation manufacturing must be industrialized. Today, it is characterized by pilots, demos and pre-commercial projects with one-off manufacturing and few units. From this small basis, manufacturing capacity must grow substantially towards the end of the decade.*
		Other grounded	**~7X** *Metric tons*	**None**		
		Floating	**~23X** *Metric tons*	**2024**		
WTIVs	Offshore wind	Total market	**~7.5X** *Vessel years*	**2024-2025**		• *Strong fleet additions in recent years have put supply in a strong position to cover demand in the next two to three years. Increased demand in the second half of the decade, primarily in the largest turbine size ranges will put pressure on supply.* • *A global fleet and increasing demand outside Europe will likely pull supply out of Europe, worsening the supply-demand balance, with new units forecast to be needed.* • *An increasing share of demand in the 15-20 MW range towards 2030 will also drive a need for new units, as the fleet of vessels capable of installing these units is currently limited.*
		>12 MW turbines	**0-25 vessel years**			

*Estimated European demand based on *2030 Targets Scenario*. Time to action refers to the estimated year when supply expansions need to be initiated to avoid a potential bottleneck. For more information, see Part 2.
Source: Rystad Energy research and analysis

Scope of the report and approach

Scope

The aim of this report is to assess the state of the European wind supply chain and its ability to support ambitious European wind energy capacity targets towards 2030.

The outset of the analysis is WindEurope's *2030 Targets Scenario* presented in its report "*Wind energy in Europe 2022 – Statistics and the outlook for 2023-2027*" published in February 2023. The scenario describes the necessary EU wind capacity additions towards 2030 to reach the targets set in the REPowerEU plan, and those required for non-EU European countries to reach their capacity and climate targets.

Rystad Energy has used this capacity outlook to estimate the demand for components, services and materials along the wind supply chain and compare this to existing supply capacities in Europe to identify potential bottlenecks, expansion needs, and the urgency of the necessary expansions. As such, the report can be regarded as a "*what-would-it-take*" analysis of the European supply chain's ability to support Europe's wind energy ambitions towards 2030.

It is important to note that the *2030 Targets Scenario* is a theoretical one, assuming a gradual increase in installed capacity per European country, according to their 2030 ambitions for onshore and offshore wind, respectively. It does not consider actual projects in the pipeline, or whether the lead times for each country's capacity additions are feasible. Thus, for some countries the capacity additions may in reality be higher or lower in the short-term, and vice versa in the longer term. On average, Rystad Energy sees it likely that actual short-to-medium term capacity additions fall short of the theoretical forecast in this scenario, especially for offshore wind, due to long lead-times. This could potentially add pressure to the required capacity additions in the longer term if targets are to be reached, which would add to the needed supply chain capacities during the second half of the 2020s.

Another important backdrop is the focus to increase European independence, not only in energy, but also from a supply chain and material sourcing perspective. As such, the focus in this report is primarily on European supply and its ramp-up needs, and to a lesser extent on the need, or ability, to solve bottlenecks through continued, or increased, imports.

Considering the challenging task of balancing renewable energy targets and a predominantly domestic supply of components, services and materials, we introduce a trilemma framework, describing the balance between reliability, affordability and sustainability. This is referenced throughout this report, where applicable.

Part 1 describes the current status of the European wind market, global energy and commodity markets and the general supply chain. Recent policies, trade measures and their impacts are discussed, setting the scene for quantifying Europe's ability to reach its ambitious wind energy targets.

Part 2 provides an overview of the future supply and demand balance for the main components and raw materials in the wind energy sector. We quantify supply-demand balances based on the *2030 Targets Scenario* for key parts of the unique wind supply chain, including turbines, towers, foundations, and wind turbine installation vessels (WTIVs). In addition, we discuss the status of other parts of the wider value chain, including cables, transmission and grid infrastructure, labor, other vessel segments, ports, and floating wind.

Lastly, we analyze the materials used in wind energy, the expected European demand in the *2030 Targets Scenario*, and assess the status and supply of selected critical or strategically important materials.

Part 3 includes WindEurope's policy recommendations, based on Rystad Energy's findings in this report.

Approach

We use WindEurope's *2030 Targets Scenario* as an exogenous factor, serving as the outset of our analysis.

Throughout our analysis, Rystad Energy leverages its broad portfolio of databases, covering onshore and offshore wind farms, manufacturing facilities for turbines, foundations, towers and cables, vessel demand and supply from oil and gas and offshore wind, energy materials, and much more.

Demand for components and services is modelled based on analysis of existing project data, leveraging Rystad Energy's in-house project-by-project databases for onshore and offshore wind farms; industry knowledge; and expected technology trends for onshore and offshore wind.

Supply for components and services is based on our bottom-up, facility-by-facility research. We use announced manufacturing capacities by facilities and manufacturers, and figures reported by suppliers regarding capacities by technology, geography, and more. Supply is measured based on both current capacities and announced expansions.

Supply-demand balances are determined based on the modeled demand and identified supply from the two approaches above.

Material demand is estimated based on Rystad Energy's extensive energy material models, applying material intensities per components and gigawatts to WindEurope's *2030 Targets Scenario* capacity outlook and the resulting component demand modeled by Rystad Energy.

Source: Rystad Energy research and analysis

The trilemma between reliability, affordability and sustainability

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

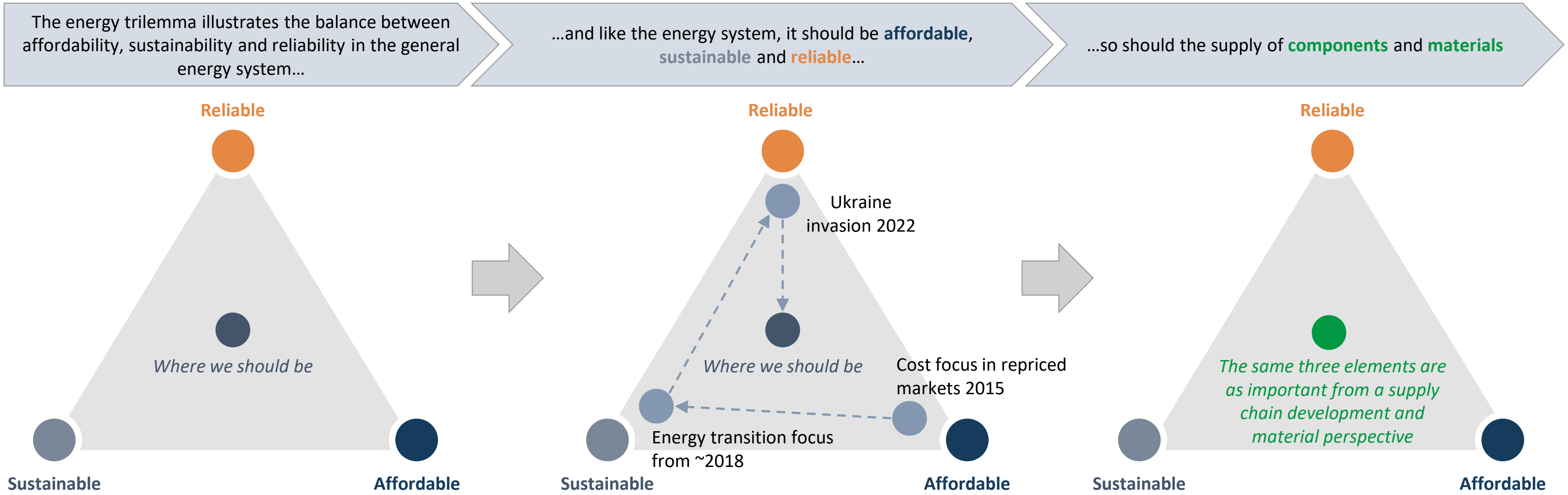
Reliability refers to whether a country or entity has an uninterrupted availability of e.g., energy. Short term, this could mean an energy system that can deliver energy to sudden changes in demand or part of the supply. Long term, this means energy security in terms of energy resources. Affordability 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 cost 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 and Russia's invasion of Ukraine have served as a reminder of the importance of reliable sources of energy supply. The focus on energy security has led nations to form new energy partnerships and replace traditional suppliers. In Europe this has accelerated the energy transition leading the region to becoming independent of Russian gas.

This is a development that is expected on the component manufacturing and materials side as well, especially connected to the energy transition. The developments of the supply chain and materials is expected to happen within the frame of the trilemma.

The affordability, sustainability and reliability of a component, service or material decides their respective relevance. If a part of the supply chain is not balanced across the elements of the trilemma, it is likely it will be replaced as new technologies, components and materials are introduced to the market.

Figure 1: Illustration of the trilemma framework



Source: Rystad Energy research and analysis

Wind manufacturing facilities in Europe

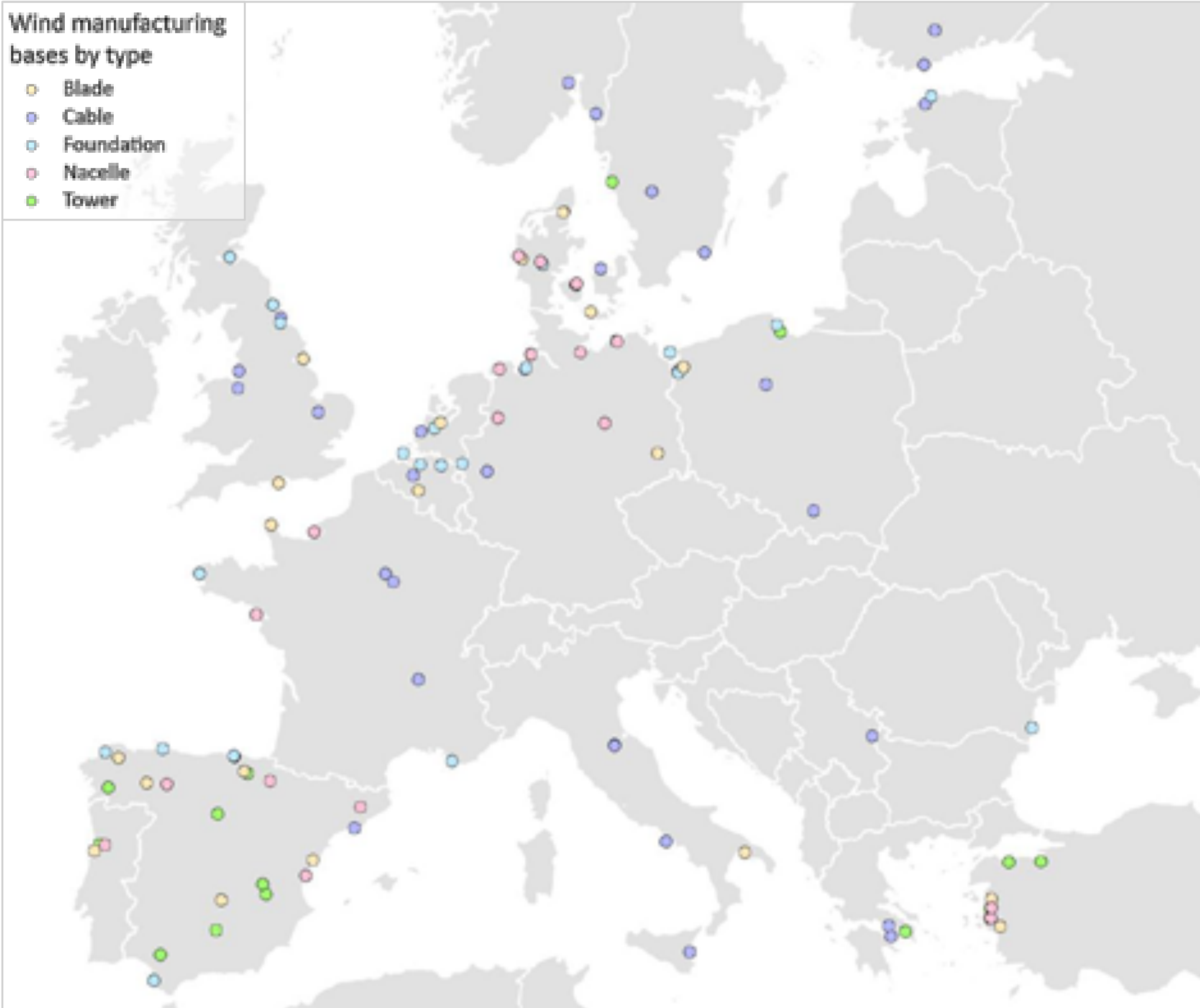
Europe is one of the regions in the world with the largest manufacturing capacity for wind power components. Europe has an interconnected supply chain, as the European Union Free Trade Agreement helps the movement of goods across member states' borders.

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 one of the key countries, 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 in Figure 2 may also produce cables for HVDC interconnectors and oil and gas electrification.

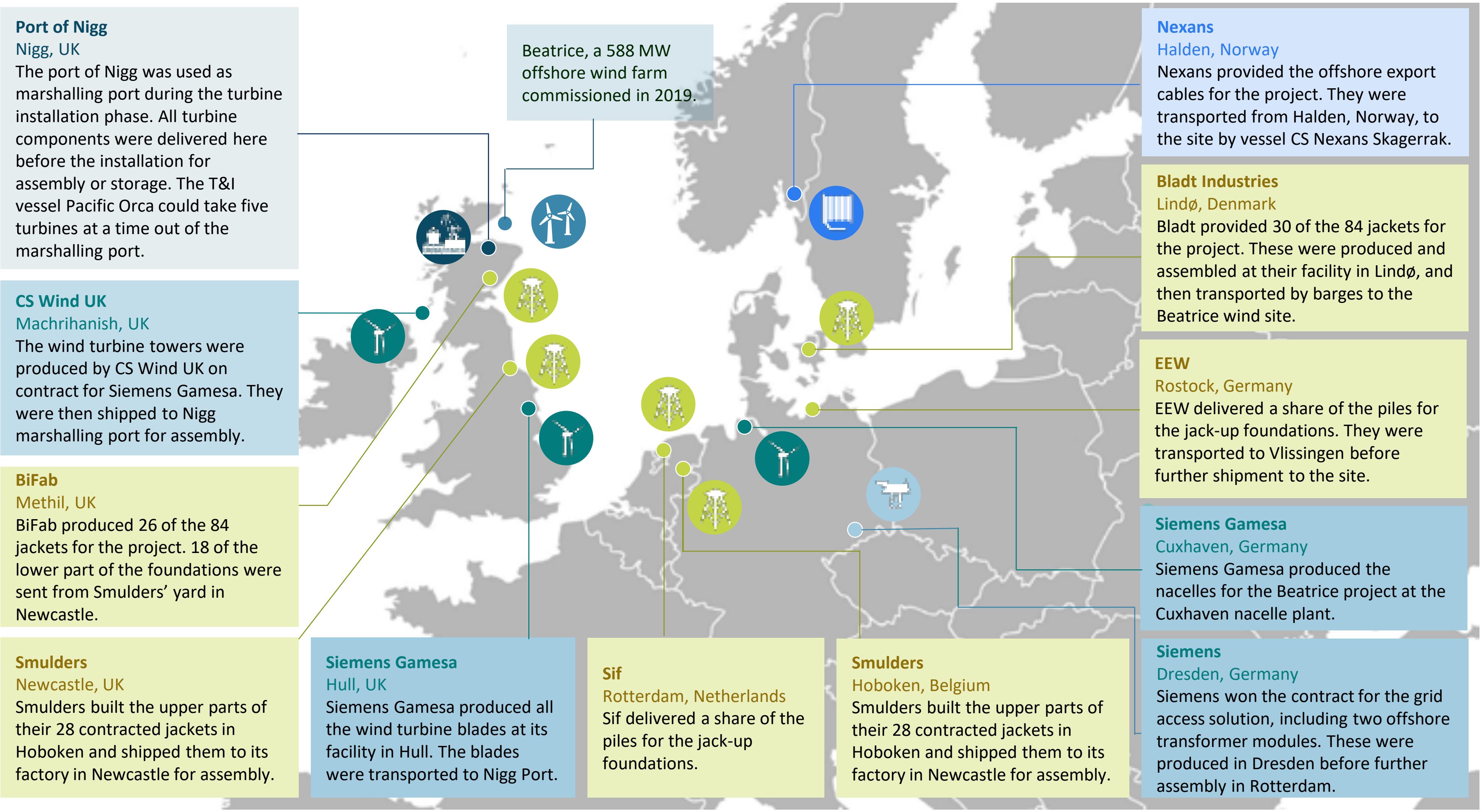
Figure 3 on the next page illustrates the complexity a project might encounter when getting all the supply chain components in place, shown using the Beatrice offshore wind project as an example. The construction of the wind farm involved 10 suppliers and 6 countries supplying the main components. One highlight is that it took 6 suppliers just to deliver the foundations, and the main parts of the turbines, the blades and nacelles, were manufactured in different countries. The illustration also shows the importance of an efficient shipping system to deliver thousands of components and sub-components.

Figure 2: Manufacturing facilities for main wind power components in Europe*



*Foundation in Figure 2 refers to offshore wind foundation bases only, onshore wind foundation bases are not included in this map.
Source: Rystad Energy research and analysis

Figure 3: Supply chain system illustration for the Beatrice offshore wind farm in the UK



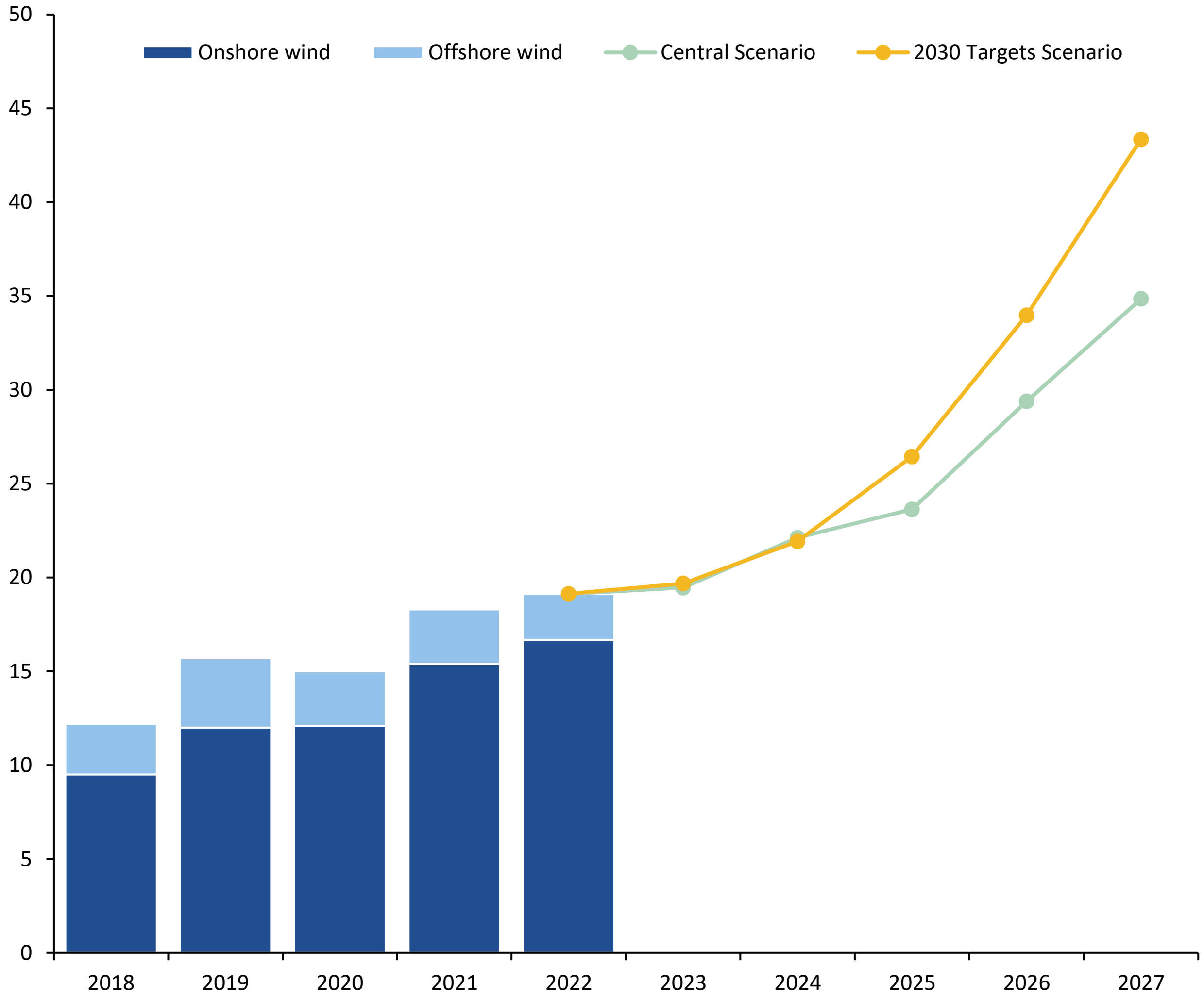
Source: Rystad Energy research and analysis

WindEurope scenario introduction and comparison

The demand scenario used in this report refers to WindEurope's *2030 Targets Scenario*, presented in the "*Wind energy in Europe 2022 – Statistics and the outlook for 2023-2027*" report published in February 2023. In this outlook, WindEurope presents two scenarios of development for the wind power capacity in Europe:

- **WindEurope 2030 Targets Scenario**: this is the demand scenario used in this report. It represents a theoretical installation rate required to meet the REPowerEU target and the 2030 targets of non-EU countries, namely the UK, Turkey, Norway, Switzerland and Serbia. The installation rate begins at the installations level from 2022 and increases to a peak growth rate between 2026 and 2027, showing the expected ramp-up in installations over the next few years. Annual installations continue to increase after 2027, albeit at a slower rate (including an allowance for expected decommissioning), leading to the 2030 targets being met. In this scenario, Europe needs to install 145 GW over the next five years to stay on target. In the EU, 117 GW would need to be installed from 2023-27 to stay on track to meeting the REPowerEU targets for 2030.
- **WindEurope Central Scenario**: this scenario lays out WindEurope's best estimate for installed capacity in Europe over the next five years, including any likely political or economic developments which 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. In this scenario, Europe will install 129 GW from 2023 to 2027, with an average installation rate of 25.8 GW per year. In the EU, installations of 98 GW between 2023 and 2027 are expected, at an average rate of 19.6 GW a year. This is significantly less than the average installation rate of 31 GW per year between 2023 and 2030, which is required to meet Europe's energy and climate targets.

Figure 4: Annual wind installed capacity in Europe by WindEurope scenario, 2018-2027
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

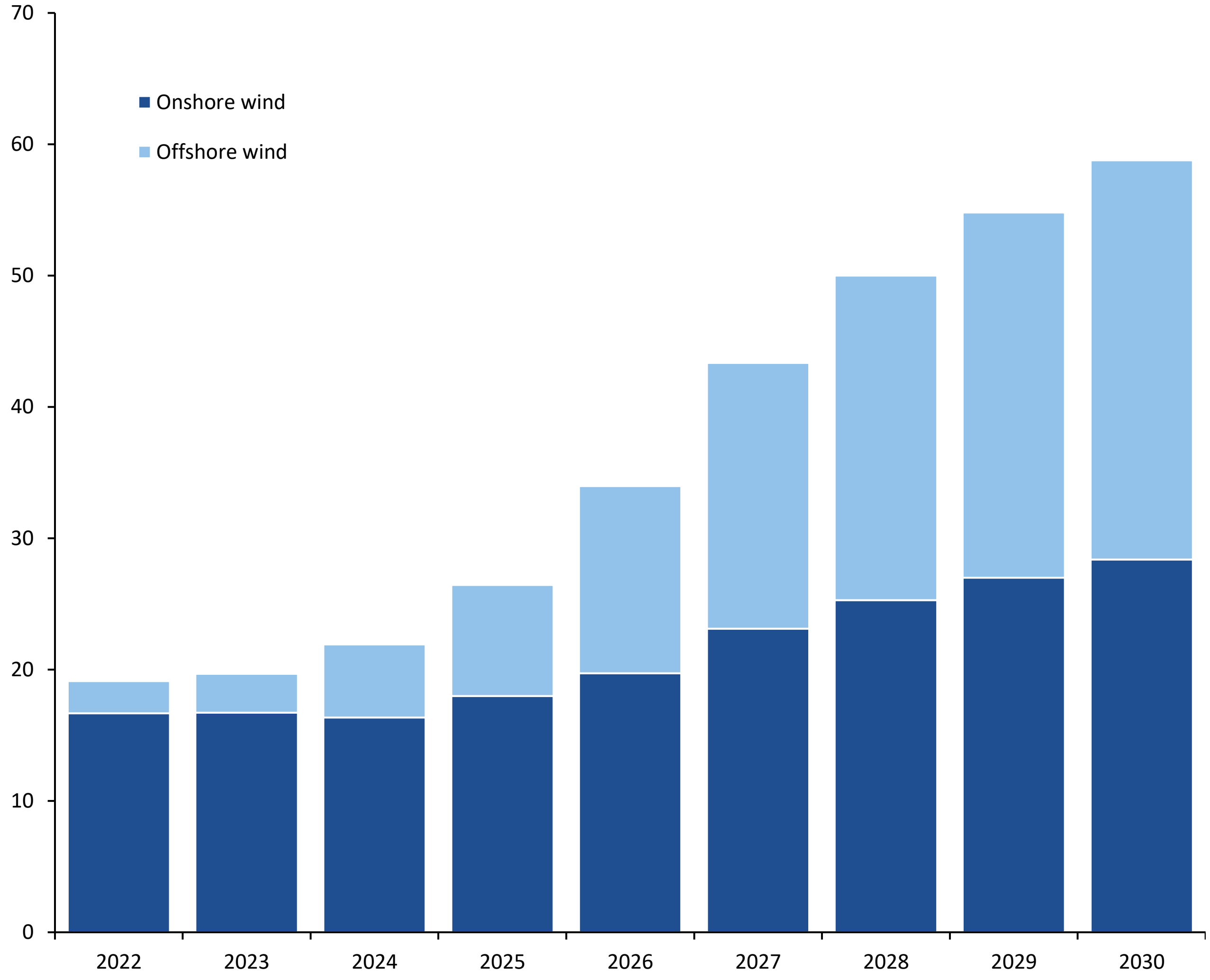
As this report aims to assess Europe's ability to meet its 2030 targets, the **WindEurope *2030 Targets Scenario*** is used as the outset of supply chain considerations, with a theorical installation rate needed to meet the different ambitions.

WindEurope reports 255 GW of installed wind power capacity in Europe at the end of 2022, including 205 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. Under REPowerEU, the EU's binding renewable energy target would be increased to 45% of total energy demand. According to the European Commission's assessments, this would mean a revised target 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 wind and 45% for offshore wind). This allows WindEurope to develop a scenario for 2030 aiming at an installed capacity of 440 GW. To meet this target, the EU needs to install on average 31 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. Also, Turkey has 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.

Figure 5: Annual wind installed 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

Policies as the main driver of renewable energy in Europe

Policy has always been the driving force behind the development of renewable energy in Europe, from the incentive schemes that kick-started the first plant to the most recent challenges to be met through public support.

Since 2019, when the EU presented the European Green Deal as its 2050 roadmap to carbon neutrality, renewable energy has been at the heart of its policy discussions. The EU then introduced the Fit for 55 package in 2021, which included a set of measures to achieve the ambitious Green Deal. One of the key proposals of the package was the EU-wide target of at least 40% renewable energy sources in the overall energy mix by 2030. Later, when the ongoing energy crisis hit Europe, the European Commission published the REPowerEU plan, which aims to reduce the EU's dependency on Russian fossil fuels and accelerate the energy transition. The main takeaways from the May 2022 package for renewables included the increased 2030 target from 40% to 45% of total energy supply, doubling solar PV capacity by 2025 and reaching 600 GW of installed capacity by 2030, and simplifying the permitting processes for renewable energy projects.

Exhaustive bureaucratic permitting processes means that new projects can take time to be approved. In most EU countries, it takes five years on average for a renewable energy project to secure all necessary permits. Thus, speeding up the process is crucial. However, these new commitments can only move forward once the updated Renewable Energy Directive (RED) is approved by all member states. As the updated RED approval could take more than a year, the industry continued over 2022 to call for concrete measures to solve permitting bottlenecks.

On the heels of an eventful year, the EU made it a priority to address rising electricity prices in September 2022 when it announced an emergency market intervention that introduced a revenue cap for renewable energy producers. Faced with the urgent need to accelerate renewable energy deployment, the EU finally hailed on 9 November short-term measures to address the well-known permitting challenges with yet another regulation. The EU adopted the associated Council Regulation on 22 December 2022 to speed up the permitting process for renewable energy projects across the EU, as a temporary and short-term response to the energy crisis.

More recently, the EU presented on February 2023 the Green Deal Industrial Plan (GDIP), aiming to tackle the remaining challenges for the energy transition. In March, the European Commission released the first steps of its plan aiming to finally address the energy trilemma of reliable, affordable, and sustainable energy. The GDIP is seen as the final piece of European clean technology policies, following a long series of plans, new targets, and emergency measures. The announced policies came in the form of three main proposals: the EU electricity market design reform, the Critical Raw Materials Act, and the Net Zero Industry Act.

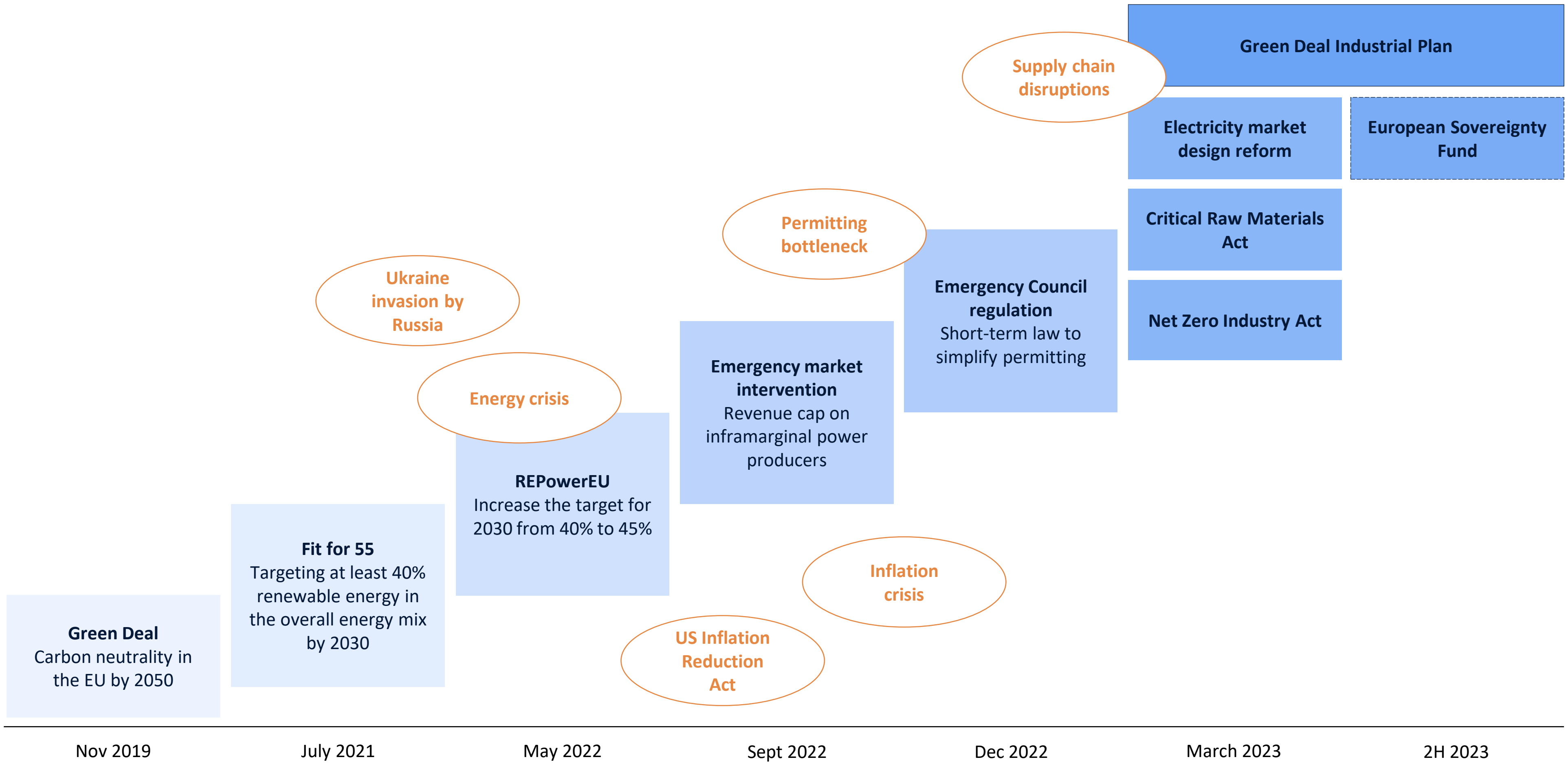
The EU is not alone in tackling the energy crisis: national initiatives have also been announced across Europe. Germany passed a new Onshore Wind Law in 2022, setting a commissioning target of 10 GW per year from 2025 and aiming to solve permitting issues. France approved its so-called Renewable Acceleration Law in 2023, which addresses administrative bottlenecks. Norway, which is betting on offshore wind due to social opposition to onshore wind, set a target last year of 30 GW of awarded offshore wind leases by 2040.

The Esbjerg and Marienborg Declarations underlined the ambition of the North Sea and Baltic Sea countries to develop their installed offshore wind capacity more rapidly by setting targets and strengthening political collaboration. Additionally, several countries are still developing roadmaps, conducive regulations or targets to accelerate their national renewable energy development.

While Europe has made significant progress in recognizing challenges, setting ambitions, and calling for relevant policy packages, much more needs to be done to address supply chain challenges and the lack of targeted financial support.

Source: Rystad Energy research and analysis

Figure 6: Timeline of EU policies for renewable energy development



Source: Rystad Energy research and analysis

The energy crisis in Europe

The record power prices over the past year clearly emphasize the energy crisis.

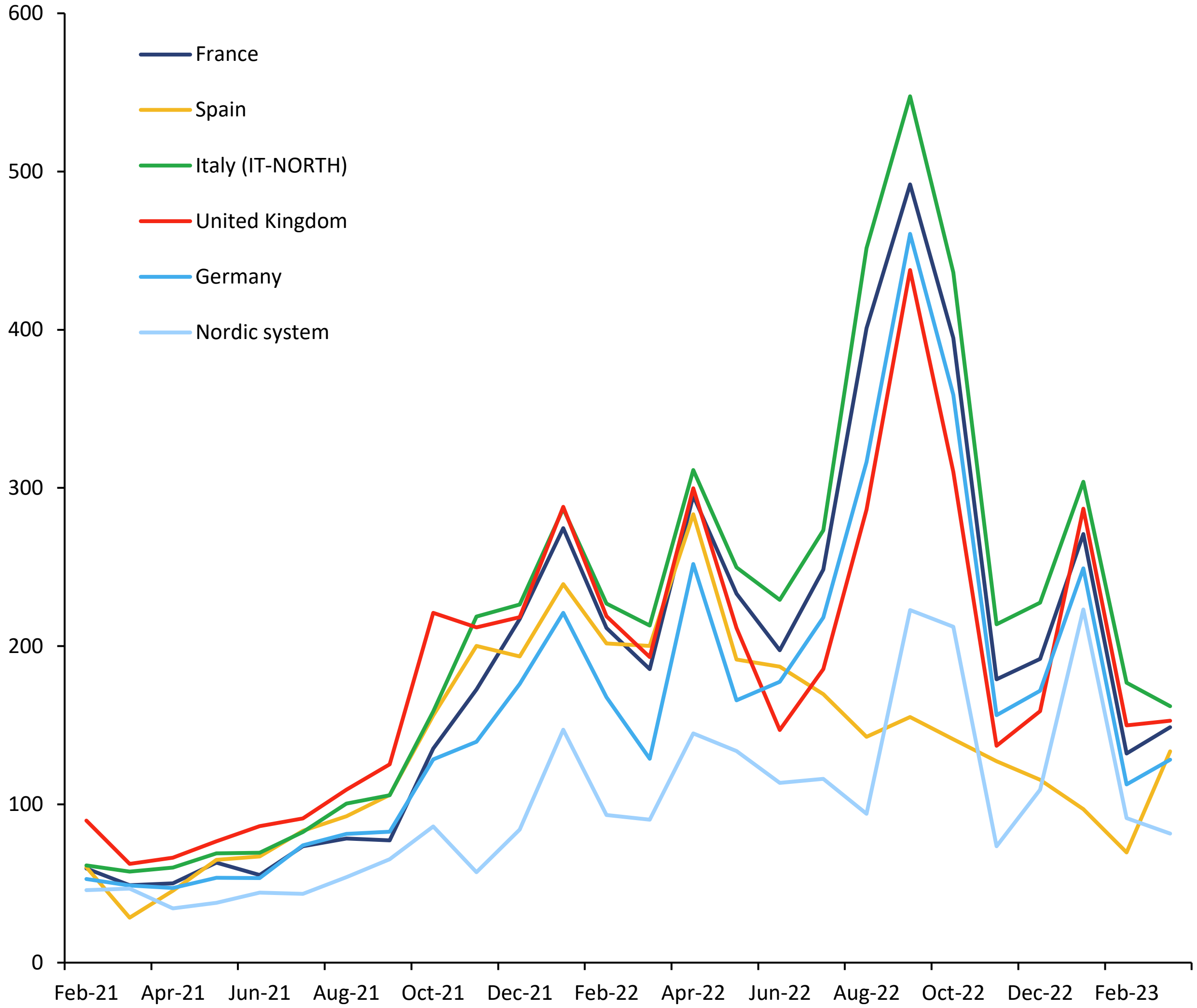
In August 2022, power prices reached record-high levels, averaging over €500/MWh, and record daily and weekly prices exceeding €700/MWh. More recently, the prices in Europe have eased, coming back to pre-crisis levels. This has been enabled by soft fundamentals, including good weather conditions: lower demand due to mild weather, and high renewable energy output.

Fundamentally, the low availability of the French nuclear fleet combined with the low level of hydro power reservoirs put pressure on the capacity of producers to switch to coal power generation. As a result, gas has been the marginal price setter for most of the past year, and the high gas prices caused by the war in Ukraine have resulted in record energy bills and increased financial stress for consumers.

Many times, high renewable energy power generation has brought relief to the energy system and to the consumers. This has highlighted a significant shift in the way to understand the role of renewables in the European power system: not only are wind and solar PV required to achieve the European decarbonization targets, but also to secure a reliable power supply for consumers and to ease energy bills.

The European industry has also been affected by rising energy prices – while inflation has put wind turbine suppliers under severe pressure, rising energy bills have also contributed to lower margins.

Figure 7: Monthly average spot price in selected European markets
EUR/MWh



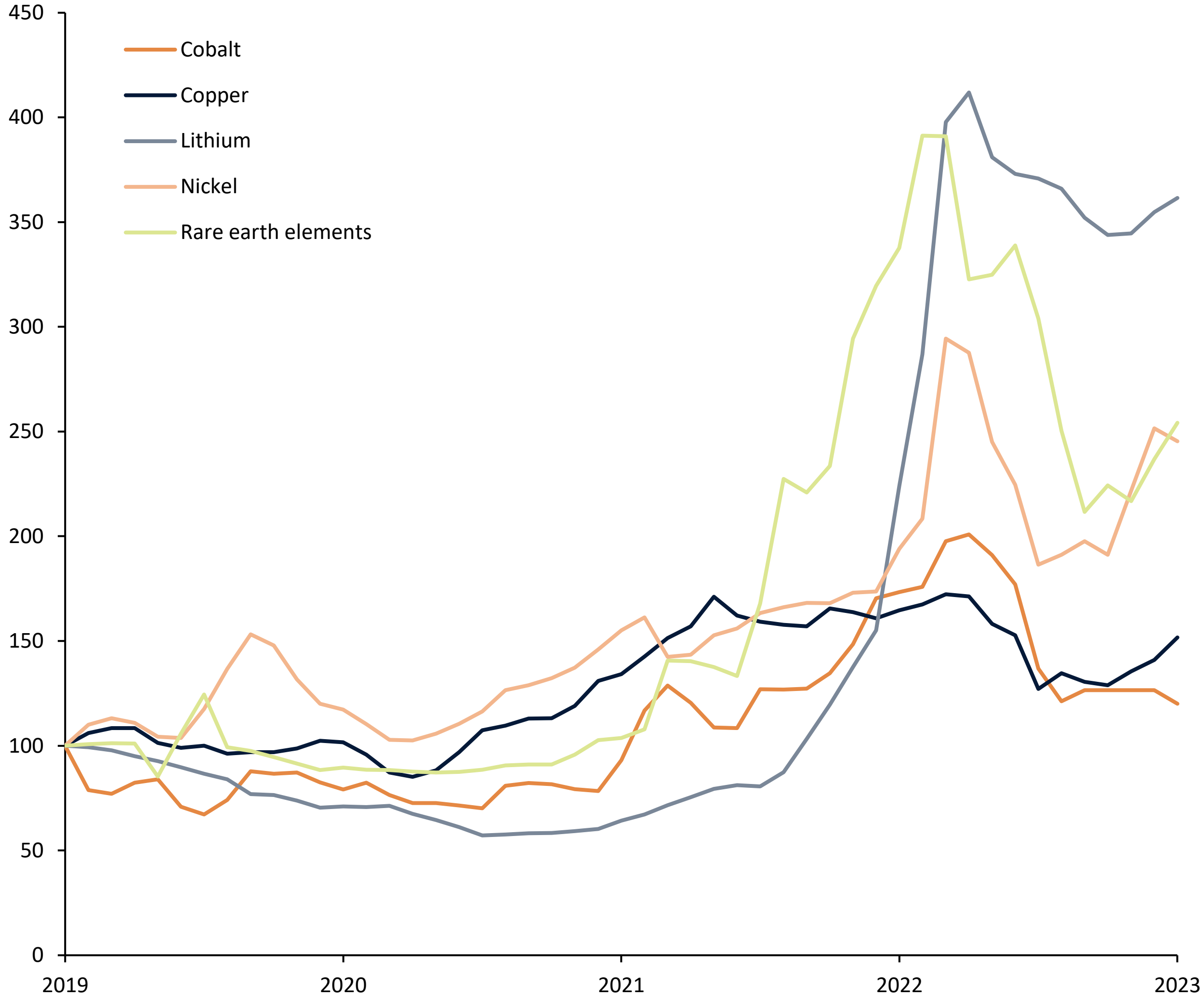
Source: Rystad Energy PowerCube

Raw material inflation

Europe did not only face an energy crisis in 2022, but also the global inflation crisis, affecting critical materials for the energy transition. The main driver was a combination of different economic and geopolitical events across the globe. The end of the Covid-19 crisis in most regions led to a strong activity recovery in key sectors such as the energy transition related industries, and thus increased demand for critical raw materials. While most regions were recovering from the crisis, China faced another major wave, resulting in restrictions on its economy. As China remains the world's largest supplier of most of these materials, the slowdown in its economy had a significant impact on global trade flows of materials and led to production shortages. Russia's invasion of Ukraine created an energy crisis, putting further pressure on material producers. Another consequence has been sanctions on exports of key materials produced by Russia. As a result, sharp price increases have been recorded for materials critical to the renewable energy industry, such as cobalt, nickel and rare earth elements.

Overall, the past year has highlighted a worrying scenario for critical raw materials supply – due to the lack of geographic diversification in the production of each material, their reliability and affordability are constantly threatened by any economic, political or geopolitical uncertainty. This vulnerability is even more true for Europe, which is heavily dependent on imported raw materials, often from quasi-monopolistic suppliers in third countries. In this regard, raw materials are the oil and gas of the energy transition, and in the context of the current war in Ukraine, there could be a similarity between Russia's use of energy as a weapon and the blocking of raw material supplies potentially used to impede Europe's energy transition. Mitigating the risks associated with access to critical raw materials therefore becomes crucial.

Figure 8: Global prices for selected critical materials in low-carbon industries
Indexed 2019=100



Sources: Rystad Energy research and analysis; International Monetary Fund, January 2023

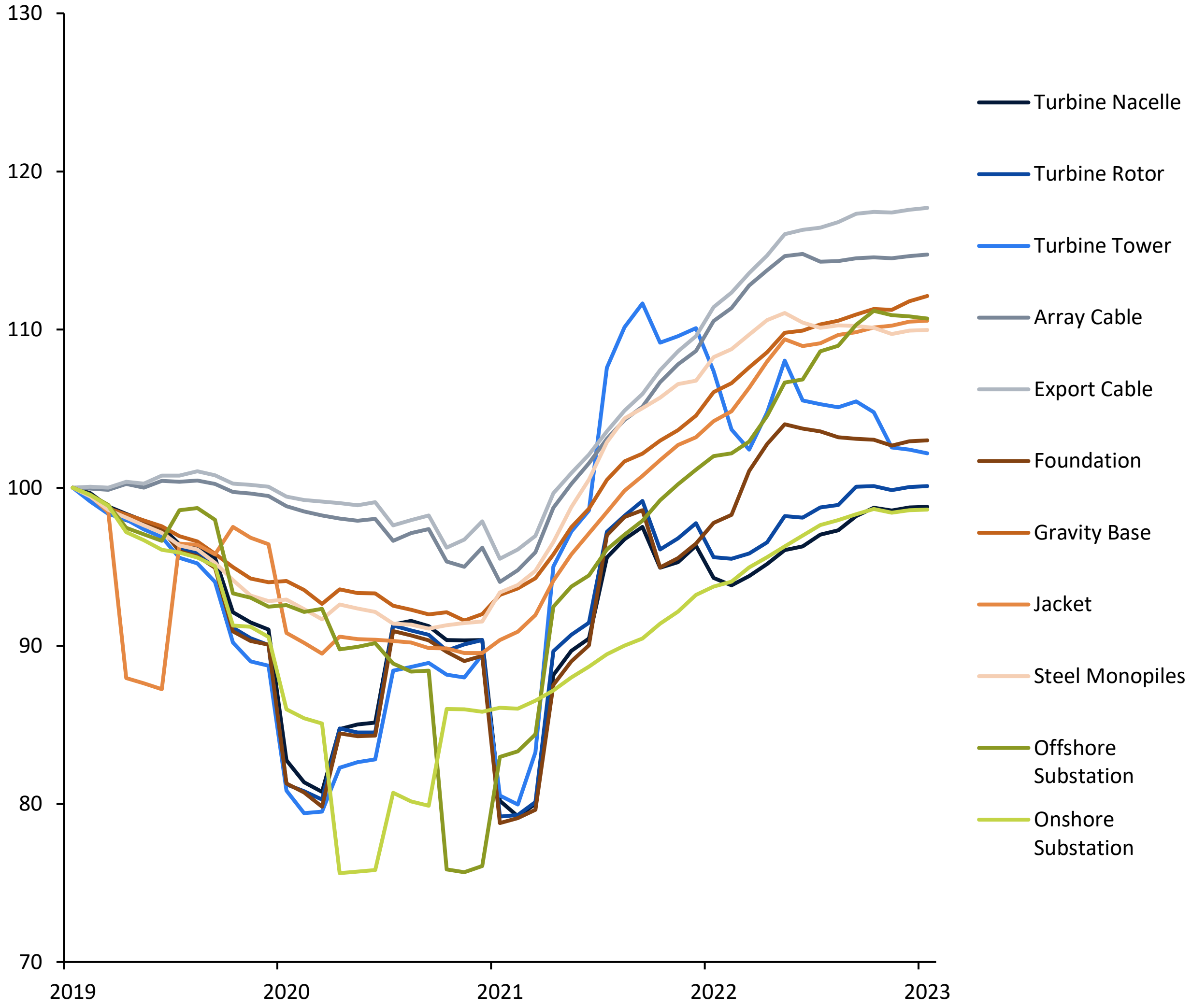
Inflation in the wind industry

Last year's price inflation in energy and raw materials led to a significant increase in price tags for key components in the wind industry, as shown through indices in Figure 9, derived from Rystad Energy's database of discrete prices, industry specific data, supplier performance and market research.

Within the wind energy industry, all sectors have been strongly affected by inflation: turbines, cables, foundations, and substations. Wind equipment manufacturers have had to contend with rising raw material prices and volatile energy prices, but also high shipping rates over the past year. Turbine components were among the most affected by inflation, followed by the sharp increase in cable and monopile costs. In addition, inflation has not only affected key materials and components, but also labor rates and installation costs. The labor market has begun to show its limitations in its ability to sustain the pace of the necessary energy transition, even in mature markets like offshore wind in Europe. As labor-intensive sectors require specific training, the labor shortage could become a major bottleneck for the wind industry in the coming years.

Prices are generally expected to decline in 2023 for most low-carbon technologies as global supply chains normalize after the disruptions caused by previously mentioned factors. In recent months, freight rates and lower commodity prices have eased global inflationary pressures, bringing input cost inflation for many key manufacturers in Europe to its lowest level in over two years. However, uncertainty remains regarding the upcoming evolution of material prices as labor shortages persist, power prices remain volatile, and the rebound in Chinese demand after the end of the zero-covid policy could put additional pressure on the global market. In addition, while costs for inputs such as steel have surpassed their peaks and most commodity prices are expected to decline from past levels, there may not be equivalent relief for component prices as the effects of cost inflation persist and struggling suppliers attempt to recoup profit margins through price increases.

Figure 9: Global service price inflation for selected wind industry segments
Indexed 2019=100



Source: Rystad Energy Service Price Inflation – Low Carbon database

Wind energy suppliers' financial results

Wind equipment suppliers' earnings have been severely affected by cost inflation and supply chain instability. After a sluggish year with an empty order book in 2020, last year brought respite in terms of new orders. However, the upward spiral in raw material prices has left wind turbine suppliers struggling to maintain their profit margins. The growing size of turbines adds to the material usage per turbine, making raw material inflation even more impactful.

Looking at the cumulative revenues of the three listed European turbine suppliers (Vestas Wind Systems, Nordex SE and Siemens Gamesa), an 11% year-on-year decline in their revenues in 2Q 2022 and a 16% drop in 3Q 2022 can be observed. The onshore wind sector revenues have proven more resilient than the offshore wind sector in recent months. In addition, suppliers' margins have also been severely hit by the inflation and supply chain instability. Fundamentally, as input prices skyrocketed, EBITDA margins suffered in the face of locked-in prices for final goods. The combined EBITDA of the three European wind turbine suppliers turned negative in the first three quarters of 2022, resulting in a negative margin of 6% in the first quarter. During the last quarter of the year, supplier revenues and margins started to return to positive levels. However, all announced negative financial results for the full year.

As wind turbine manufacturers begin to shed their locked-in price contracts, most are already beginning to raise their average selling prices to shore up profit margins and shift the cost pressure onto developers. Siemens Gamesa, for example, has announced an increase in its average selling price for onshore turbines from €0.83 million per MW in the fourth quarter of 2022 to €0.95 million per MW in the first quarter of 2023. Despite the soaring wind power demand, it is not yet clear what cost situation developers will face in coming years.

Figure 10: Revenue changes for selected wind turbine suppliers
Percentage change

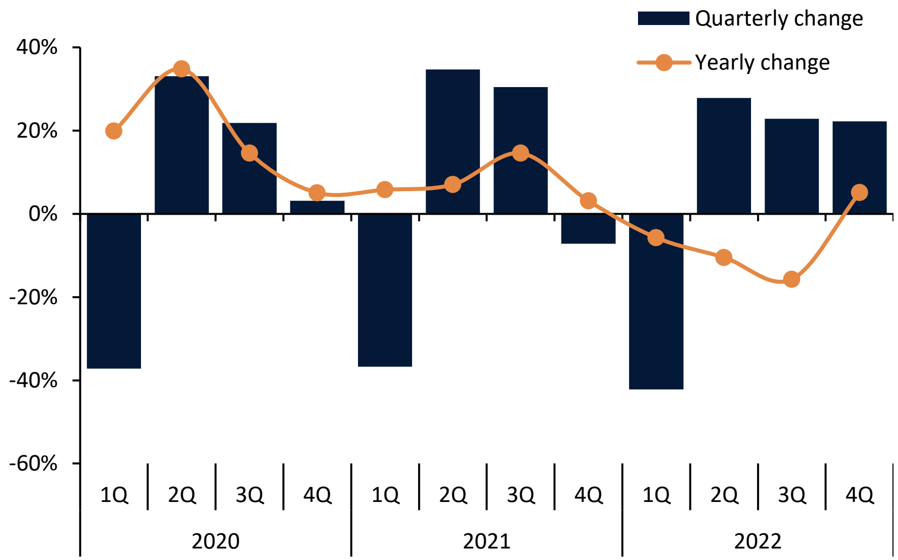
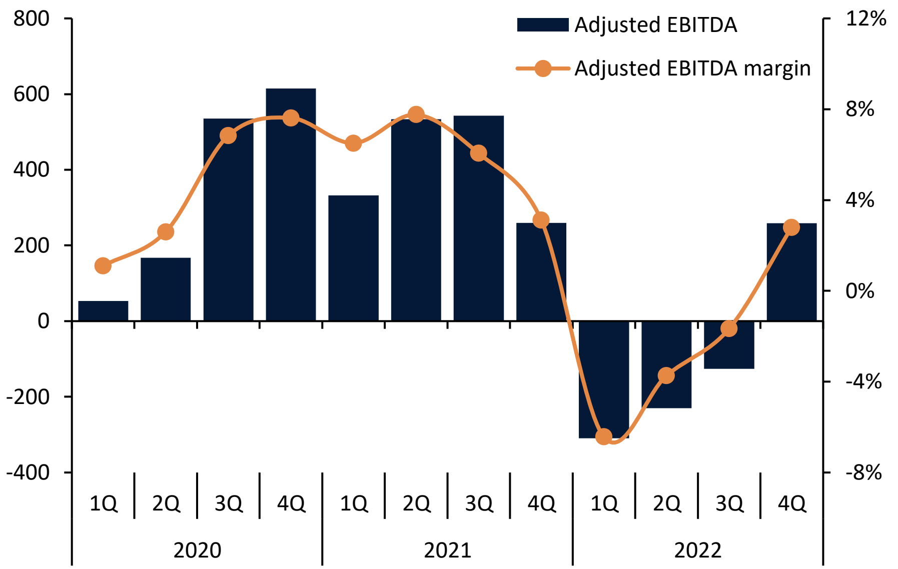


Figure 11: Adjusted EBITDA and EBITDA margin for selected wind turbine suppliers
Million EUR
Percentage



*The selected peer group includes Vestas Wind Systems, Nordex SE, and Siemens Gamesa.
Sources: Rystad Energy research and analysis; Companies financial reporting.

A note on REPowerEU

In May 2022, the European Commission released the REPowerEU plan to address the energy crisis. The plan, now well known, aims to reduce the EU's dependence on Russian fossil fuels and accelerate the transition to carbon-intensive energy sources. The plan focuses mainly on setting new targets, especially for the development of solar PV and diversification of gas supply. Wind power was barely mentioned, with initially no official target for 2030 despite a new ambition for the wide share of renewables in the energy mix. REPowerEU defines the following targets for the renewable energy industry:

- Increase the target for renewables to 45% of total energy supply by 2030
- Double installed capacity of solar PV by 2025, and reach 600 GW by 2030
- Eliminate red tape for renewable energy project permitting
- Produce 10 million metric tons of renewable hydrogen and import an additional 10 million metric tons by 2030

According to the WindEurope *2030 Targets Scenario*, an estimated 440 GW of wind installed capacity would be needed to deliver the REPowerEU target, combined with the targeted 600 GW of solar PV. Based on forward-looking cost assumptions and WindEurope's estimates on the additional capacity needed, Rystad Energy estimates that a total investment of $960 billion would be required between 2023 and 2030 to meet the target. While the cost assumptions considers a learning curve for different technologies, the large upcoming demand for new capacity could put additional pressure on the related supply chains and lead to further cost increases and additional spending needs.

In contrast, the European Commission has estimated an additional investment of €210 billion between May 2022 and 2027 to achieve REPowerEU and phase out Russian fossil fuel imports. While this amount does not suggest funding the entire renewable energy development, it is intended to support the various channels of the plan, including renewable energy, hydrogen infrastructure, grid development or energy efficiency. REPowerEU has estimated that about €584 billion will be needed to be invested in the electricity network between 2020 and 2030. In addition to our previous estimate, this calls into question the actual capacity of the EU to support its own ambitions.

Overall, the plan was criticized for its lack of details on the pathway to achieving the newly announced ambitious goals. REPowerEU primarily announced targets and acknowledged challenges but did not take concrete steps towards addressing the ongoing administrative and supply chain issues.

Figure 12: REPowerEU pillars

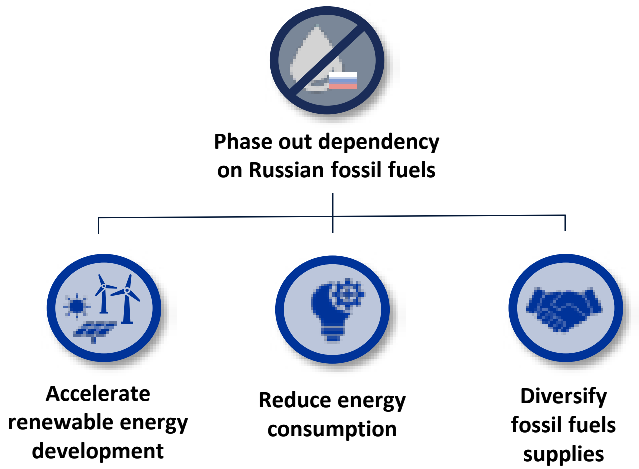
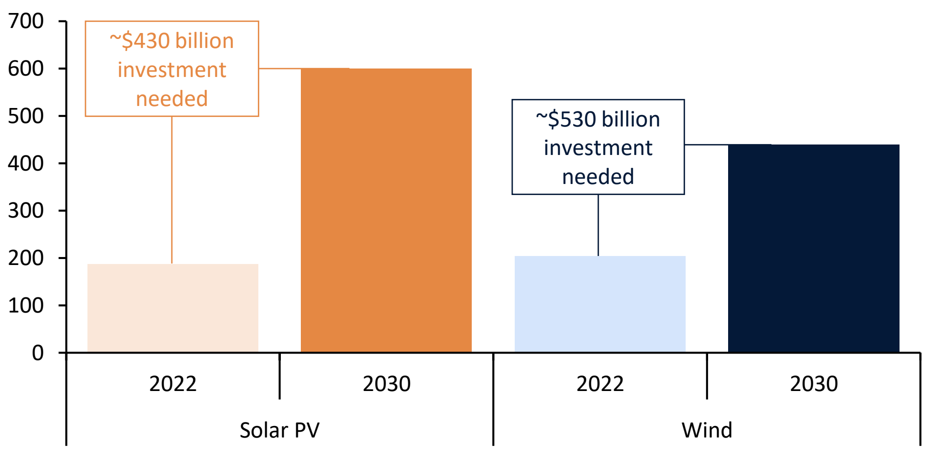


Figure 13: Existing and estimated need for solar PV and wind capacity
Gigawatts (GW_{AC})



Sources: Rystad Energy research and analysis; Rystad Energy RenewableCube

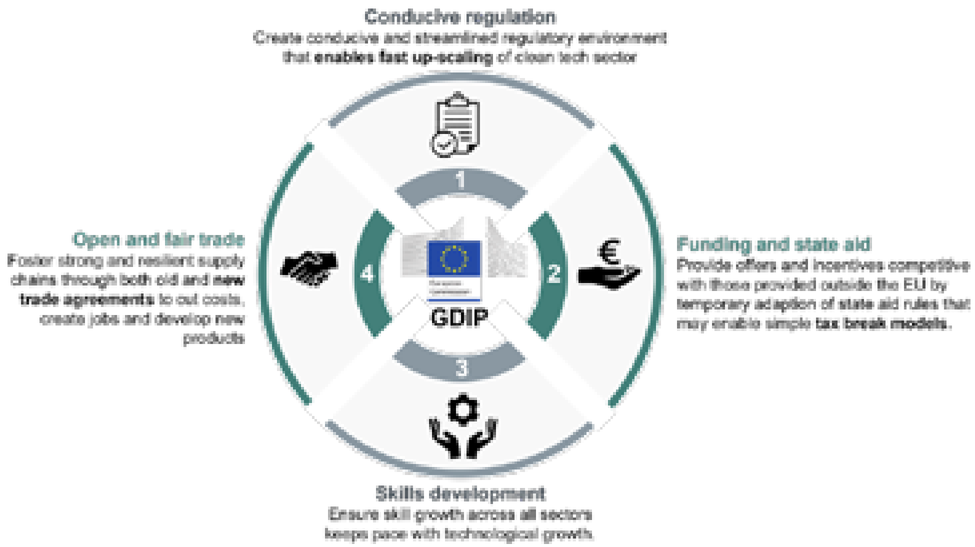
Green Deal Industrial Plan – EU's step towards clean tech sovereignty

The EU entered 2023 working to tackle the ongoing risks to its energy transition by launching the Green Deal Industrial Plan (GDIP). Although Europe has managed to overcome winter despite the energy and inflation crisis, new challenges need to be addressed. Europe's main concern at present is securing access to critical raw materials, developing its domestic production and retaining its clean tech industry.

There are three main levers for the EU to meet these challenges: de-risking disruptions from other markets, solving historical bottlenecks through a conducive regulatory framework, and dedicating financial support. While the US Inflation Reduction Act could disrupt transatlantic trade and investment, the EU aims to allow its domestic industry to benefit and enhance EU-US collaboration. It is unclear at present how European firms could potentially be exempt from the Inflation Reduction Act regulations in the US, but if it were to happen, it would only be a temporary solution as companies would eventually have to relocate to the US after 2025 to meet the conditions set under the regulations. And, in the case of China, the EU sees it as essential to reduce the risks of unfair practices against EU companies through means such as Foreign Subsidies Regulations, but without breaking ties with a key partner.

To address regulatory bottlenecks and supply chain challenges, which have remained the largest hold-up to renewables development in Europe for years, the EU proposed the GDIP. As part of it, the implementation of centralized 'one-stop-shops' for permitting has been announced, which could help to streamline the process if adequate administrative capacity is available. When it comes to supply chain bottlenecks, Europe is facing growing challenges. China is dominating the entire solar PV value chain, from polysilicon production to cell and module manufacturing. In addition, the wind industry supply chain needs similar support to recover supplier margins and competitiveness. It would be relevant for the GDIP to set anti-relocation measures for the renewable energy supply chain sector in the form of direct financial support, simple tax break models, tax credits or even accelerated depreciations. The European Commission released on 16 March 2023 the first steps of the GDIP. The recent policies came in the form of three main proposals: the EU electricity market design reform, the Critical Raw Materials Act, and the Net Zero Industry Act. The proposals still need to be approved by the European Council and Parliament, which could result in changes and address some of the concerns raised by the industry. Details of the packages are listed on the next page.

Figure 14: The four pillars of the EU Green Deal Industrial Plan



Sources: Rystad Energy research and analysis; EU Commission

Figure 15: Key measures of the March 2023 policy packages communicated by the EU

GDIP first pillar – Conducive regulation facilitation	
Policy packages	*Relevant measures for the renewables industry*
Net Zero Industry Act	• Definition by each Member State of a national authority acting as a **centralized "one-stop shop" for the permitting process of net-zero technology manufacturing projects**. The national authority will oversee the coordination, facilitation and **digitization** of the permitting process • **Capping of the permitting process** for those projects at **12 months for an annual production capacity of less than 1 GW, 18 months for more than 1 GW** • '**Net-zero strategic projects**' to be granted priority status for permitting, reduced delays, and potentially, the overriding public interest status • Framework for accounting sustainability and resilience criteria when awarding projects through auctions • Implementation of '**Net-Zero Industry Academies**' to design courses to ensure a properly skilled workforce
Critical Raw Materials Act	• Identification by the EU of a list of critical and strategic raw materials for which domestic capacities should be by 2030 of at least (as a share of annual EU consumption): **10% for extraction, 40% for processing, 15% for recycling** • Capping of each strategic raw material **dependance on a single third country at 65%** of its annual consumption, at any relevant processing stage • Permitting procedures simplification for critical raw materials supply chain projects in the EU • Selected strategic projects will benefit from support to **access finance and shorter permitting timeframes** (24 months if involving extraction and 12 months if involving processing and recycling)
Electricity Market Design Reform	• Facilitation of power-purchase agreement (PPA) deployment through public support, such as **governmental financial guarantees** for offtakers • Common framework for direct support schemes through the **two-way contracts for difference (CfD)** mechanism • **Combination** of CfDs and PPAs is allowed, and electricity producers keep the right to sell their electricity on the **merchant market** • Incentives for demand response and **storage** deployment • Non-application of the **inframarginal electricity revenue cap** as a market long-term feature • Introduction of **Transmission Access Guarantees** for hybrid offshore wind farms*

Note: *Offshore wind farms that have grid connections to two or more countries.
Sources: Rystad Energy research and analysis; EU Commission

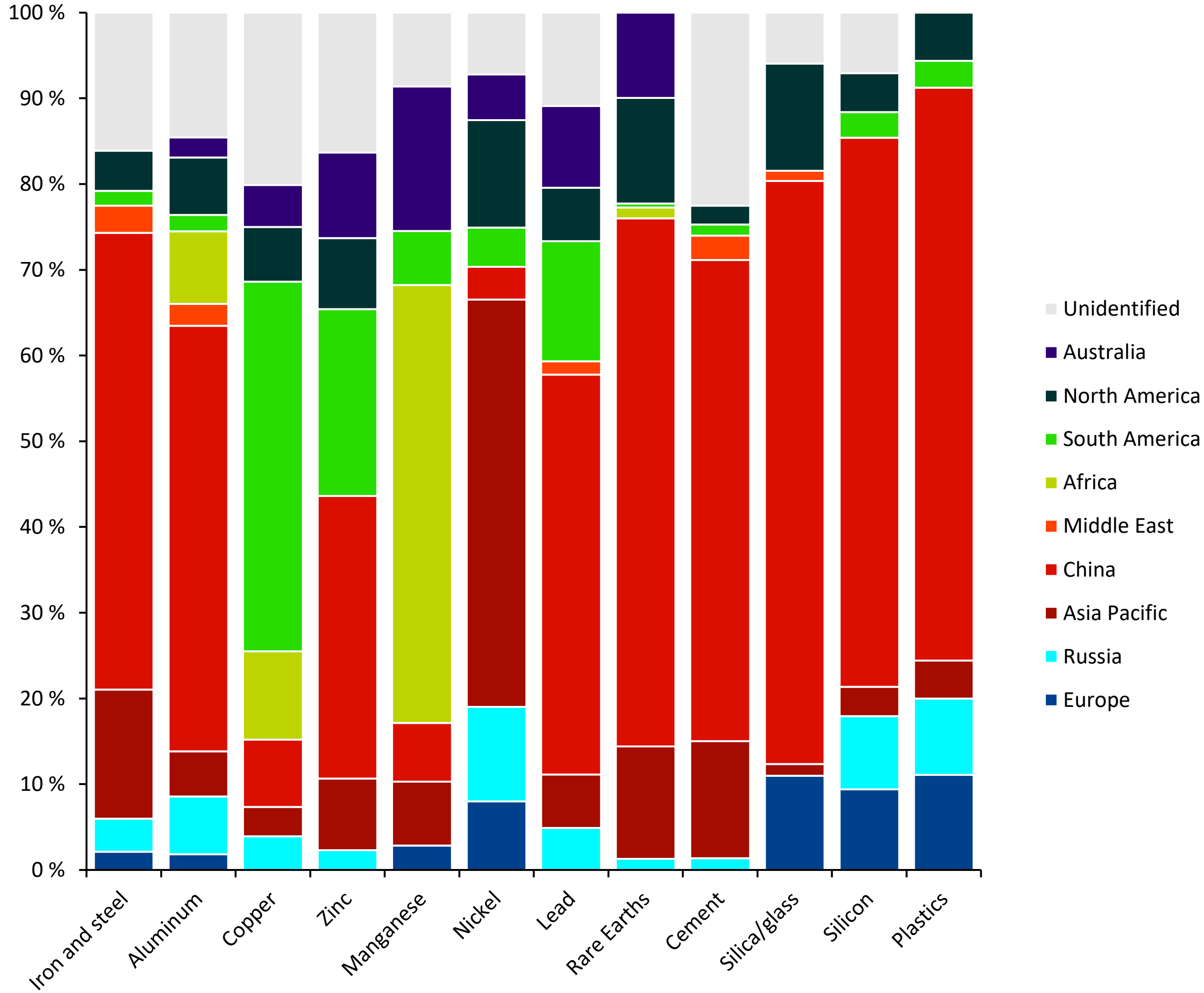
Europe’s place in global material production

Recent European policies have acknowledged that raw material dependence is a major risk to EU sovereignty in the energy transition. Global supply remains heavily dominated by China, which is the leading global supplier for nine of the materials analyzed. Europe remains underrepresented in the global materials supply due to a combination of low reserves and past mining investments. The events of the past year – combining post-Covid-19 shortages and several impacts of Russia's invasion of Ukraine – have highlighted the need for Europe to mitigate the risks of such strategic dependencies.

On average, China's share of global materials production is three times the share of Chinese reserves, illustrating both China's rapid economic growth and investment in its mining sector, as well as the potential for greater diversification in the global supply chain. China controls more than half of the wind production process, including raw material production and individual component manufacturing. This dominance can be nuanced as Chinese domestic demand meets most of China's wind production capacity. However, while China’s polysilicon supply dominance has been of most concern so far due to the huge global demand for solar PV, potential geopolitical issues in China could also strongly affect the global wind energy supply chain balance.

Russia remains a significant producer of some of the materials analyzed, such as steel, aluminum, nickel or silicon. Russia's invasion of Ukraine has therefore significantly impacted materials’ trade flows. In response to the invasion, roughly 45 countries added targeted sanctions against Russia or committed to a combination of US and European sanctions. Among the sanctioned materials relevant to the wind industry were fossil fuels, steel, cement, and plastics. Additionally, a further 35% tariff was added by the US on imports of metals including copper, aluminum, lead, silver, iron, and steel. These sanctions illustrate the potential disruptions that could affect the current picture of global material supply.

Figure 16: Global material production by region, 2019
Share (%)



Note: Unidentified supply refers to production that is unknown or spread over too many countries. Steel supply includes primary and secondary production. Zinc, manganese and nickel include primary production only. Aluminum, copper and lead do not include production from recycled materials. Source: Rystad Energy research and analysis

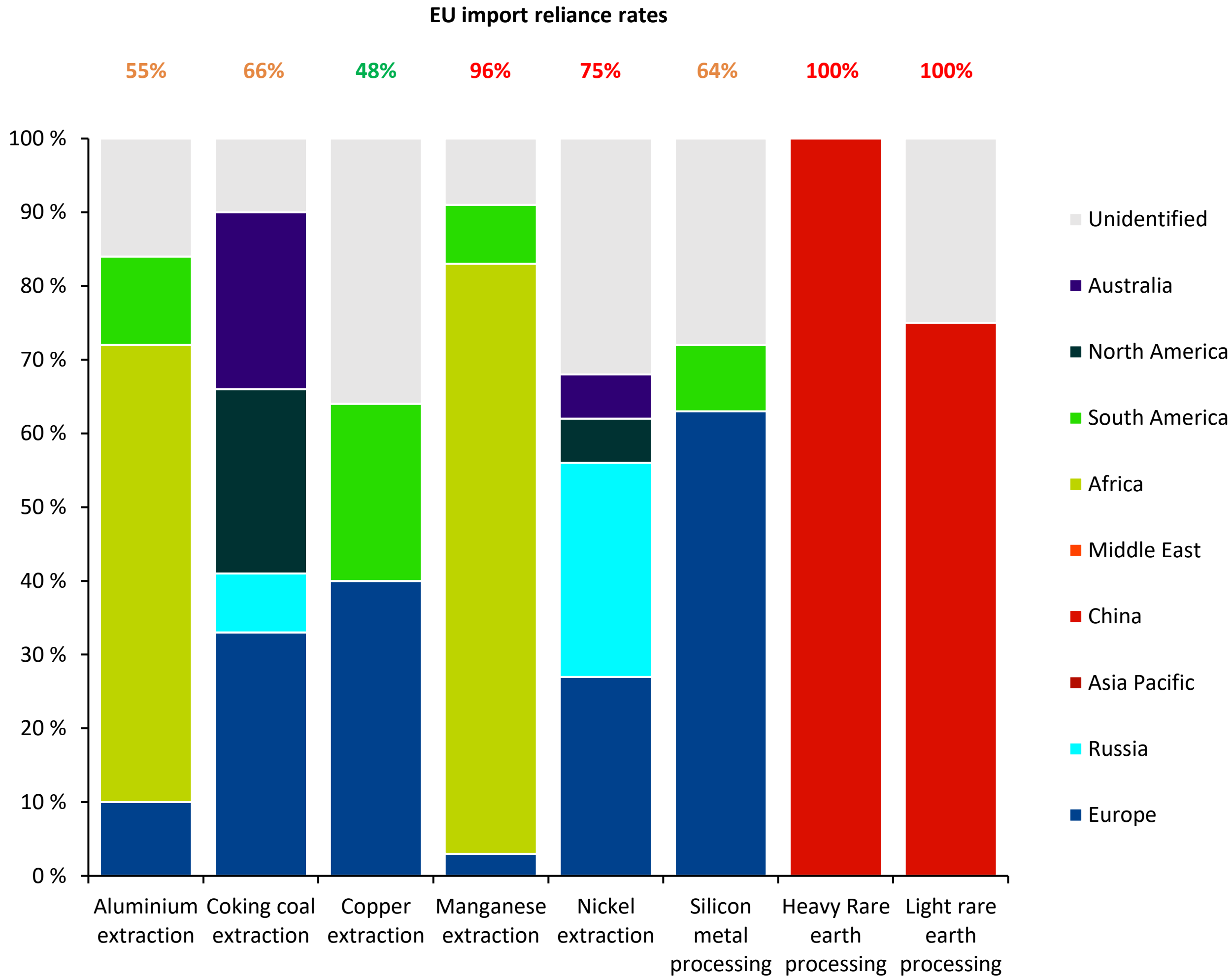
European material import dependency

As the EU aims to reduce its dependency on third-country suppliers for its cleantech sectors, it becomes critical to increase its manufacturing capacity along the entire value chain, i.e., from raw material extraction and processing to component production. Indeed, even if Europe increases its turbine manufacturing capacity but still depends on a third country for raw materials inputs, the bottleneck is only shifted. While the Net Zero Industry Act aims to support component supply chain sovereignty, the Critical Raw Materials Act aims to ensure the EU's access to a secure, diverse, affordable and sustainable supply of critical raw materials. In that sense, the EU has submitted an updated list of raw materials identified as critical or strategic for Europe's green and digital transition. The domestic capacities for those materials will have to meet the following objectives:

- Extraction, at least 10% of the EU's annual consumption
- Processing, at least 40% of the EU's annual consumption
- Recycling, at least 15% of the EU's annual consumption
- Cap of each strategic raw material dependance on a single third country at 65% of EU's annual consumption, at any relevant processing stage

Figure 17 illustrates some of the raw materials impacting the wind industry and considered by the EU as critical or strategic. For most of these materials, the import reliance rate is above 50%, which defines the supply risk for the EU. Although China is the world's largest supplier of most critical raw materials, analysis of the EU's primary supply (i.e., domestic production plus imports) tells a different story. The selected raw materials come from a wide range of countries, but for most of them, Europe is heavily dependent on imports, often from near-monopolistic third-country suppliers.

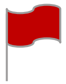
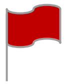
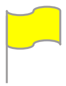
Figure 17: EU's primary supply of selected critical raw materials by region of origin, 2023
Share (%)



Note: Unidentified supply refers to production that is unknown or spread over too many countries. Import Reliance rate = (Import – Export) / (Domestic production + Import – Export)
Sources: Rystad Energy research and analysis; European Commission, Study on the Critical Raw Materials for the EU 2023 – Final Report

Key findings

Table 1: Key findings summary, selected parts of the supply chain unique to the wind industry

Segment	Industry	Sub-segment	2022-2030 demand growth*	Time to action*	Urgency assessment	Comment
Turbines	Onshore & Offshore wind	Total market	**~3X** *Capacity (MW)*	**2024-2025**		• *High inflation, low margins and an R&D race to supply the largest turbines on the market has put pressure on western OEM's ability to expand manufacturing capacities or repurpose facilities to accommodate a changing demand.* • *While onshore wind turbine size demand is relatively more stable, expansion of manufacturing is needed to match growth in activity levels in the 2030 Targets Scenario.* • *Offshore wind serves as the key challenge, with a large gap between current manufacturing capacity and projected demand for the largest models.* • *Rotor blade manufacturing represents the current bottleneck for European turbine supply, but both need a rapid expansion to meet demand in this scenario.*
	Offshore wind	>12 MW turbines	**0-29 GW**	**2024**		
Towers	Onshore & Offshore wind	All	**~2.5X** *Metric tons*	**2025**		• *Centralized tower supply for a larger range of turbines has enabled the supply chain to expand with growing activity.* • *Tower demand will be driven by a relatively high number of onshore wind turbines (compared to offshore wind) and increasing offshore wind activity and sizes.* • *Growth is expected to accelerate in the second half of the decade, creating an additional need for expansion.*
Foundations	Offshore wind	Monopiles	**~12X** *Metric tons*	**2024-2025**		• *Monopiles will remain the most popular concept in Europe, and with rapid growth in activity and turbine sizes in offshore wind, manufacturing must be scaled up quickly within the largest monopile segments.* • *Jacket manufacturing capacity less constrained thanks to O&G industry.* • *Floating foundation manufacturing must be industrialized. Today, it is characterized by pilots, demos and pre-commercial projects with one-off manufacturing and few units. From this small basis, manufacturing capacity must grow substantially towards the end of the decade.*
		Other grounded	**~7X** *Metric tons*	**None**		
		Floating	**~23X** *Metric tons*	**2024**		
WTIVs	Offshore wind	Total market	**~7.5X** *Vessel years*	**2024-2025**		• *Strong fleet additions in recent years have put supply in a strong position to cover demand in the next two to three years. Increased demand in the second half of the decade, primarily in the largest turbine size ranges will put pressure on supply.* • *A global fleet and increasing demand outside Europe will likely pull supply out of Europe, worsening the supply-demand balance, with new units forecast to be needed.* • *An increasing share of demand in the 15-20 MW range towards 2030 will also drive a need for new units, as the fleet of vessels capable of installing these units is currently limited.*
		>12 MW turbines	**0-25 vessel years**			

*Estimated European demand based on *2030 Targets Scenario*. Time to action refers to the estimated year when supply expansions need to be initiated to avoid a potential bottleneck.
Source: Rystad Energy research and analysis

Global wind turbine manufacturing and shipments

We estimate that the global wind turbine manufacturing capacity is approximately 166 GW, about 8% higher compared to 2021's tally. Europe contributed for about 16% of the global manufacturing capacity in 2022. Europe's turbine manufacturing capacity is discussed in detail on pages 28 to 31.

Expansions last year were seen in Europe and China, with multiple Chinese suppliers unveiling their capability to make offshore wind turbines in the range of 12 to 16 MW.

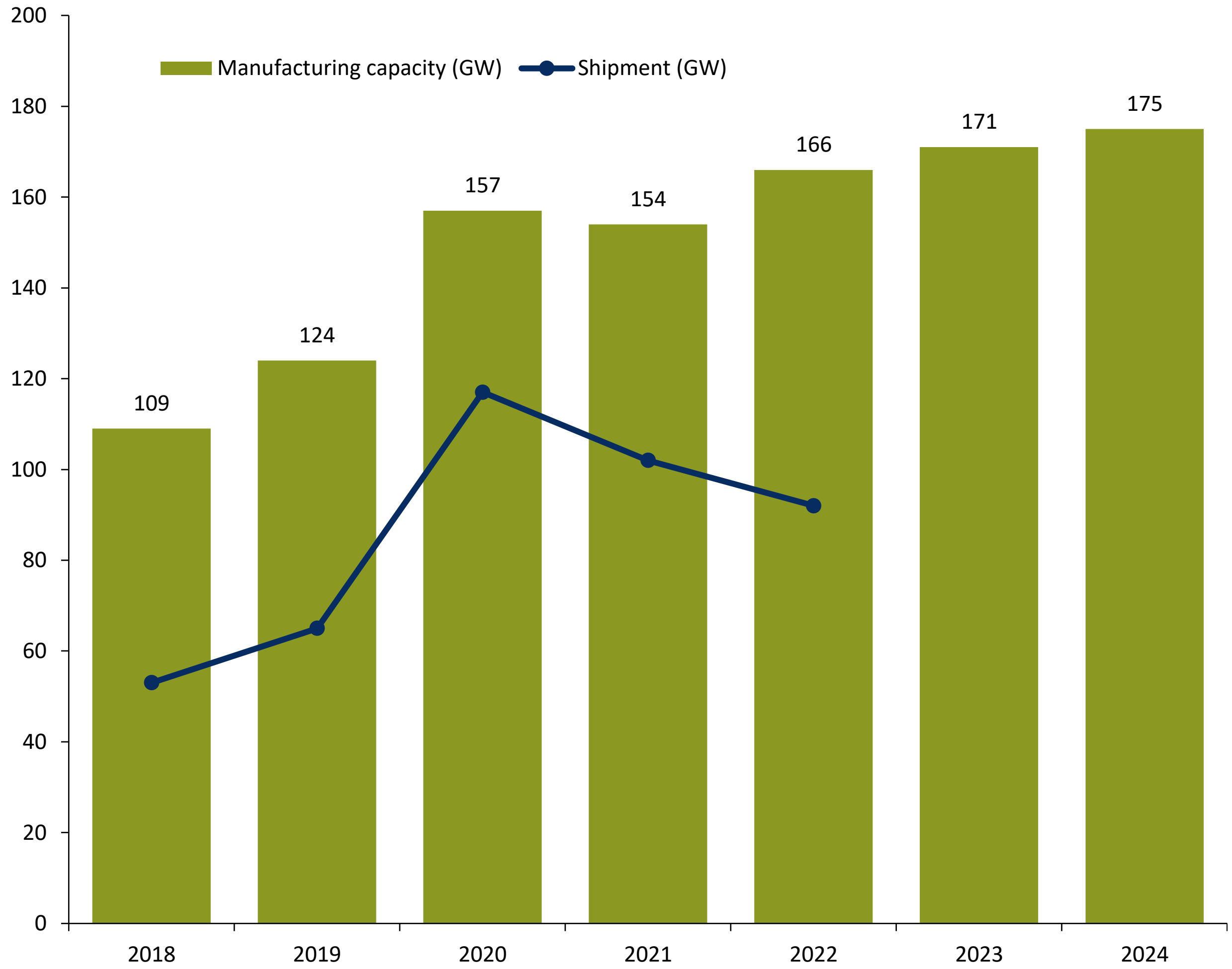
In Europe, Siemens Gamesa opened its French turbine manufacturing base in Le Havre in March 2022. Meanwhile, multiple companies in China, such as Envision, CSSC Haizhuang Windpower, Shanghai Electric, MingYang and Windey, expanded their manufacturing capacities with new facilities, totaling more than 8 GW. Most of these Chinese expansions are for offshore wind turbines, with turbine capacities ranging from 10 to 13 MW.

The manufacturing capacity in 2021 saw a decline compared to 2020 as some plants capable of making 2 MW turbines were shut down due to a lack of orders. On the other hand, the steep ramp-up in manufacturing capacity observed in 2018-2020 was mainly driven by a significant wind installation ramp-up in China, where about 65 GW of onshore wind was installed in 2020 and about 14 GW of offshore wind capacity was deployed in the country in 2021.

We forecast that by the end of this year, global wind turbine manufacturing capacity will stand at 171 GW, with further expansions led by China. This tally is envisaged to increase to 175 GW next year, with turbine manufacturing for offshore wind driving expansions.

In 2022, the utilization rate dropped to about 55%, as slow permitting and inflation affected turbine manufacturers' sales and deliveries. This tally is lower compared to 2021's utilization rate of more than 65%, when global wind shipments reached more than 100 GW for both onshore and offshore wind turbines.

Figure 18: Wind turbine manufacturing capacity forecast up to 2024
Gigawatts (GW)



Sources: Rystad Energy research and analysis; Companies' annual reports and websites.

Turbine manufacturers supply capacity in 2022

The top five wind turbine manufacturers account for more than half of the global wind turbine manufacturing capacity. Vestas leads with more than 20 GW of manufacturing capacity, while China's largest wind turbine maker Goldwind sits on the second position with about 18 GW. Vestas' Western competitors, including General Electric and Siemens Gamesa, stand in the third and fourth place, respectively, with a combined manufacturing capacity of more than 30 GW. Another Chinese manufacturer, Envision, holds the fifth position with almost 14 GW.

With the rising installation demand in recent years in China, many other Chinese OEMs ramped up their manufacturing capacity.

Outside of Goldwind and Envision, other Chinese OEMs such as MingYang and Windey are within the top ten rank of global wind turbine manufacturers.

Regarding shipments, Vestas leads with more than 13 GW of turbines shipped last year, followed by Goldwind and Envision, which shipped more than 20 GW of turbines combined last year. Siemens Gamesa delivered more than 8 GW of turbines, while GE delivered only about 7.5 GW of turbines last year, a 45% drop compared to its previous year's turbine shipments of almost 12 GW.

Figure 19: Wind turbine manufacturers' capacity in 2022
Gigawatts (GW)

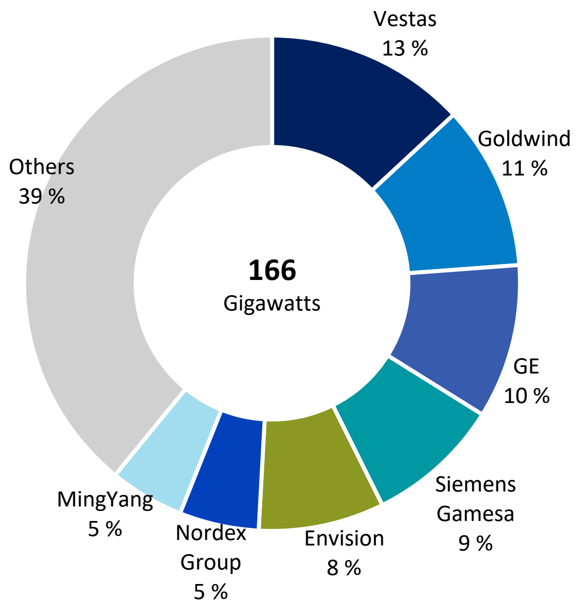
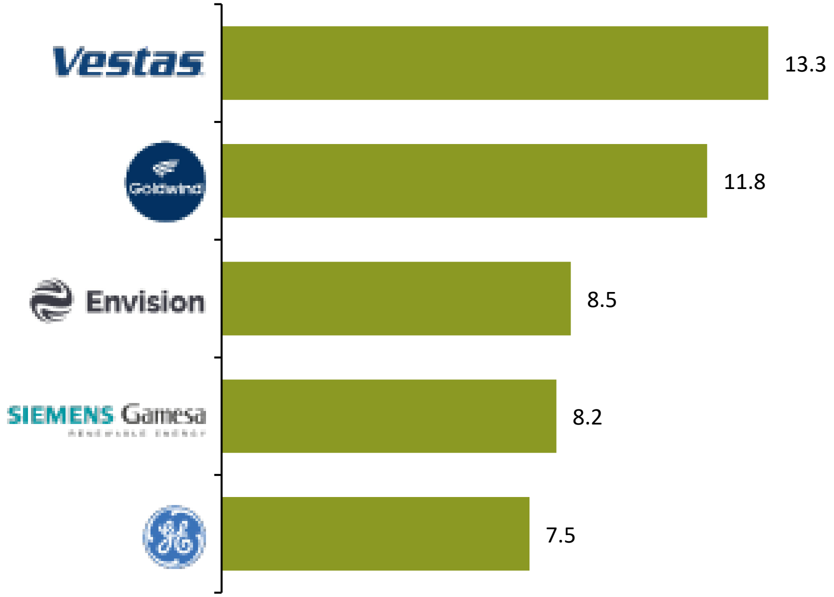


Figure 20: Top five turbine manufacturers' shipment* in 2022
Gigawatts (GW)



*Chinese OEMs' shipments are estimated based on annual installed capacity.
Sources: Rystad Energy research and analysis; Rystad Energy RenewableCube; Vestas annual report 2022; Siemens Gamesa activity report Q1-Q4 2022; GE annual report 2022; Companies' annual reports and websites.

Global blade and nacelle manufacturing capacity

We estimate that global blade manufacturing capacity stood at 166 GW by the end of last year. China holds most of blade manufacturing, accounting for more than 60%, while Europe follows with about 15%. India and the US have also contributed significantly to global wind turbine manufacturing, although both mainly produce smaller, onshore wind turbines. The wind blade market largely depends on independent blade producers, such as TPI Composites and other prominent Chinese blade manufacturers, including LZ Blades, Zhuzhou Times New Material and Sinoma. We estimate that TPI is the largest blade manufacturer globally, with many Western manufacturers sourcing blades from it.

Blades are currently the bottleneck among the main wind turbine components, with slightly less global manufacturing capacity than that for nacelles. China also leads the nacelle market, accounting for almost 60% of the global manufacturing capacity. Rystad Energy estimates that Europe's contribution to global nacelle manufacturing was about 17% in 2022. Vestas, Goldwind, and Envision are estimated to be the top three nacelle manufacturers globally. Based on Rystad Energy research, most of the prominent manufacturers produce nacelles in-house rather than outsourcing them.

Strong domestic demand and a strategy to build up its domestic wind supply chain are the main reasons for China's lead in wind manufacturing. In addition, ample raw material supplies and cheap labor rates have made Chinese turbines competitive on the global market. In China, the estimated price range in 2022 was around $350 to $450 per kW for onshore wind turbines and $560 to $700 per kW for offshore wind turbines. This is significantly lower than Europe's range of $800 to $1,100 per kW for onshore and $1,000 to $1,600 USD/kW for offshore turbines.

Figure 21: Blade manufacturing capacity by region and manufacturer, 2022
Gigawatts (GW) per year

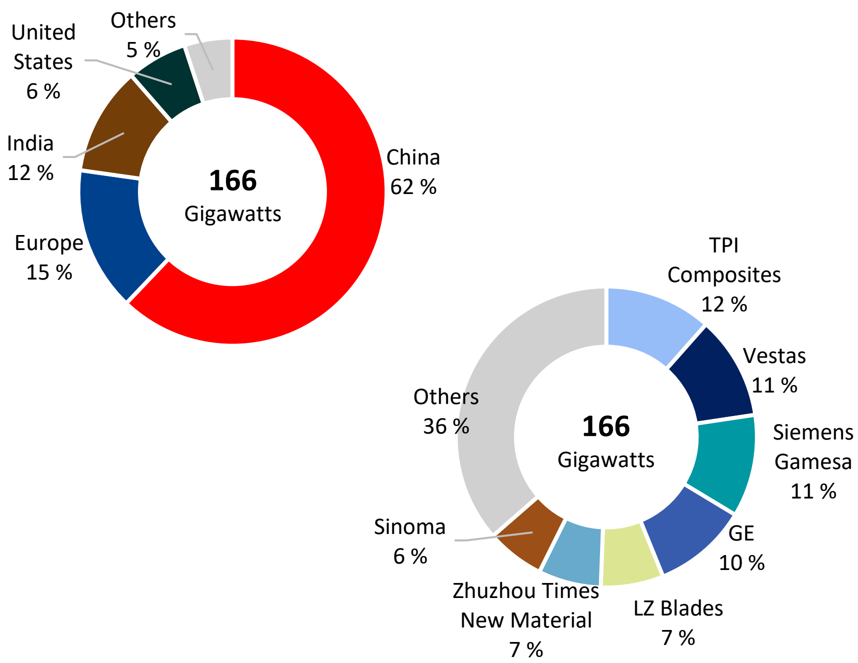
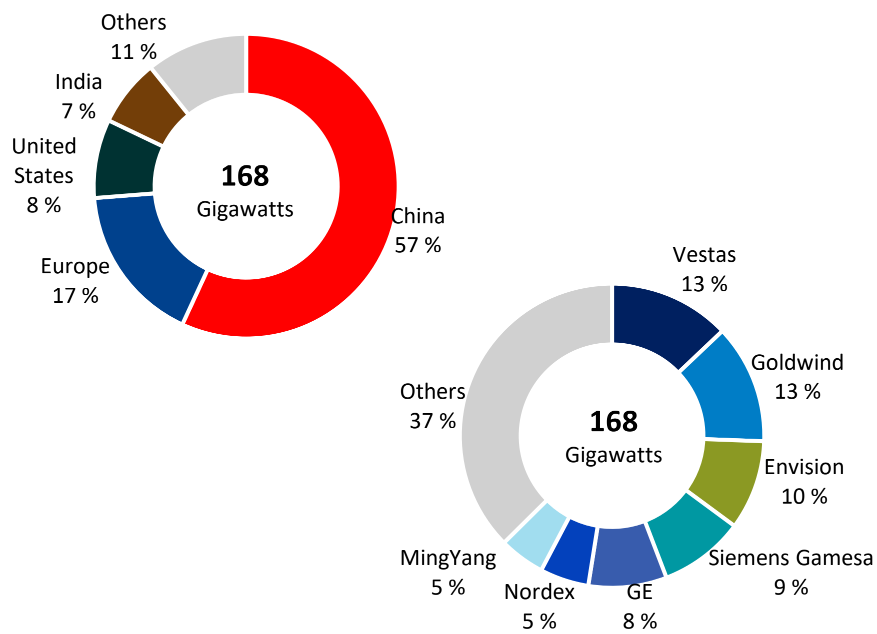


Figure 22: Nacelle manufacturing capacity by region and manufacturer, 2022
Gigawatts (GW) per year



Sources: Rystad Energy research and analysis; Companies' annual reports and websites; Chinese wind projects' turbine bid results in 2022.

Blade and nacelle manufacturing facilities in Europe

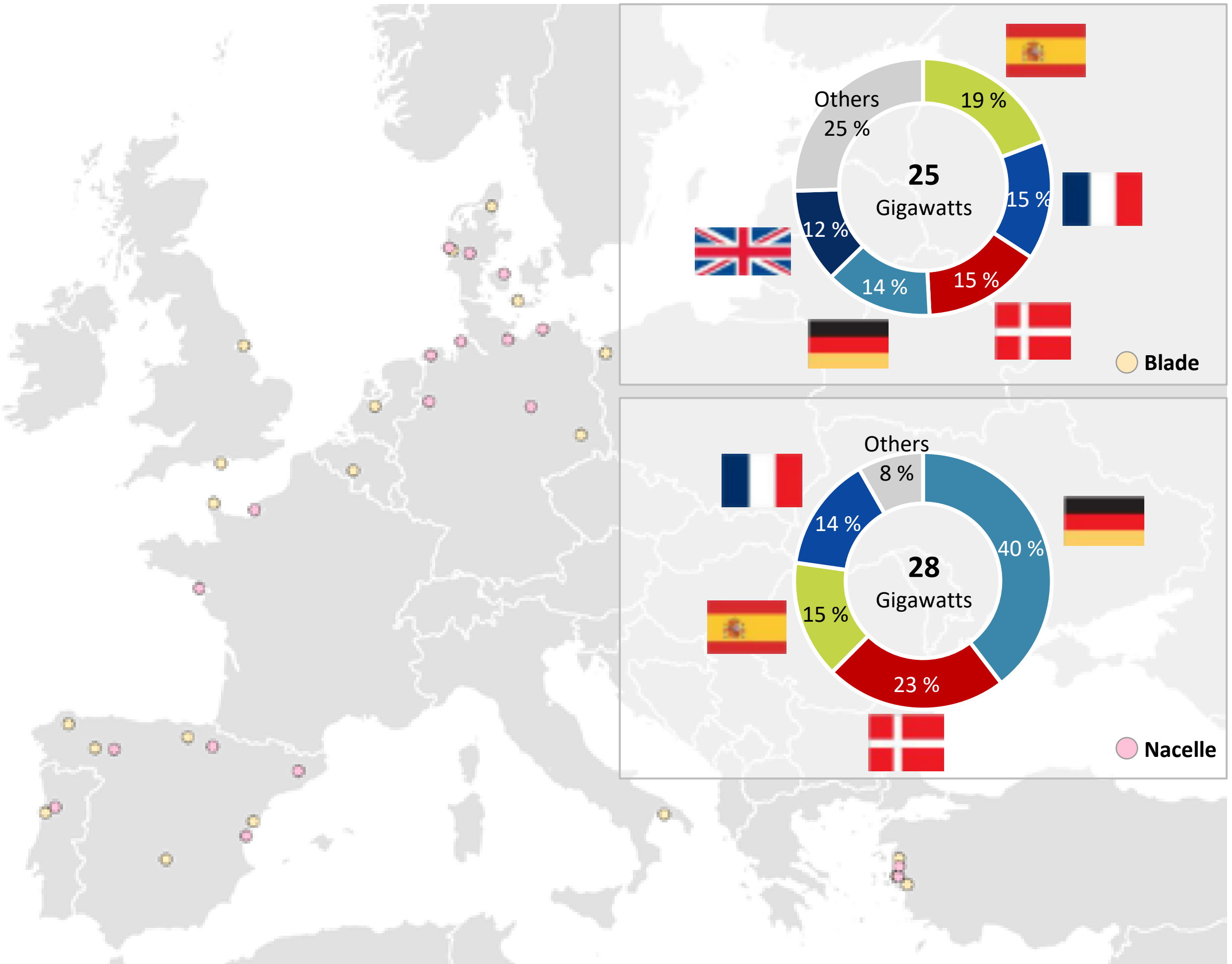
Rystad Energy estimates that the manufacturing capacity for blades and nacelles in Europe is around 25 GW and 28 GW as of 2022 year-end, respectively. Spain, Germany, Denmark, and France lead Europe's nacelle and blade production. These countries account for more than 60% of the blade manufacturing capacity and more than 90% of the nacelle manufacturing capacity in Europe.

Most of the blade facilities in Spain serve the onshore wind market. Nordex and Vestas have a strong presence of blade manufacturing in Spain, with major bases in Lumbier and Daimiel, producing blades mainly in the range of 4 MW and above. US manufacturer GE is also well-established in Spain with two blade plants in Ponferrada and Castellon, which belong to its subsidiary LM Wind Power. Meanwhile, Spanish-German manufacturer Siemens Gamesa closed its Spanish blade plant in As Somozas in 2020 due to Covid-19 and a lack of demand for the 2 MW class turbines. However, it kept its blade maintenance bases in the country.

France and Denmark are the two countries with significant offshore wind blade production. We estimate that GE's Cherbourg base and Siemens Gamesa's Le Havre base contribute more than 4 GW to Europe's offshore blade manufacturing capacity. Denmark also has two bases, Siemens Gamesa's Aalborg and Vestas' Nakskov facilities, capable of manufacturing blades for turbines larger than 12 MW. Other European countries known to produce blades include the UK, Turkey, and Portugal.

Meanwhile, European nacelle production is dominated by Germany, with each of the top western manufacturers, including Vestas, GE, Siemens Gamesa, Nordex, and Enercon, having at least a base in the country. Denmark also contributes quite significantly to Europe's nacelle manufacturing portfolio, with Siemens Gamesa and Vestas having factories in Brande, Ringkobing, and Lindo.

Figure 23: Manufacturing bases for blade (top chart) and nacelle (bottom chart) in Europe*, 2022



*Facilities without known latitudes and longitudes are not included in the map.
Sources: Rystad Energy research and analysis; Companies' annual reports and websites.

European supply-demand balance for turbines

Rystad Energy estimates that Europe's wind market may face a supply chain bottleneck for wind turbine manufacturing as early as 2026. Based on WindEurope's *2030 Targets Scenario*, annual wind capacity additions in 2026 stand at 34 GW, about 5 GW higher than Europe's expected nacelle and blade manufacturing capacity in the same year.

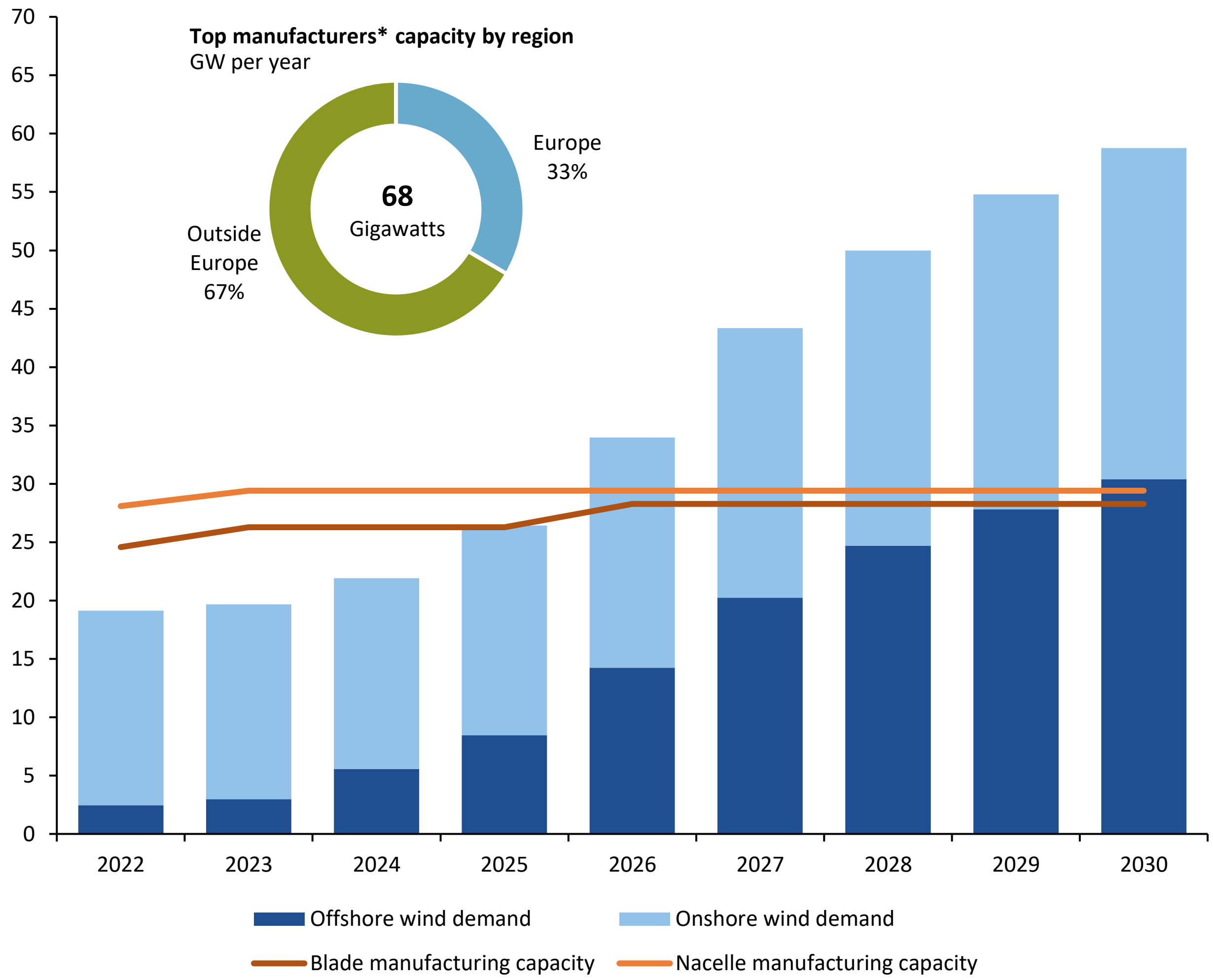
In a scenario where European demand is to be met by only European supply, demand is expected to outpace supply by 2026, particularly for blades. As we approach 2030, the current supply capacity levels are roughly half of Europe's forecast demand, with the offshore wind sector contributing most of the demand in 2030.

However, it is also important to note that top Western turbine manufacturers, such as Vestas, Siemens Gamesa, GE, Nordex and Enercon, hold significant manufacturing capacities outside of Europe, including Southeast Asia, China, India, and the US, which could provide room for extra supply to Europe from these bases.

Nevertheless, this may be challenging as these regions also are expected to see increasing domestic demand, pulling on their respective domestic supply bases.

From an overall European turbine supply-demand balance perspective, the potential bottleneck in 2026 suggests that work to expand current capacities would need to be initiated by 2024 or 2025 to be able to ramp up in time to meet forecast demand.

Figure 24: Wind turbine manufacturing capacity and demand in Europe
Gigawatts (GW)



*Top manufacturers include Vestas, Siemens Gamesa, GE, Nordex, and Enercon.
Sources: Rystad Energy research and analysis; Companies' annual reports and websites.

European blade and nacelle manufacturing capacity by turbine size

One important aspect to look at is the supply capacity for different sizes of turbines. On the global or regional level, turbine supply may be higher than the overall installation demand in a certain year, but the story can be different when one dives into certain turbine size groups.

Figure 25 presents Rystad Energy's analysis of supply capacities for different turbine size groups. The largest share of supply capacity for blade and nacelle is estimated to be for the 4-6 MW size group, primarily serving the onshore wind market. This size group has a noticeable difference in its blade and nacelle manufacturing, as Nordex closed its blade plant in Rostock, Germany, in 2022.

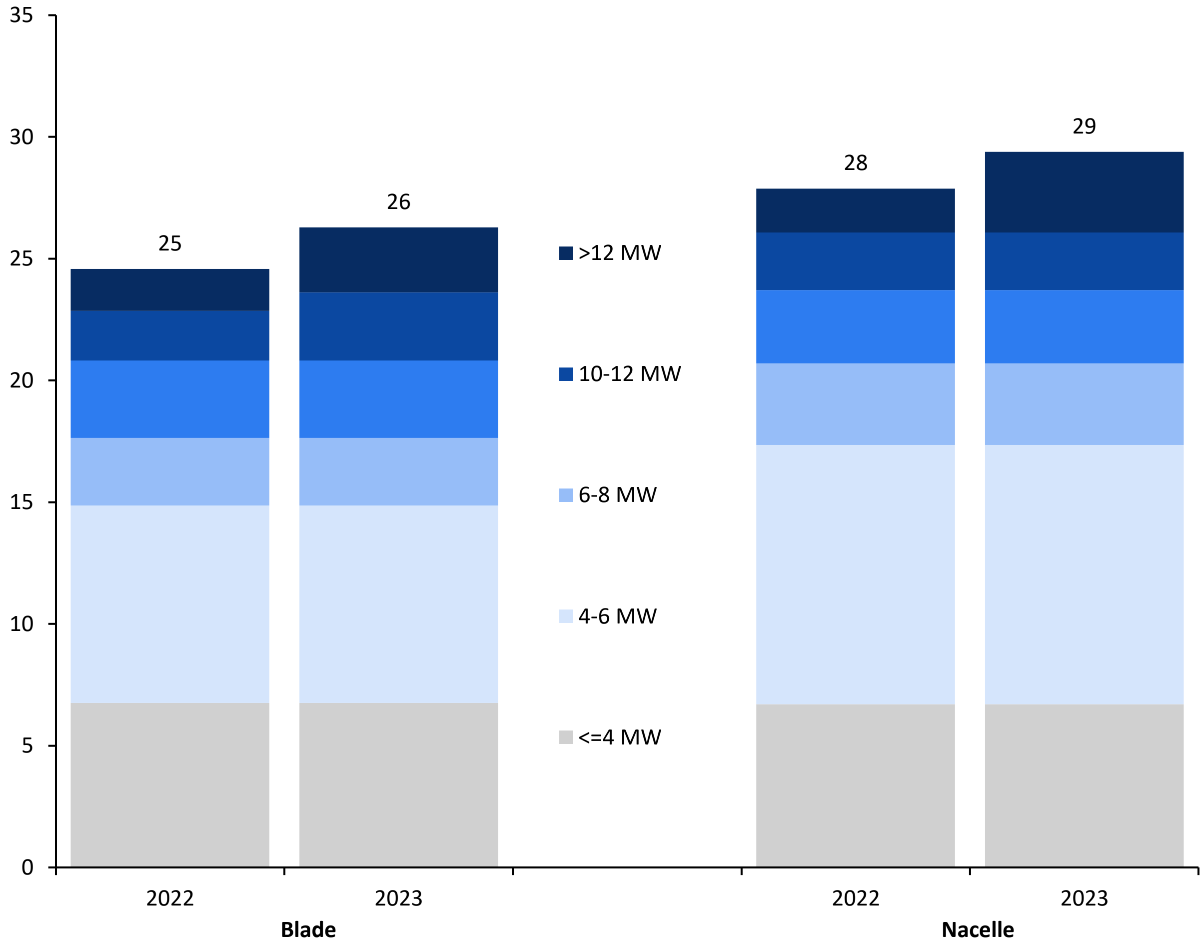
Meanwhile, the <4 MW size group accounts for about a quarter of the total supply capacity for blades and nacelles, contributing quite significantly to the mix.

In the larger turbine size groups serving the offshore wind market, most of the supply capacity is estimated to serve the 8-10 MW group. For both blades and nacelles, the manufacturing capacity in this group reached more than 3 GW by the end of 2022. This finding aligns with the average offshore turbine size installed in 2022 and expected to be installed in 2023 in Europe, approximately 8.3 MW and 9.7 MW, respectively.

By the end of 2022, European manufacturing of blades and nacelles for turbines of 10 MW and above was limited, totaling about 4 GW for both segments, on average. Nevertheless, when Siemens Gamesa's extension of its Hull facility is fully up and running this year, the >12 MW turbine size group is expected to see a boost of at least 1.5 GW.

Meanwhile, European nacelle manufacturing capacity is expected to increase by about 1.5 GW* in 2023 as Vestas is constructing its base in Szczecin, Poland, to produce nacelles for its 15 MW turbines.

Figure 25: Blade and nacelle manufacturing capacity in Europe by turbine size group, 2022-2023
Gigawatts (GW)



*Typically, a major blade or nacelle manufacturing facility has a manufacturing capacity in the range of 1.5-2 GW.
Sources: Rystad Energy research and analysis; Companies' annual reports and websites.

European supply-demand balance for different turbine sizes

Figure 26 compares the current European turbine manufacturing capacity and the forecast demand for different turbine size groups. In the onshore wind sector, which includes the <=4 MW, 4-6 MW, and 6-8 MW groups, moderate bottlenecks are expected to occur for the first two groups. Most turbines for onshore wind during the 2020s are expected to be below 6 MW, and the activity growth forecast in the *2030 Targets Scenario* will drive demand to levels above current supply.

However, the 6-8 MW group is well supplied as many European facilities produce this turbine size for offshore wind development today. We expect the demand for onshore wind in this group to put some pressure on supply by 2030, from a limited number in 2026.

For offshore wind, supply of turbines between 6 MW and 12 MW looks well-positioned to cover the forecast demand in 2026 and 2030. However, a significant undersupply is imminent in the >12MW group, as most offshore wind projects are expected to opt for the largest turbines available in the market during the second half of the decade.

Only a few European bases can currently produce turbines larger than 12 MW, including GE's Cherbourg, Siemens Gamesa's Aalborg and Hull facilities, and Vestas' Nakskov – the latter three have not yet gone into serial production. We estimate that the current manufacturing capacity for the >12 MW group in Europe is less than 2 GW, significantly lower than the demand in 2026 and 2030 of about 12 GW and 29 GW, respectively.

Since it takes 2-3 years to construct a major manufacturing base and 1-2 years to repurpose a base, expansions are necessary to be initiated as early as 2024 to avoid undersupply for these large turbines in 2026, assuming that European demand will only be satisfied by European supply. This notion considers that manufacturers need to start producing these turbines at least one year before a wind project commences turbine installation activities.

Figure 26: European wind turbine manufacturing capacity and demand by size group
Gigawatts (GW)

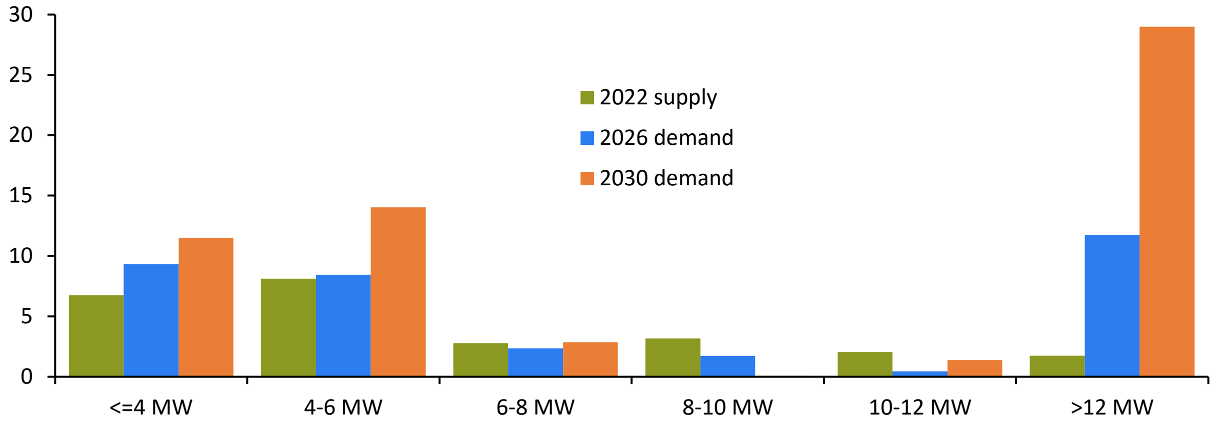
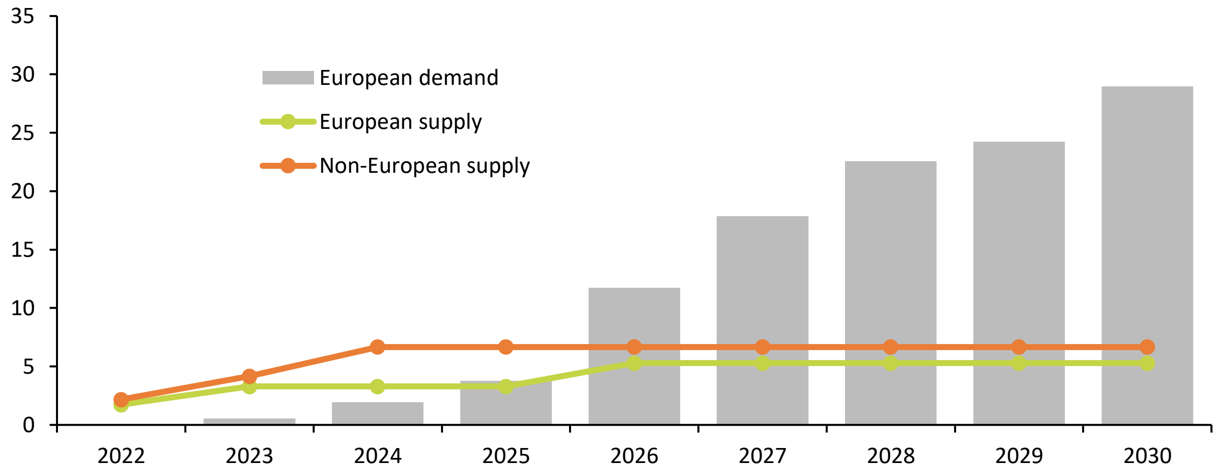


Figure 27: Wind turbine manufacturing capacity and demand for >12 MW turbines
Gigawatts (GW)



Sources: Rystad Energy research and analysis; Companies' annual reports and websites.

Announced expansions for >12 MW blades and nacelles

As demand for mega-size turbines increases, many expansion plans have been announced. In 2022, China announced manufacturing capacity expansions for the largest turbine sizes with multiple Chinese OEMs aiming for new facilities to be operational by 2023 and 2024.

In addition, blade manufacturing expansions were also announced in the US, as Siemens Gamesa plans to build an offshore blade facility in Virginia to support the Coastal Virginia Offshore Wind project, estimated by the manufacturer to come online by 2024.

In Europe, about 1.5 GW of blade manufacturing capacity is expected to come into operation by the end of 2023, including Siemens Gamesa's extension of its Hull facility and Vestas' Taranto base which is planned to be repurposed to supply blades for its 15 MW turbines. TPI Composites is also planning to build a new offshore blade factory in Turkey, with a planned capacity of at least 2 GW.

In the nacelle market, Siemens Gamesa has announced an expansion of its nacelle facility in Taichung, Taiwan, capable of making nacelles for its 14 MW turbines. This plant extension is envisaged to be done by 2024, lifting the base's capacity to 2 GW. Chinese OEMs are also expanding their nacelle manufacturing capacity to accompany their expansions for >12 MW offshore blades. In the European nacelle market, Vestas is set to open its Polish plant to supply nacelles for its 15 MW turbines.

In the US, GE, through its subsidiary LM Wind Power, is also eyeing the construction of bases able to produce offshore nacelles and blades in New York, but these are subject to the result of New York's third offshore wind solicitation round, due to be announced in the second quarter of 2023. Siemens Gamesa also plans a nacelle facility in New York, depending on the third offshore wind solicitation result of the Empire State**. These companies will continue with the plans only if their turbines are selected in said solicitation round.

Figure 28: Blade manufacturing expansions for >12MW turbines, 2023-2026*
Gigawatts (GW) per year

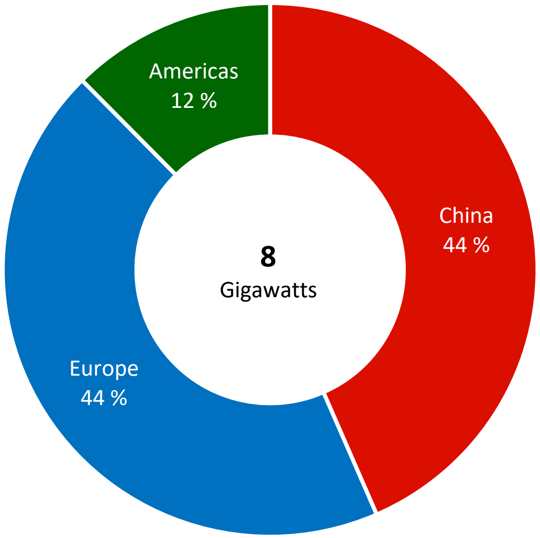
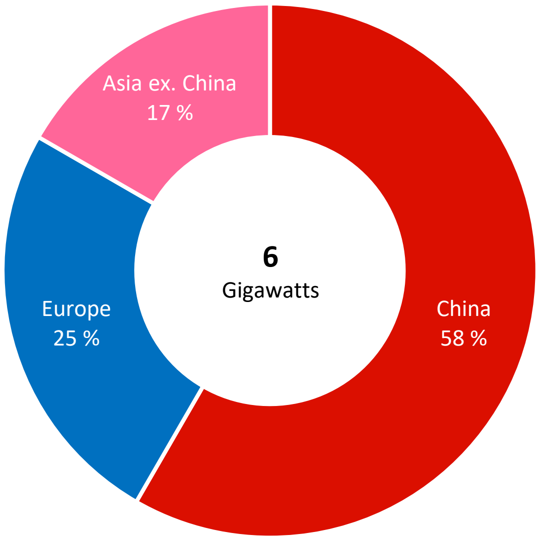


Figure 29: Nacelle manufacturing expansions for >12 MW turbines, 2023-24
Gigawatts (GW) per year



*Include announcements until 30th March 2023. We assumed that TPI's planned offshore base in Turkey will supply >12 MW blades. **Capacity related to these announcements is not included to the analysis.
Sources: Rystad Energy research and analysis; Companies' annual reports and websites.

Tower and offshore wind foundation manufacturing facilities in Europe

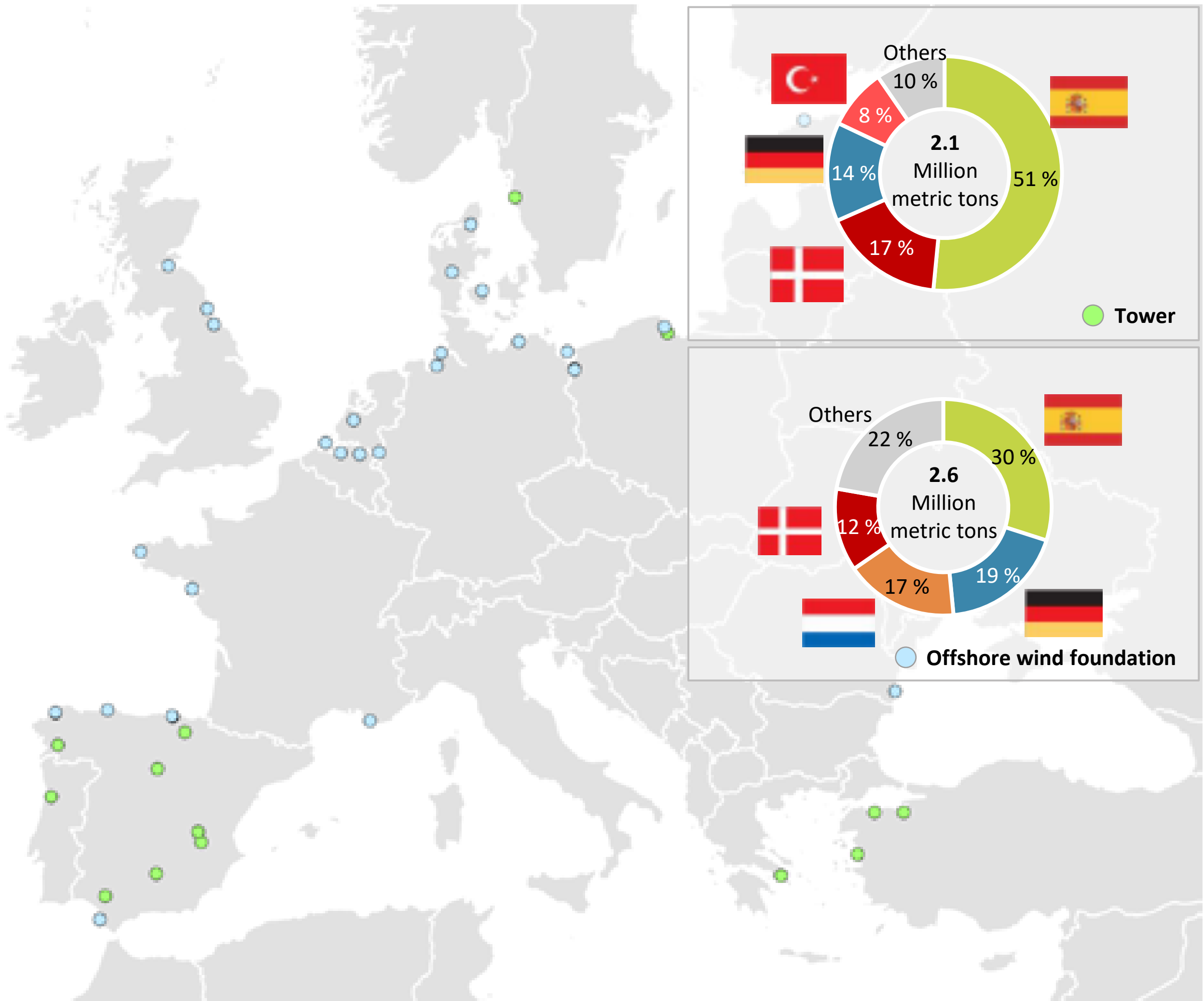
Rystad Energy's analysis shows that the European tower manufacturing capacity in 2022 stood at 2.1 million metric tons of steel. Significant tower manufacturing capacity lies in Spain, accounting for approximately half of Europe's tower manufacturing capacity. Three major turbine tower producers, including GRI Renewable Industries, Windar Renovables, and Haizea Wind Group, have multiple factories in Spain, with a cumulative annual manufacturing capacity of over 900,000 metric tons of steel.

Other tower manufacturing locations with significant capacities include Denmark, Germany, and Turkey. Welcon is the most prominent in Denmark, while Max Bogl is estimated to be the leading producer in Germany. In addition, GRI Renewable Industries has a manufacturing base in Turkey, lifting the manufacturing capacity in the country.

For the offshore wind foundation sector, manufacturing capacity for Europe is estimated at about 2.6 million metric tons by year-end 2022, with Spain, Denmark, Germany, and the Netherlands leading the way. Most of this capacity is for monopiles, which is the most popular foundation type used for offshore wind, given its simplicity for serial production and low cost compared to alternative solutions.

Navantia's Spanish bases have a total manufacturing capacity of 550,000 metric tons for offshore wind foundations, 55% of which is for jacket foundation. The Netherlands' Sif and Germany's EEW lead in terms of monopile manufacturing capacity, with a combined annual potential throughput of 500,000 metric tons.

Figure 30: Manufacturing bases for towers (top chart) and foundations (bottom chart) in Europe*, 2022



*Facilities without known latitudes and longitudes are not included in the map. We do not include manufacturing facilities for onshore wind foundations.
Sources: Rystad Energy research and analysis; GRI Renewable Industries; Haizea Wind Group; Windar Renovables; Companies' annual reports and websites.

European supply-demand balance for towers

Besides the blade and nacelle, the tower is another critical wind turbine component. However, unlike its two counterparts, the tower is not as complicated to manufacture, as it is not a moving part and is not connected to electrical systems.

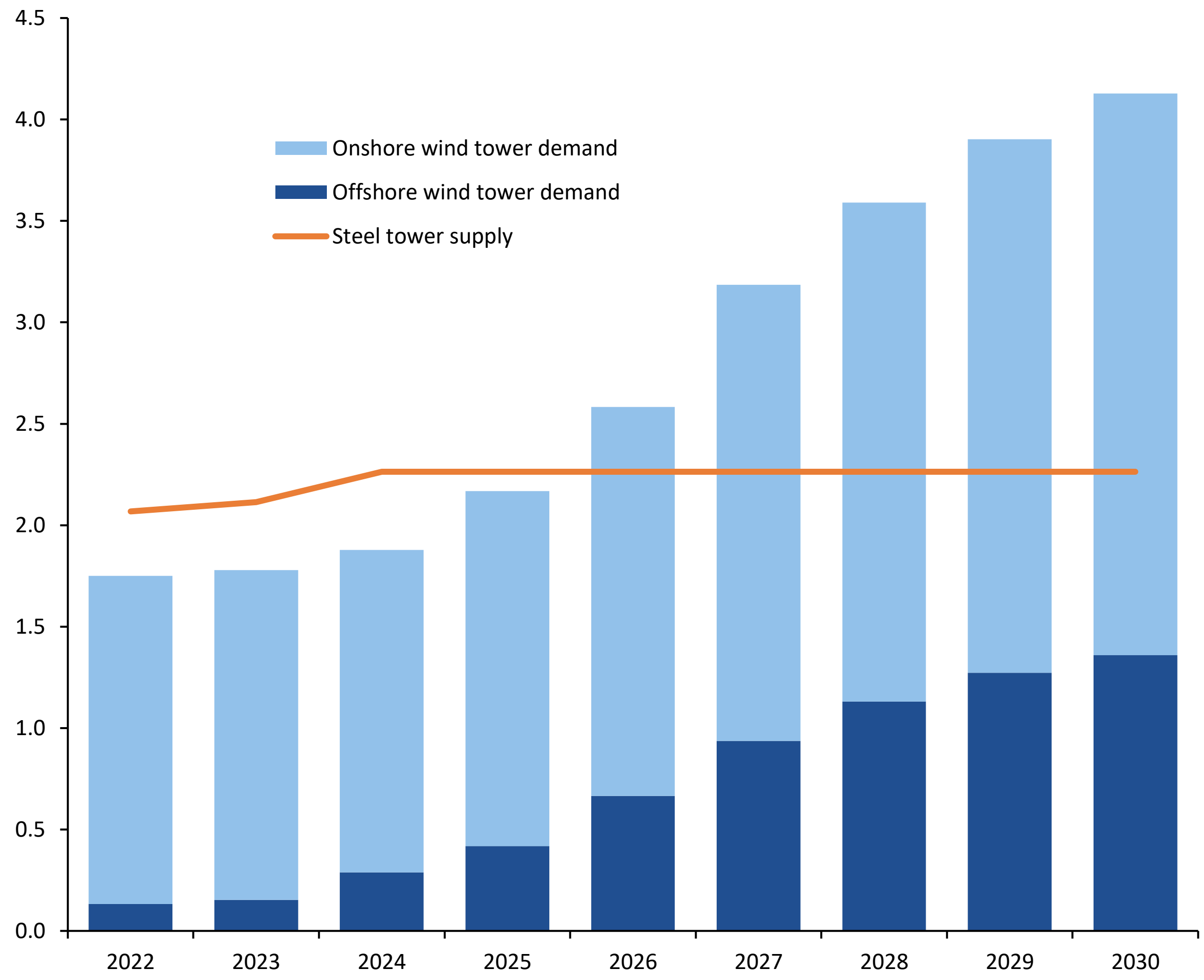
As towers are manufactured using steel predominantly, and because tower heights vary greatly for different turbine sizes, metric tons of steel is used to measure the manufacturing capacity levels. By the end of 2022, the European tower manufacturing capacity was estimated to have reached about 2.1 million metric tons of steel. Announced expansions are expected to lift this tally to almost 2.3 million metric tons by 2024.

With the current supply capacity outlook, the steel demand for towers is envisaged to surpass the supply in 2026, as the cumulative annual steel demand for onshore and offshore wind is expected to exceed 2.5 million metric tons. We expect this tally to grow to more than 4 million metric tons by decade-end in the *2030 Targets Scenario*.

The steel usage going into wind towers depends on several key factors, including hub height and turbine size. The hub height used for an onshore wind project is typically less than for an offshore wind project as it uses smaller turbines. Although requiring less steel on a per-unit basis, onshore wind is expected to drive demand, as it will require a higher number of turbines compared to offshore wind.

For offshore wind, the rapid growth in turbine sizes will increase the tower steel intensity per unit but is expected to reduce tower steel usage per megawatt installed, thanks to fewer units and the fact that hub heights do not grow linearly with turbine sizes.

Figure 31: Tower manufacturing capacity* and demand in Europe
Million metric tons of steel per year



*This estimation excludes the European concrete tower supply of around 200 thousand metric tons.
Sources: Rystad Energy research and analysis; Tower manufacturers' annual reports and websites.

European cable supply and demand

Cable supply in Europe is not only dedicated to the wind industry. Cables for electrification of other offshore infrastructure, onshore and offshore interconnector cables, and cables for grid expansions are typically supplied by companies active within the offshore wind sector, such as Prysmian, TFKable, NKT, Nexans and Hellenic Cables.

In 2022, the annual European manufacturing capacity of cables (excluding voltages below 33 kV) was estimated to be 15-20 thousand kilometers. Most of Europe's cable suppliers have manufacturing bases in Poland and Sweden, with France and the UK also being production centers for LV to MV* inter-array cables made by Prysmian, Nexans and TFKable. Facilities in Italy and Greece produce significant lengths of MV, HV and EHV cables and are located close to the Mediterranean and Adriatic, making for efficient cable transportation for offshore wind and subsea interconnector projects.

Measured using forecast turbine demand as a proxy, demand for onshore wind inter-array cables is expected to grow by 45% towards 2030 in the *2030 Targets Scenario*, from already high levels. Onshore transmission demand is highly dependent on a wind projects' proximity to the grid and is therefore difficult to quantify.

Demand for offshore wind inter-array cables is expected to grow nearly seven-fold, as activity for offshore wind is forecast to increase more rapidly compared to onshore wind. While larger turbines reduce the number of turbines (and array cables) needed to reach targets, the distance between turbines will also increase, somewhat offsetting this effect. Export cable demand for offshore wind is forecast to grow more than 14 times towards 2030, driven by the rapid activity growth, and further helped by growing distances to shore.

The demand for cables from European wind will have to compete with other sectors mentioned above, and the expected large growth in European renewables and the electrification of energy systems are expected to put upwards pressure on demand.

Figure 32: Estimated MV, HV and EHV* cable manufacturing capacity in Europe, 2022
Kilometers per year

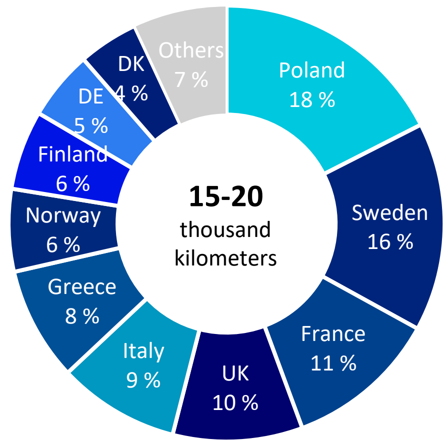
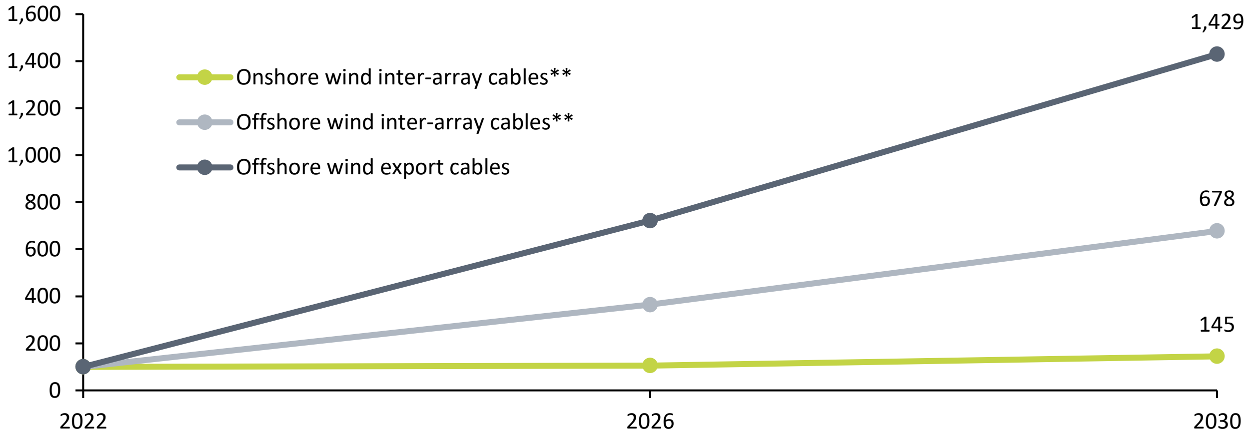


Figure 33: Indexed demand growth for inter-array cables and offshore wind export cables
Index, 2022=100



*LV = low voltage, <33 kV; MV = medium voltage, 33-66 kilovolts (kV); HV = high voltage, 66-320 kV; EV = extra-high voltage, >320 kV. **Using forecast number of turbines as a proxy.
Sources: Rystad Energy research and analysis; Rystad Energy Subsea HVDC Interconnector database; Companies' annual reports and websites.

Demand drivers for European offshore wind

Unlike onshore wind, where the main market driver is expected to be the general growth in activity levels and to a lesser extent rapidly growing turbine sizes, European offshore wind is forecast to experience a more dynamic and rapidly changing demand.

Larger turbines have been the key driver for the cost reductions observed within offshore wind over the recent decade. This has naturally driven developers to prefer the largest turbines on the market and resulted in a race between turbine manufacturers to supply them. Figure 34 shows the turbine and project sizes for European offshore wind farms expected towards 2030, according to Rystad Energy's project-by-project database. Current project announcements and plans show a clear trend: projects are becoming larger and larger, using gradually bigger turbines. Turbine sizes are expected to approach the 18-20 MW range towards 2030, with the average turbine size expected to climb to around 15 MW by 2030.

The rapidly growing turbine sizes means increasing hub heights and larger turbine towers, and a need for larger foundations, such as monopiles with wider diameters. The larger components will in turn require improved handling equipment, such as installation vessels with bigger cranes and larger lifting capacity.

In established offshore wind regions, areas close to shore and with shallow waters are beginning to get populated, which means that new developments will need to move further from shore and potentially into deeper waters. This is expected to drive the need for longer export cables and a shift to wider monopiles, or jackets or floating solutions.

The *2030 Targets Scenario* also includes countries with communicated offshore wind ambitions and primarily water depths suitable to floating wind solutions. Countries such as Portugal, Spain, Norway and Italy, among others, are expected to drive increasing demand for floating foundations, as shown in Figure 35.

Figure 34: European offshore wind farms by start-up year, turbine size and capacity*
Megawatts (MW)

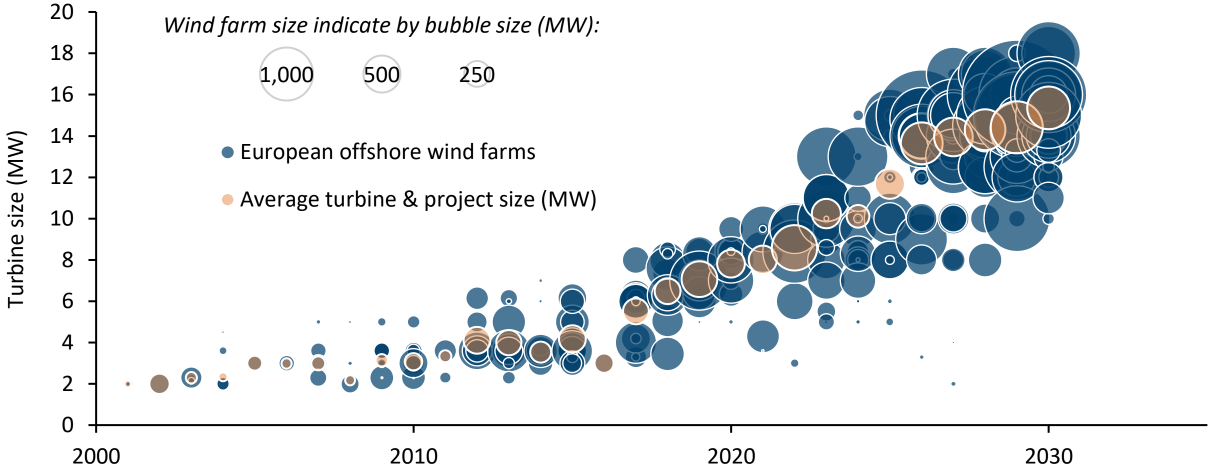
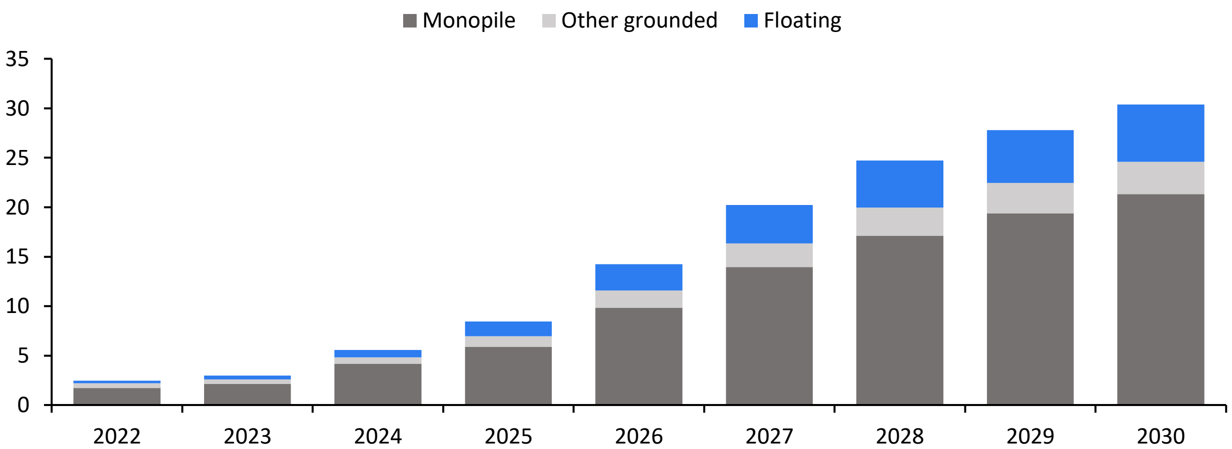


Figure 35: Forecast offshore wind capacity additions by foundation type*****
Gigawatts (GW)



*Based on Rystad Energy's project-by-project database. Weighted average turbine size. **According to *2030 Targets Scenario*. ***Rystad Energy analysis based on country-by-country targets, project pipelines and water depths in relevant development areas. Sources: Rystad Energy research and analysis; Rystad Energy OffshoreWindCube

European monopile supply and demand

Demand for monopiles is expected to increase rapidly with the accelerated growth in offshore wind towards 2030, as forecast in the *2030 Targets Scenario*. Floating wind is expected to see an increasing share of turbine installation towards 2030, as the forecast includes countries where waters are too deep for bottom-fixed solutions. Nevertheless, monopile has been, and is forecast to continue to be, the preferred option in Europe this decade.

Growing turbine sizes are expected to dampen the required number of turbines and, therefore, foundations to reach capacity targets. However, the larger turbines and gradually deeper waters will also drive demand for longer and wider monopiles. While the majority of monopile demand in 2022 was in the "Regular and XL" segment, suppliers have already started to scale up capacities to meet the demand for XXL and XXXL monopiles to support this trend. Most of the announced expansions of manufacturing capacity will come in the XXXL segment, as shown in Figure 36.

By 2027, demand is expected to outpace the announced supply of monopile manufacturing from a tonnage perspective. Given that foundations must be delivered early in the construction stages of an offshore wind project, manufacturing capacity likely should be expanded by 2025, and facility expansions may need to be initiated as early as 2024.

By 2030, foundation demand is forecast to surpass 3 million metric tons. This tally is more than double the current and planned capacity of XXL and XXXL monopiles. Assuming that most demand will come from the largest segments, then supply must be doubled from 2026 (the last year of planned expansions) to 2030 to meet demand.

Figure 36: Monopile manufacturing capacity and demand in Europe
Million metric tons of steel per year

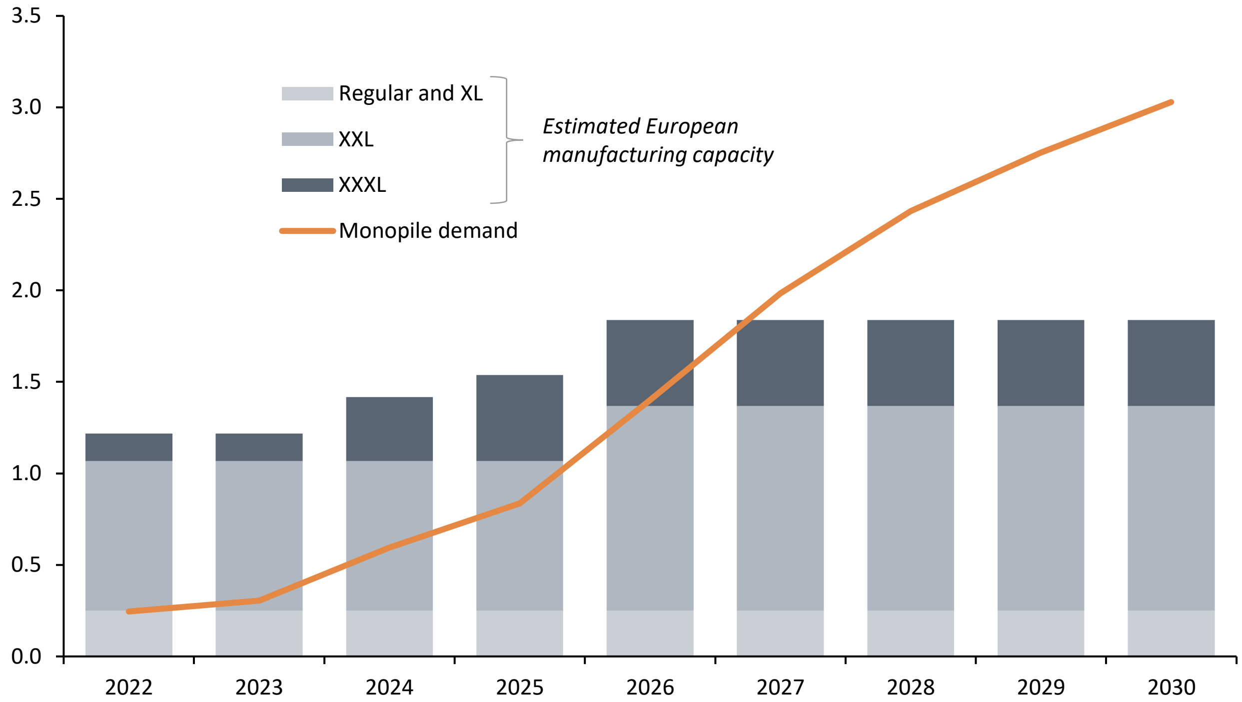


Table 2: Monopile size overview

Type	Typical diameter	Typical turbine size supported
Regular	5-6 m	<6 MW
XL	6-8 m	6-10 MW
XXL	8-11 m	10-14 MW
XXXL	>11 m	>14 MW

Sources: Rystad Energy research and analysis; Foundation manufacturers' annual reports and websites.

European supply and demand of non-monopile and floating foundations

Demand for non-monopile grounded foundations is expected to increase rapidly during the 2020s. However, the levels are modest, as monopiles have been the most popular choice of foundations in European offshore wind, a trend that is expected to continue.

Most of the demand growth for non-monopile grounded solutions is expected to come from jackets, as offshore wind farms in Europe have gradually moved into deeper waters, on average. In addition, jackets are expected to be used in some areas in Europe, for example in France, where the seabed complicates monopile usage, despite often otherwise suitable water depths. The gradual move further out from the coast and into deeper waters also limits the need for other shallow-water solutions, such as e.g., gravity-based structures (GBS). A few exemptions exist, however, like the Fécamp project in France.

Jacket supply in Europe is relatively abundant, thanks to its regular use in the oil and gas industry. As such, supply is expected to remain higher than forecast demand for the decade, with limited risk of becoming a bottleneck, shown in Figure 37.

Floating foundation manufacturing, on the other hand, is only in its infancy. A strong demand forecast towards the end of the 2020s will put pressure on the supply chain to expand, with an expected undersupply from 2025 onwards, as shown in Figure 38. From the current and announced floating foundation manufacturing levels, capacities must grow five to sixfold towards 2030 to meet the projected demand.

For floating foundation manufacturing, a lot of upside potential exists among the traditional yards, where part of the areas could be repurposed for floating wind. However, space requirements for both wet and dry storage are high for floating wind and would require large capital investments. Coupled with a still uncertain outlook for a large-scale floating wind build-out, the investment signal may still be missing for these yards.

Figure 37: European manufacturing capacity and demand of non-monopile grounded foundations
Thousand metric tons of steel per year

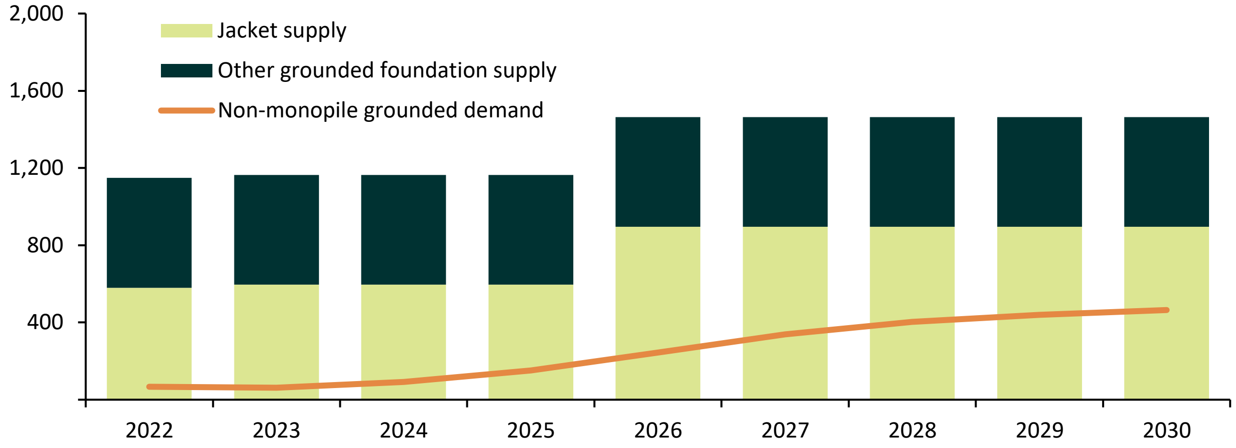
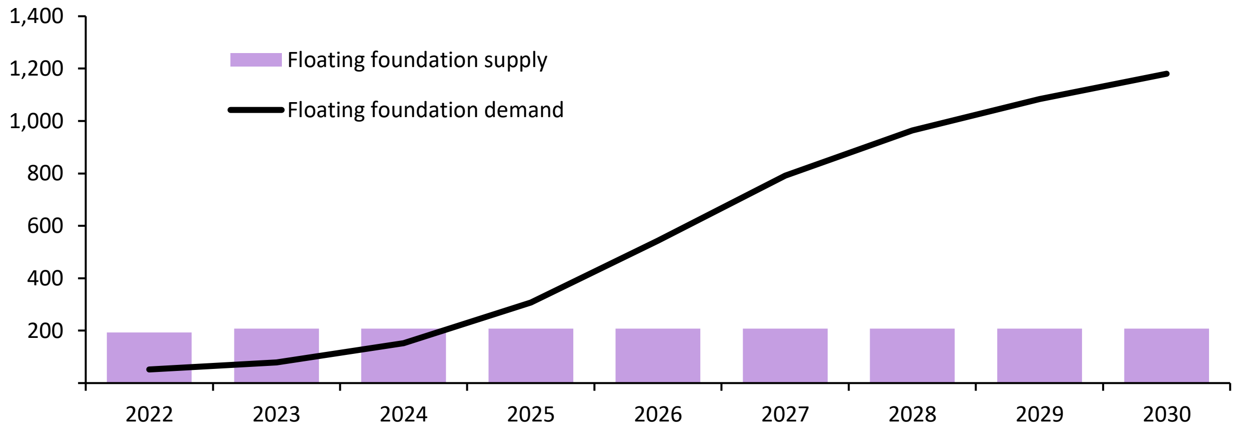


Figure 38: Floating foundation manufacturing capacity and demand in Europe
Thousand metric tons of steel per year



Sources: Rystad Energy research and analysis; Foundation manufacturers' annual reports and websites.

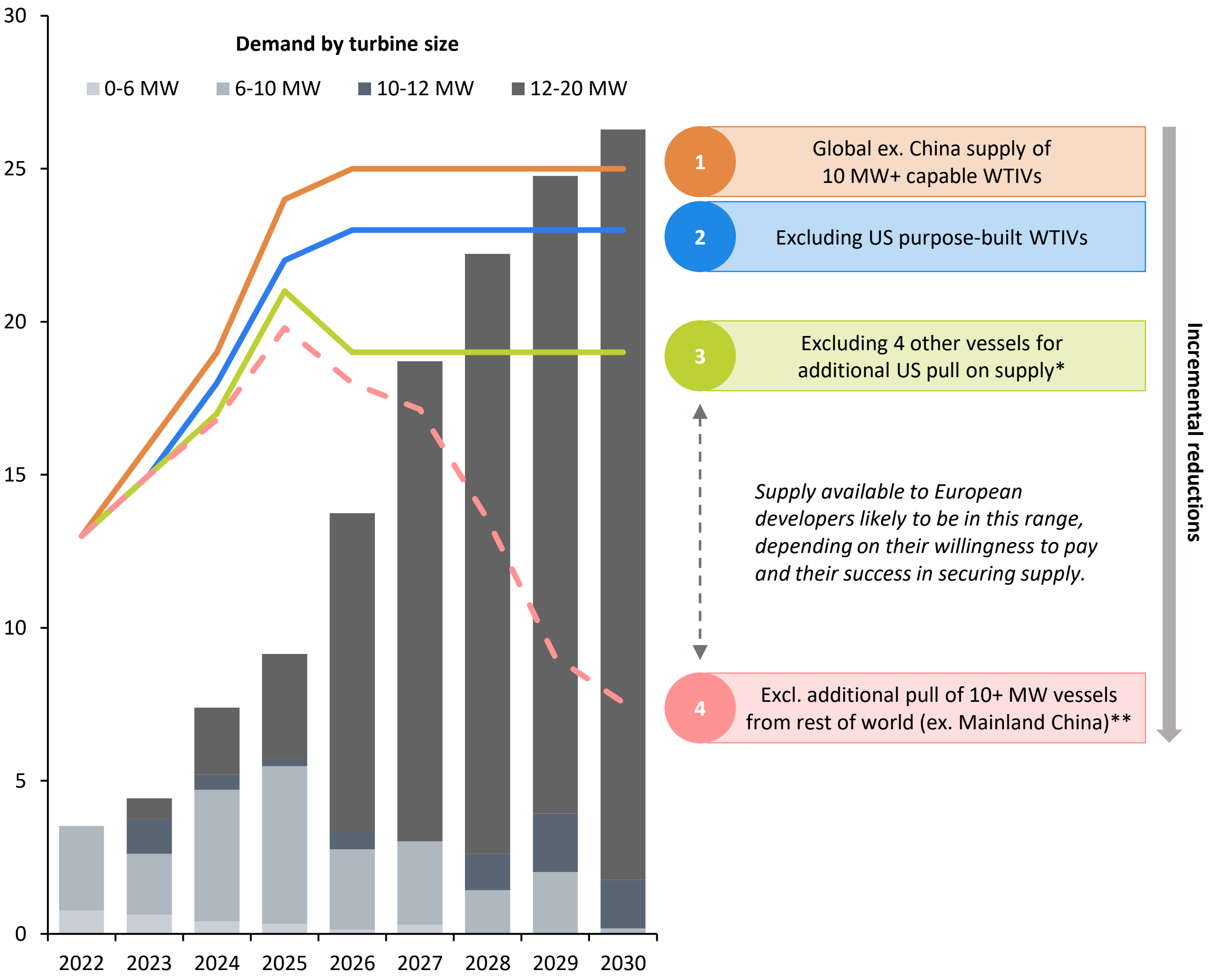
Supply and demand of wind turbine installation vessels

Global demand for wind turbine installation vessels (WTIVs) is expected to grow more than five-fold towards 2030 in the *2030 Targets Scenario*. The rapidly increasing turbine sizes will limit the number of turbines needed to be installed but is expected to add pressure on the fleet of next-generation WTIVs capable of installing the largest turbine models.

Figure 39 shows the forecast annual demand for WTIVs in Europe towards 2030 in vessel years, split by turbine sizes. This is coupled with the current and future supply of specialized WTIVs capable of installing turbines larger than 10 MW. The assessment of capable vessels are made on a vessel-by-vessel basis, considering lifting heights and crane capacities. Excluding Chinese WTIVs, the global number of operating vessels is expected to grow from 13 in 2022 to 25 by 2026, based on confirmed newbuild orders (1). Among these, two WTIVs are made specifically for the US market, making it unlikely that they will be available to support European installation (2). European developers will have to compete for the remaining 23 vessels. If we assume that a total of 6 units are needed in the US by 2030*, the remaining supply is on par with European demand in 2027 (3). Further, if we assume that other markets, such as Vietnam, Taiwan, South Korea, Japan, and potentially more will require the same type of vessels, the remaining supply may fall below 2027-demand. This is expected to worsen towards 2030, as demand in both Europe and other markets increases (4).

It is important to note that demand is shown in **working years** (aggregate of vessel days needed for turbine installation, loading, mobilization), and not number of units needed. Limited weather windows for turbine installation lower utilization rates, which means that demand in terms of units needed will be significantly higher. As such, the market is expected to be tight around 2026 in the *2030 Targets Scenario*, creating a need for initiating newbuild work by 2024-2025. The market may be even tighter in the largest segments as a growing portion of the 12-20 MW demand will move towards the upper limits of the range, where the fleet of capable vessels is currently limited.

Figure 39: European demand and global (ex. China) supply of wind turbine installation vessels (WTIVs)
Vessel years



Sources: Rystad Energy research and analysis; Rystad Energy VesselCube. *NREL's "A Supply Chain Road Map for Offshore Wind Energy in the United States" (2023) estimates a need of 4 to 6 WTIVs per year to reach the US' 30-GW target by 2030, in line with Rystad Energy base case. **Rystad Energy base case.

Other parts of the wider wind supply chain

As shown throughout this chapter, a scenario where Europe reaches its ambitious targets for wind energy would require a rapid ramp-up along nearly all parts of the supply chain that are unique to the wind industry. In addition, the forecast build-out would also put pressure on several parts of the wider supply chain. For these, a clear-cut supply-demand balance is difficult to forecast without covering demand from all relevant sectors. This was exemplified on page 35 for cables, where demand for subsea export cables for offshore wind and high-voltage transmission for onshore wind must compete with demand from large-scale interconnector projects and general grid expansions. In this section, some of the other parts of the wider supply chain will be described.

HVAC & HVDC*
With the general expansion of renewables, interconnectors and electricity grids, added pressure on the supply of HVAC and HVDC solutions is expected. Suppliers are reporting increasing lead-times for HVAC solutions, posing a risk for large-scale projects such as offshore wind farms. Worse are reports of HVDC lead-times, challenging timelines for distant offshore wind farms, large renewable expansions in areas located far from demand centers, and interconnector projects.

Labor
Although a large portion of the wind supply chain is capital-intensive, the demand for labor will grow in line with the forecast activity levels. Several parts of the manufacturing processes that are less complex are expected to experience a relatively easy expansion of the workforce, as workers shift from high- to low-carbon sectors as part of the broader energy transition. However, *skilled* labor is expected to be a challenge for the many specialized workstreams along the wind supply chain. This may be especially true for offshore wind, where activity is forecast to grow faster, and offshore-specific training is required.

Other vessel segments
WTIVs are not the only vessel segment that will see increasing demand: vessels for foundation, cable and offshore substation installation will be needed for the rapid capacity deployment; service operation vessels (SOVs) will be required to support construction and to tend to the growing operational base of offshore wind farms; and for floating wind the tow-out and mooring of numerous large-scale floating foundations is expected to put pressure on the fleet of anchor handling tug supply (AHTS) vessels with sufficient deck space, chain locker capacity and bollard pull.

For foundation installation vessels, a small, global fleet of specialized units exists. In addition, a long list of heavy-lift vessels that are not purpose-built for foundation installation has a track record within the segment. A significant fleet of additional, potential supply exists within the oil and gas sector. Many of these vessels have typically been considered too large (and too expensive) for foundation installation, with some having a track record of installing offshore substation topsides. The same goes for cabling vessels, with a fleet of specialized units and a significant potential supply from other sectors. While the non-specialized vessels *could* do the job with no or a few adjustments to their specifications, the efficiency is lower than for the purpose-built fleet. Additionally, the increase in offshore oil and gas production in Europe following Russia's invasion of Ukraine, especially in the short-to-medium term, is likely to reduce the availability of these non-specialized vessels for cable, foundation and offshore substation installation.

For SOVs, the supply is expected to be less constrained. These vessels are less complex to construct and constitute smaller capital investments compared to e.g., large and specialized WTIVs. Furthermore, the SOVs are often purpose-built for the offshore wind farm(s) they will serve, with long-term contracts (typically 15+ years) already in place for the vessels.

Ports
Fabrication, assembly and marshalling/staging activities will require significant port infrastructure in addition to operations and maintenance (O&M) bases. Available areas are limited to certain parts of Europe, and the increasing component sizes add challenges as increasing space and air draft are needed. For floating wind, the need for specialized and integrated ports is especially high, given the amount of steel and concrete going into the foundations, their sheer size driving additional space requirements, and the need for significant wet-storage areas before dock-side turbine installation and tow-out.

Floating offshore wind
An expansion need for foundation manufacturing, AHTS vessels and specialized ports for floating wind has already been identified on page 38, and in previous sections on this page. In addition, demand for mooring lines (chain, fiber rope and wire) is quickly expected to outpace current supply. Mooring lines have historically been supplied to oil and gas, with a few, large floating offshore units installed per year. With the growth in floating wind, the volume of separate units in need to be moored will grow exponentially, driving a need for a massive supply expansion.

Materials
Material demand from onshore and offshore wind manufacturing is expected to increase rapidly. Some of the key parts of the material value chain will be explained in the following sections.

*HVAC = High Voltage Alternating Current, HVDC = High Voltage Direct Current
Source: Rystad Energy research and analysis

Materials used in wind turbines

Materials used in the manufacturing of the main components of a wind turbine are listed to the right. Additionally, **copper, manganese, silicon, nickel and lead** have also been included in the materials assessment due to their importance for other parts of the wind turbine such as electrical equipment, bearings, shafts and hydraulic components.

Component	Description	Materials
Blades	Blades are typically made from sturdy, lightweight materials that are flexible and durable enough to withstand environmental elements and wind forces for an extended period. Fiberglass-reinforced plastic and carbon fiber-reinforced plastic are composite materials mostly used.	Fiberglass Polymers
Nacelle	Most nacelles are made from steel, aluminum, composites and hybrid materials to be strong and durable in order to protect the critical components inside, such as the turbine's generator, gearbox and electrical equipment.	Steel Aluminum Zinc Rare earths Iron Fiberglass Polymers
Tower	The tower brings the turbine to an elevated height to capture the best wind conditions. It therefore needs to be strong, durable and able to withstand potentially harsh weather conditions. Steel, concrete, zinc and hybrid materials are mostly the materials used.	Steel Cement Zinc
Foundation	**Onshore** Material is selected based on strength, durability and ability to withstand harsh environmental conditions. Most used material is cement, steel and gravel. **Offshore** The foundation need to withstand harsh marine environments such as strong waves, currents and winds. Foundation types commonly used: monopiles, jackets, gravity-based and floating structures. Zinc coating is used to resist corrosion.	Cement Steel Zinc

Source: Rystad Energy research and analysis

Turbine and cable material breakdown

Figure 40 shows the material composition of an 8-MW and a 15-MW offshore wind turbine. Smaller turbines typically contain more glass fibers in the blades, as the blade weight requirements are not as strict as the larger turbines. They also use more plastics such as PVC, thermosets and PET. On the other hand, larger turbines are more steel-intensive due to the increase in tower height.

Furthermore, plastics like thermosets and carbon fibers play a more important role as the industry tries to design lighter blades. The increasing turbine size means that the blades get longer, increasing the importance of lightweight and durable materials such as carbon fibers.

Figure 41 shows the typical material demand for 1 kilometer of inter-array and export cable used in offshore wind, and the material breakdown of the export cable. Inter-array cables are typically low-to-medium voltage cables (33 to 66 kV) that connect wind turbines to substations. As turbine sizes increase, developers are expected to opt primarily for 66 kV cables, which use more material per cable than lower voltage cables.

In offshore wind, export cables connect the offshore substation to the onshore power infrastructure. In many ways, they are similar to inter-array cables, but with higher voltages, such as 132 kV and 220 kV, reducing the power loss when carrying huge amperage to the shore. An export cable has about six times bigger amperage than its counterpart.

As offshore wind farms are deployed increasingly further from shore, the export cables become longer and absorb more power loss. Thus, HVDC (high-voltage direct current) export cables are expected to gain popularity, since HVDC is known to have less loss than the reigning HVAC (high-voltage alternating current) export cable. Growing project sizes will also drive the need for higher voltage cables, increasing material demand.

Figure 40: Material composition for 8-MW wind turbine (left) and 15-MW wind turbine (right)*
Metric tons

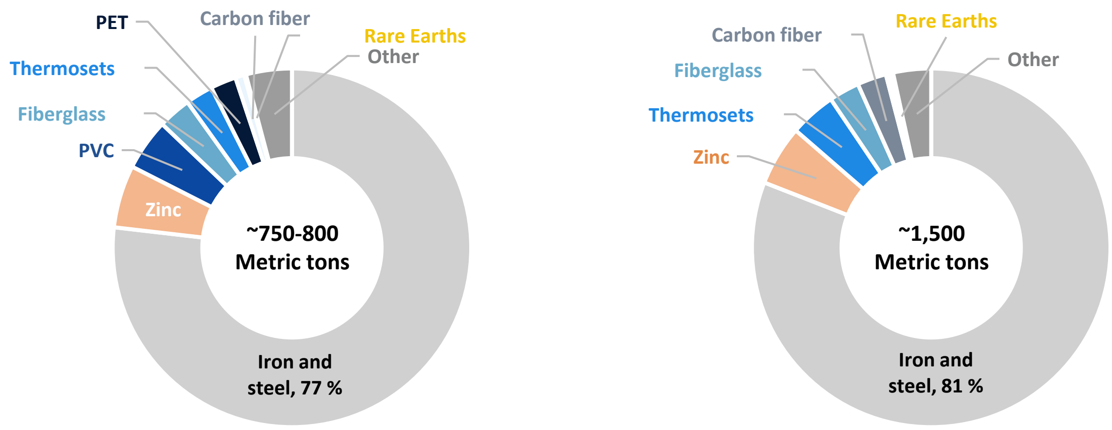
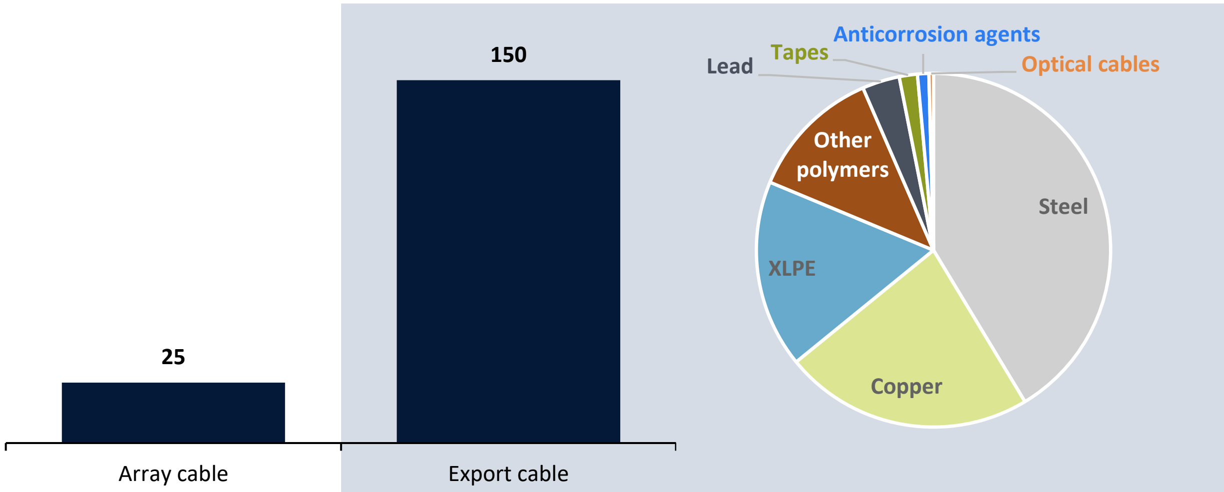


Figure 41: Material demand per kilometer of offshore wind inter-array cable (left) and export cable (right)**
Metric tons



*An offshore wind turbine is used in this example. **66 kV cable is used for the inter-array example, and 132-220 kV (average) for the export cable.
Source: Rystad Energy research and analysis

Demand for materials from European wind manufacturing towards 2030

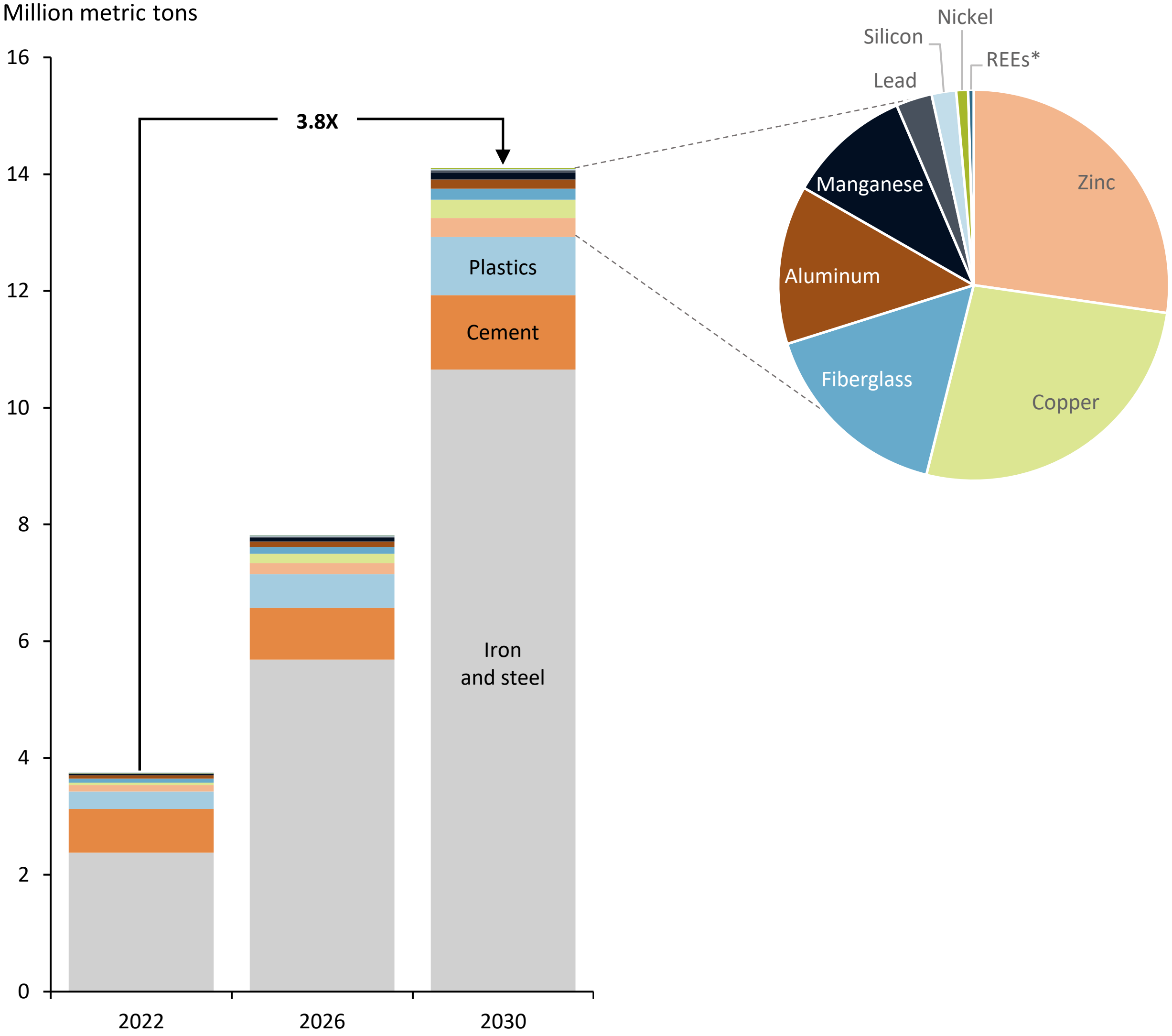
For the European wind industry to be able to deliver on its targets and deploy the projected wind capacity, access to materials for manufacturing is essential. Rystad Energy has assessed the increased demand for these materials based on the capacity outlook in WindEurope's *2030 Targets Scenario*, and the resulting component demand outlook estimated by Rystad Energy.

Iron and steel make up the largest share of the materials used in wind manufacturing, being a key part in foundations, towers and turbines. In 2022, iron and steel is estimated to contribute nearly 65% of the total material demand from European wind. This share is forecast to grow to around 75% by 2030, driven by offshore wind making up an increasingly large share of the installed capacity, requiring large-scale foundations. The growth of floating wind is expected to add to add to this trend, as steel-based foundations require large amount of the material. Although smaller in terms of their contribution to total demand, manganese, silicon and nickel will follow the same trend as steel demand, being important materials in iron and steel alloys, used to increase strength and wear resistance.

Cement is the second largest contributor with around 20% of total material demand in terms of weight and expected to stand for around 10% of demand in 2030. Cement is the main material in concrete foundations used in onshore wind, and since onshore wind's share of capacity additions is expected to decrease relative to offshore wind, cement's share of total demand falls.

Among the materials expected to see the largest relative demand growth towards 2030 are lead, copper and rare earth elements, driven primarily by the forecast growth in offshore wind. With demand for materials from European wind manufacturing expected to increase rapidly if Europe is to reach its ambitious targets, an assessment of the supply-demand status of these materials is important. These considerations will be presented in the following pages.

Figure 42: Demand for materials from European onshore and offshore wind
Million metric tons



*REE = Rare Earth Mineral
Source: Rystad Energy research and analysis

Assessment of critical materials in the European wind industry

Table 3 shows an assessment of the materials used in wind manufacturing, including turbines, foundations, cables and transmission infrastructure.

The materials, ranked by estimated demand in Europe in 2022, have been assessed along the three dimensions of the trilemma across reliability, affordability and sustainability.

Reliability: Where the material is produced/sourced. Is the material being produced in Europe? And if not, is production well diversified? Is European supply resilient to potential disruptions? Europe's relationship with the producing countries and the alignment of Europe's general values and standards with the material producing countries.

Affordability: Price, price fluctuations and price dependencies (if the material is produced mainly by a single country).

Sustainability: General impact on the environment and related greenhouse gas emissions as well as human rights and working conditions related to the production of the material.

Each material has been given a score from 1 to 3 for each part of the trilemma.

The overall status assessment includes the results from the trilemma scores, in addition to an assessment of each material's relative importance in wind manufacturing, and its growth trajectory towards 2030.

Iron and steel, fiberglass, copper, silicon, nickel and rare earth elements are the materials which according to this assessment have substantial risks associated with them, which the European wind industry should be aware of.

Three of these materials are highlighted later in this report – copper and rare earth elements, due to their criticality and strategic importance, and steel because of its widespread usage in wind component manufacturing.

Table 3: Results of the assessment of critical materials for the European wind industry

Material	Estimated European wind demand 2022 (thousand metric tons)	2022-2030 growth from European wind	Reliability score	Affordability score	Sustainability score	Overall status assessment
Iron and steel	2,378	4.5X	3	2	2	Yellow
Cement	748	1.7X	3	3	3	Green
Plastics	302	3.3X	3	3	3	Green
Zinc	105	3.1X	2	3	3	Green
Fiberglass	70	2.7X	2	2	3	Yellow
Aluminum	55	2.8X	2	3	3	Green
Copper	44	7.2X	2	1	2	Red
Manganese	27	4.5X	2	3	3	Green
Silicon	5	4.5X	1	2	2	Yellow
Nickel	3	4.5X	2	2	1	Yellow
Lead	3	13.9X	3	3	3	Green
Rare Earth Elements	1	6.7X	1	1	2	Red

Source: Rystad Energy research and analysis

Steel – European supply and demand

Steel is an alloy made from iron and other materials. Access to steel, and the right quality of steel, is important to the wind industry since most of the material needed for the construction of a wind turbine, and offshore wind foundations, is steel. One of the most common types of steel used in the wind industry is in the form of plates, and often thick or "heavy" plates mainly used for monopiles in offshore wind.

The top steel producing continent in the world is Asia, specifically China. However, steel production is considered well diversified, and the EU was the second largest producer in 2022 after Asia, closely followed by North America.

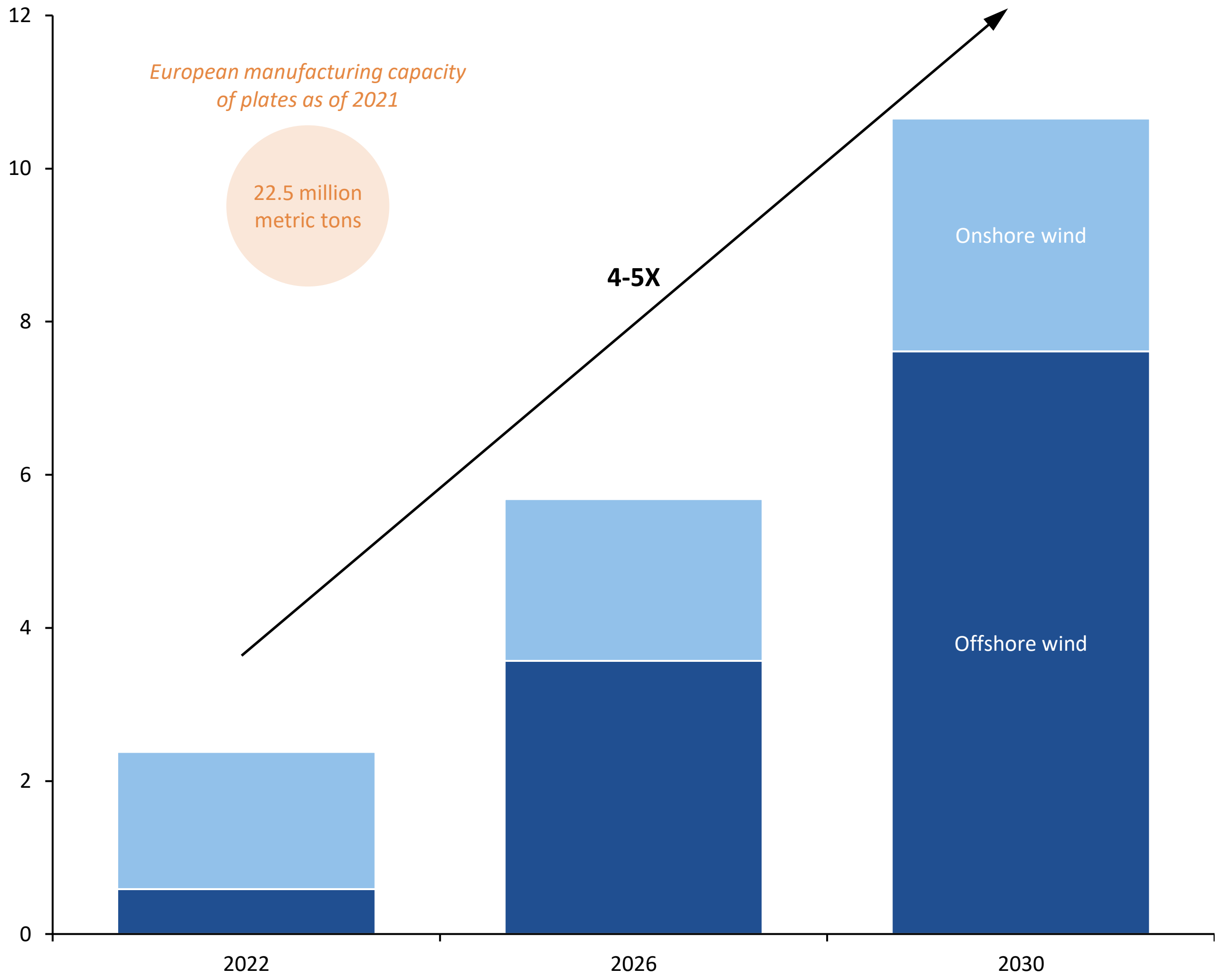
For steel plates, Ukraine has been a significant producer and in 2021, the country supplied close to 50% of the EU's plate imports. Due to the Russian invasion of Ukraine in February last year, the largest Ukrainian plate producer Metinvest lost control of its two plate mills in Mariupol, resulting in a plate production drop of over 70% in 2022. Consequently, countries like India, Indonesia, Japan and even Turkey, with only one plant, drastically increased their plate exports to the EU.

Russia and Ukraine have until now also been the largest slab providers to the EU, exporting 93% of EU's imported slabs in 2021. This is significant for European plate production seeing that various facilities in the region, especially in Italy, are entirely dependent on slab feed.

The supply disruption continued throughout 2022, when in September South Korea, a large producer of heavy steel plates, was struck by a typhoon causing large damages to several manufacturing facilities belonging to the country's largest steel producer POSCO. The company announced that the steel mills were fully restored and back to original operational capacity as late as in January 2023.

The market is now settling after continuous disruptions and unless other non-predictable situations should arise, the steelmakers should be able to sufficiently supply the market.

Figure 43: Iron and steel demand from European onshore and offshore wind
Million metric tons



Sources: Rystad Energy research and analysis; Rystad Energy Steel Solution.

Steel plate production capacity and price

A utilization rate slightly above 50% has been the general trend for most of the plate makers in Europe over the past 10 years, meaning they are not producing at their maximum capacity. This is due in part to the competitive threats from international plate supply, specifically from Asia. However, Ukraine is not included in Figure 44, where steelmakers, until the beginning of 2022, exported close to half of their steel to the EU. Traditionally, European plate producers are export-market dependent and contrary to the patterns in most steels, the EU remains a net exporter of plates, but typically for higher quality, heavier plates. For large volume, lower value (so-called commercial) plates, the region has increasingly been dependent on plates produced in countries with typically lower production costs.

Many plates in Europe are also produced by steel processors or “re-rollers” rather than steel producers, meaning that for example in Italy and the UK, steel is imported, in the form of slab, and subsequently converted into plates. As stated before, this slab traditionally comes from plants in Ukraine and Russia, which are at risk of being permanently disrupted. However, plates for the wind industry are unlikely to be disrupted given the green credentials renewable energy provides the steelmakers that are eager to reduce their exposure to more carbon-intense applications such as the oil and gas industry.

Since steel is an alloy and not a raw material, there is not a global steel market in the same way as other critical materials such as zinc and copper. The qualities of steel can be found in different regions and often with significantly different price tags. Markets geared for export, such as Europe and Asia, are often more competitive than import markets such as the US. In general, plate prices were unusually high in 2022, given the supply-side constraints emanating from Ukraine, but as regional supplies adjust, Rystad Energy expects the prices to decline year-on-year with 2023 being a year of corrections. The potential corrections for steel plates could in fact be greater than for other steels such as coils and bars, given the unusual premiums that plate prices achieved last year. With Europe’s focus on reducing emissions, wind manufacturers with a goal of reducing their carbon footprint might have some options to procure green(er) steel in the latter part of this decade. Currently, Industeel in France and Belgium are the only steelmakers in Europe that operate with electric arc furnaces (EAF). Dillinger will follow in 2027 when it is scheduled to commission its first EAF.

Figure 44: Utilization of European plate manufacturing capacity**
Million metric tons / Percentage

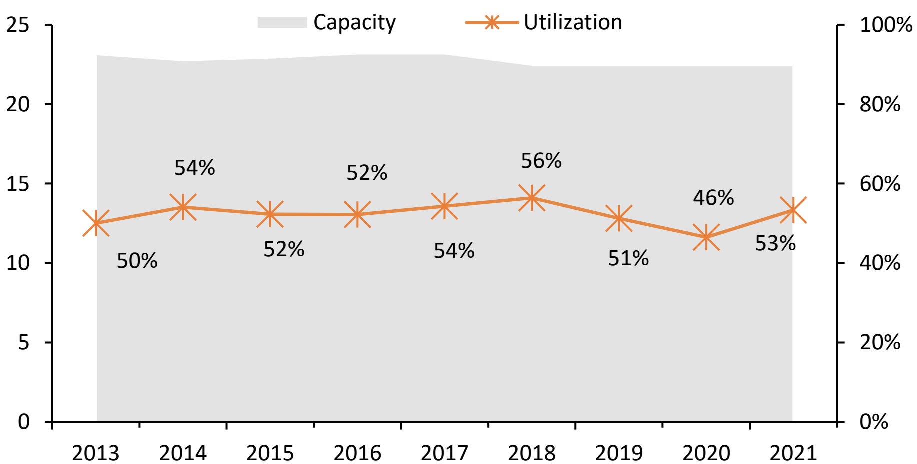
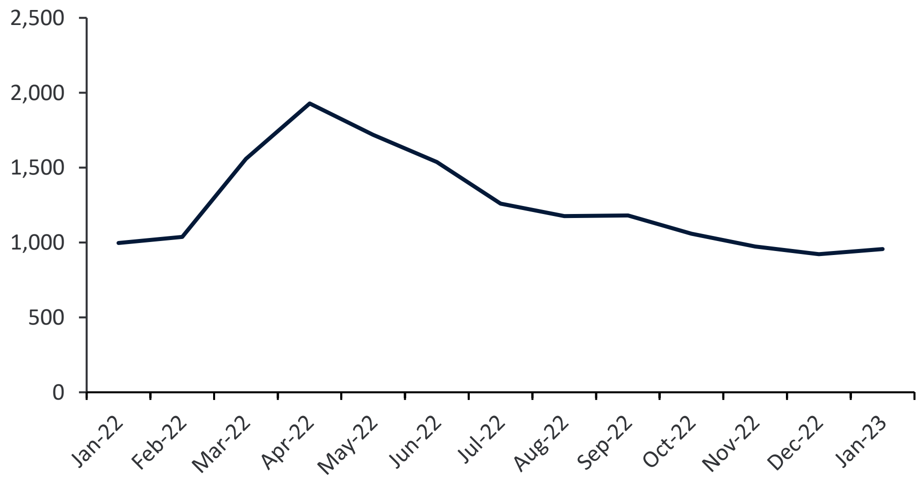


Figure 45: Plate steel price*
EUR per metric ton (nominal)



*Price for the S235 structural steel. Carbon steel plate up to 40 mm thickness. **European plate manufacturing capacity is referring to EU 27 countries, North Macedonia and UK.
Sources: Rystad energy research and analysis; Rystad Energy Steel Solution.

Copper – European supply and demand

Copper is the 25th most abundant metal in the earth's crust. It is malleable, ductile, corrosion-resistant and, perhaps most importantly, has strong conductive properties which make it extensively usable in electrical equipment such as wiring and motors. This is also the case for the wind sector which needs copper for its electrical components. Most of the copper is used for cables but it is also needed for power generators and transformers.

Copper demand mainly comes from three sectors: transportation, construction and renewable energy. Long-term copper demand is expected to increase significantly due to the energy transition and the general electrification of our societies. Electric vehicles (EVs) need three to four times as much copper as standard vehicles with internal combustion engines. With passenger vehicles expected to grow six times and commercial vehicles to grow nine times by 2030, a significant increase in copper demand is expected to come from this sector. With the expansion of renewable energy, grid and network infrastructure will both grow and improve, further increasing demand for copper. From European wind, the expected increase in demand based on WindEurope's *2030 Targets Scenario* will be seven times higher than in 2022.

Last year, total copper production globally was around 22 million metric tons, according to the US Geological Survey, with Chile, Peru and China as the three largest producers. Europe produces approximately 1.8 million metric tons (as of 2021) excluding recycling, where Russia stands for close to 50% of this. Although most of the global production is outside Europe, copper production is well diversified globally which is the reason why the metal does not make the threshold of the European Commission's list of critical raw materials. However, it has been deemed a *Strategic Raw Material* and is therefore included in the fifth and most recent assessment of EU's critical raw materials as of 2023. Lately, large copper mines in Peru have either been halted or shut down due to political unrest and, together with China's lockdown in 2022 due to Covid-19, copper production fell significantly. Additionally, stockpiles are at very low levels which results in a currently tight global copper market.

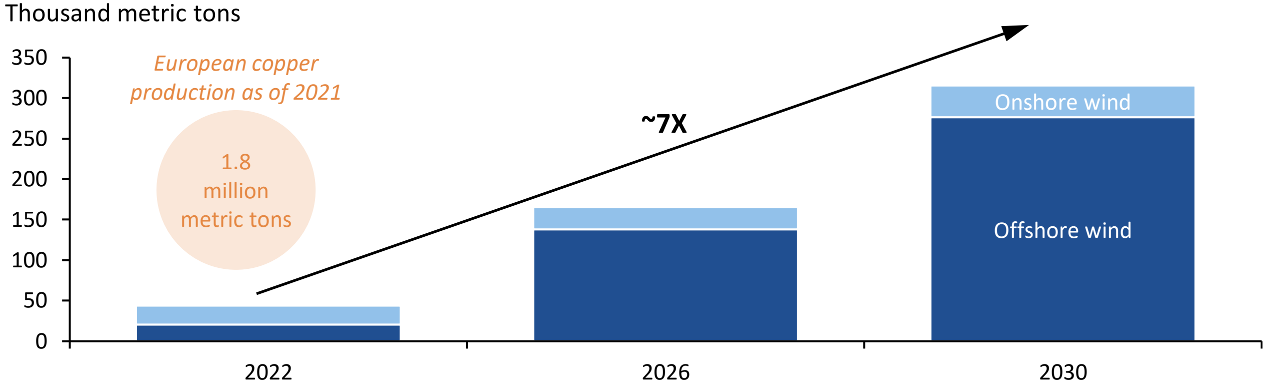
The lockdowns around the globe in early 2020 because of Covid-19 limited global supply drastically and pushed copper prices through the roof. The current short-term supply tightness coupled with the long-term energy transition related demand can potentially push prices even higher in the future. At the same time, with copper prices sustained at relatively high levels since the effects of Covid-19, copper producers will likely seek to expand their production.

According to the International Copper Study Group, Europe recycles about 50% of its used copper. This greatly reduces the dependency on production expansions and if the share of recycled copper increases, it will greatly aid the region to secure copper for future products – including the wind industry.

Copper is produced in many developing countries and human rights organizations have issued warnings about illegal working practices, particularly in African countries. Copper workers of multi-national firms are forced into dangerous conditions with little safety precautions and low wages. Ensuring the wind industry supports a fair and just copper industry with proper worker rights can therefore mean utilizing as much European copper as possible.

Aluminum and fiber are two potential copper alternatives. With the increased copper price, the price gap between fiber and copper has become smaller, making fiber more cost competitive. Fiber is especially applicable for network transmission as it has the advantage of greater bandwidth and hence increased transmission speed. Aluminum is also a lower cost alternative to copper, and despite having inferior conductivity, it is expected to see an increasing share in cables used in the wind industry in the longer term.

Figure 46: Copper demand from European onshore and offshore wind
Thousand metric tons



Source: Rystad energy research and analysis.

Rare earth elements – supply and demand

There are 17 defined Rare Earth Elements (REE) in the world, and, despite their name, these are found in relative abundance around the world. In the wind industry, the REEs are important for the manufacturing of permanent-magnet generators, located inside the nacelle. REEs are crucial components in direct drive wind turbines which do not require gearboxes. The three most important REEs for the wind industry are Neodymium, Dysprosium and (although in relatively small amounts) Praseodymium.

Demand for REEs coming from the wind industry, mainly offshore wind, is forecast to grow about seven-fold by 2030 if Europe is to reach its wind energy targets. REEs are also used in the traction motors of EVs, and the electrification of the transport sector globally will significantly increase the demand for REEs.

According to the European Commission, Europe currently imports 98% of its REEs from China. As such, there are concerns for direct supply chain bottlenecks, also in terms of geopolitical tensions. The biggest threat for the supply of REEs for the European wind industry is the dependence on China for production. Consequently, to a large extent, China also controls the prices for REEs.

REEs are generally found as a mix of multiple elements and due to their similar characteristics, the process of separating them is complex. In addition to extracting most of the ore, China also has the most process and refining facilities, meaning that even if Europe and the rest of the world would expand their mining capacity, processing will still likely take place in China. Europe is therefore forced to build out the entire value chain to reduce its dependency.

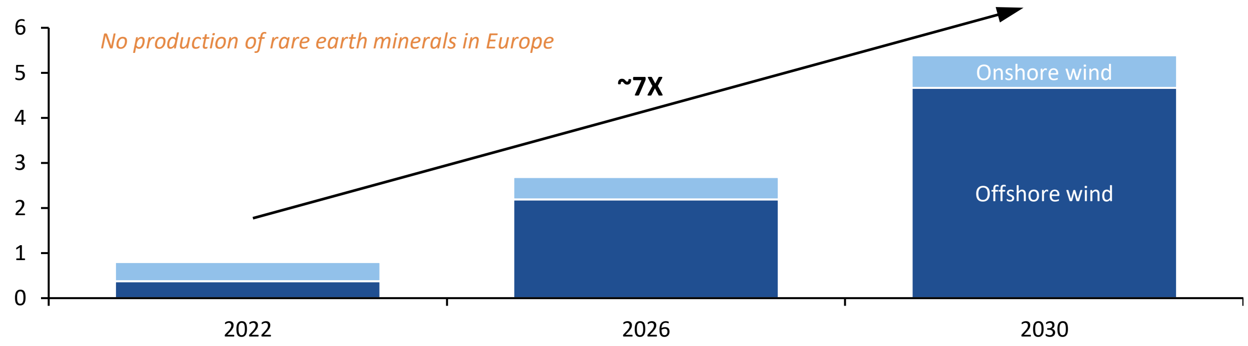
The European Commission started its first work mapping critical raw materials for multiple industries in 2011, and rare earths made the list. The Commission exclusively mentions the importance of REEs for the wind industry. Together with the rare earth crisis in 2010-2011, the need to diversify global production for REEs has for some time now been on the mind of the global community and in 2020, the European Commission launched the European Raw Materials Alliance. The first focus of the alliance has been to increase EU's resilience in the rare earth and magnets' value chain. The largest producer outside China is Lynas Rare Earths in Australia. They also own a separation and processing facility in Malaysia, and the US supported the company with funding to build two additional processing facilities in the US (both in Texas).

The EU-funded EURARE project from 2013 was tasked with mapping out potential REE deposits in Europe and identified several potential sites in Greenland (Denmark), Sweden, Greece and Spain. However, the main challenge with producing REEs in Europe does not seem to be the discovery, but the extraction process and improving the techniques and extracting minerals in an environmentally-friendly way.

Canadian company Neo Performance Materials owns the only rare earth processing facility in Europe (in Estonia) and has announced planned upgrades to the plant. It has also announced plans to establish a new magnet factory, which will be a vertically-integrated rare earth production facility. Additionally, Swedish mining company LKAB discovered a large deposit of rare earths in Sweden at the beginning of this year. This is so far the largest known deposit in Europe and could potentially greatly aid the European production of REEs.

Since China controls most production, it also effectively control the prices. Current prices are reflected in low mining and production costs in China together with lower environmental standards compared to Europe and North America. At the same time, global demand is pushing prices upwards. There are different prices for various products, and mixed products are generally cheaper compared to individual rare earths. Europe could therefore obtain lower prices should it invest in processing and refining plants.

Figure 47: Demand for rare earth elements from European onshore and offshore wind
Thousand metric tons



Source: Rystad energy research and analysis.

Recycling and emission reduction

Recycling

A strong positive for steel is that it is infinitely recyclable. At the end of its life cycle, if the steel cannot be directly used for other applications, it can return to the steelmaking process to be reprocessed into new products. The value of the steel scrap will therefore become a significant cost for plate producers in the future, especially in Europe and Asia which are the largest plate producing regions that currently depend on iron ore and coke, either purchased or produced by the plate mills themselves.

The process of extracting, refining and producing copper is carbon-intensive. The mining process emits 2.3-2.5 metric tons of CO_2 per metric ton of metal. If smelting and further production is included, 1.65 metric tons of CO_2 per metric tons of the metal can be added. However, copper is recyclable and currently around 30% of total copper consumption is covered by recycling, thus reducing emissions by 65% compared to primary production. Copper retains 90% of its value when recycled and is therefore in the interest of the producers to recycle it.

Last year, US company Carbon Rivers commercialized its recycling technology which upcycles all components of the wind turbine blade, including the steel, fiberglass and carbon fiber. Glass-fiber materials are also essential components of wind turbine blades, and currently European manufacturers are heavily dependent on imports. In 2021, WindEurope called for a Europe-wide ban on landfills for decommissioned turbine blades by 2025 and with recycling technologies improving, re-using blade materials can become more widespread. Denmark-based company Continuum is planning to build six recycling factories across Europe, with the first expected to become operational by the end of 2024 and start taking in end-of-life blades by the end of this year.

Green steel

Over the past decade, the relationship between steel production and carbon emissions appears to have been intensifying as traditional blast furnace technologies have become more popular, especially in China. More environmentally-friendly electric arc furnaces (EAFs) depend on scrap, which has traditionally only been abundant in fully industrialized markets, unlike growing, developing steel markets like China or India. Last year was an unusual year as steel production fell, and with it, CO_2 emissions. However, the demand outlook suggests production will soon reach new heights.

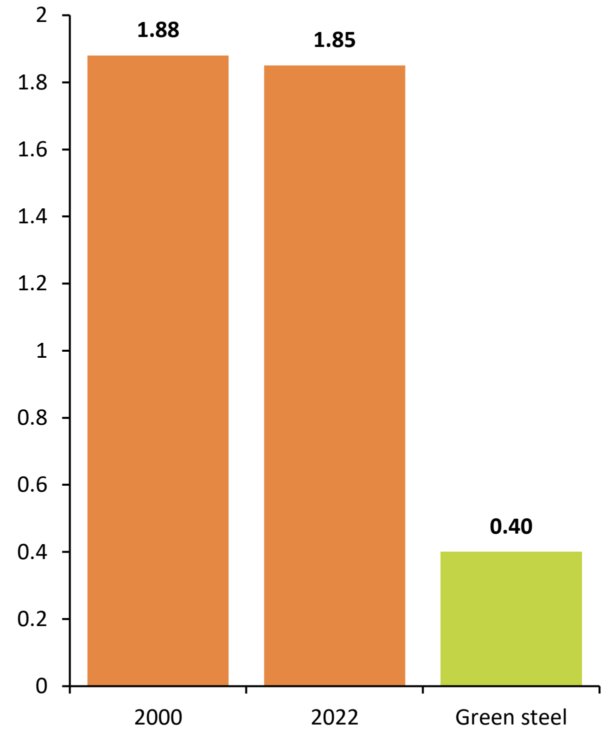
To stop CO_2 emissions rising at the same time, the concept of 'green steel' is gaining attention, most notably in Europe where carbon taxes are well established, and climate and net zero goals are in focus. Green steel production is the concept of using renewable energy sources to at least power the steel production, notably among EAFs, and carbon capture to collect emissions, notably from blast furnaces (BFs) and basic oxygen furnaces (BOFs). There are also plans to use green hydrogen in place of natural gas or coal at Direct Reduced Iron (DRI) facilities, and coal and coke at BF facilities to reduce iron ore, given that scrap supplies may struggle to meet all the raw material demand from steel producers.

Companies such as H2 Green Steel are developing this technology and have entered partnerships with renewable energy and mining players. The industry can expect to see at least a handful of steel plants trying to run on green hydrogen prior to 2030, but this technology would not make up a significant part of the European steel production within this decade, as it is still in a nascent stage. Europe is primarily focused on replacing blast furnaces with DRI/EAF alternatives, whereas Asia is more interested in a combination of clean options.

From a sustainability point of view, European wind farm owners should first and foremost make sure that the end-of-life turbine blades are being recycled, and secondly, companies manufacturing wind turbine components should seek to use steel made from electric arc furnaces before the green steel technology is made commercially available for the market.

Figure 48: Iron and steel emission intensity

Ton of CO_2 per ton of steel (t CO_2/t)



Sources: Rystad energy research and analysis; Rystad Energy Steel Solution

The EU has committed to becoming climate neutral by 2050. This means accelerating the renewables-based electrification of Europe's energy mix. The war in Ukraine has only underscored the need for Europe to shift away from volatile fossil fuel imports and accelerate the roll out of home-grown energy.

To this end, European legislators have now agreed that the EU must meet a 42.5% target for renewables in its energy mix by 2030. This means the EU must install 28.5 GW of wind energy each year between 2023 and 2030. A very significant increase on the 16 GW installed in 2022. This is at a time where 80 GW of wind energy projects are stuck at various stages of permitting procedures across Europe.

The European wind supply chain will need to expand to deliver on those volumes and having a healthy European supply chain is vital. But all indicators currently point in the wrong direction. With €17bn invested in new wind farms in Europe in 2022, wind investment numbers are the lowest since 2009. They only represent the equivalent of 12 GW financed, less than half of the required annual deployment volume. With turbine orders down 47% compared to 2021, Europe needs to significantly increase investor confidence to ensure that its renewable energy goals can be met. The EU must also stick to a targeted reform of the electricity market design and remove revenue caps which hold back investments.

In March 2023 the EU presented its legislative response to the growing issues faced by the industry in the form of the Green Deal Industrial Plan. Included in this plan are the Net Zero Industry Act and the Critical Raw Materials Act. These aim to create a more predictable and simplified regulatory environment, offer faster access to funding, develop open trade for resilient supply chains and to ensure that Europe has the skills base needed for the increased deployment of renewables. The plan also calls for 36 GW of annual European wind turbine manufacturing capacity by 2030. To finance this, the EU is proposing to initially utilise the Innovation Fund before transitioning to the yet to be confirmed EU Sovereignty Fund. However, focusing on innovation rather than volumes does not send the right signal to the market and so a dedicated and fit for purpose funding and financing instrument is required. Whilst the Green Deal Industrial Plan is a step in the right direction, the plan falls short of delivering the support needed to maintain and grow Europe's wind energy supply chain and to ultimately allow us to meet our 2030 targets.

In parallel, in 2022 the US agreed its Inflation Reduction Act, earmarking USD$369bn for its clean technology supply chains, and China continued to apply very robust target-driven industrial policies. Unless Europe wants its ambitious climate objectives to be met by non-European technology, it needs to set out very clear Financing and Regulatory measures to preserve and expand its clean technology supply chains.

This requires national governments to accelerate renewables permitting so that national commitments on renewables translate into actual projects. Having the right wind auction design, supporting the expansion of the wind supply chain and ensuring renewables investors have the right market signals to accelerate wind deployment are crucial.

To achieve Europe's renewable energy ambitions, there are three sets of policy recommendations that will make the difference.

1) **National Governments must apply the rules now agreed at EU level to accelerate renewables permitting by:**
   - Reflecting in their permitting processes that renewables are in the 'overriding public interest'
   - Applying a population-based approach to biodiversity protection
   - Meeting their binding 2-year permitting deadline including the grid connection permit and evaluation of the environmental impact assessment.
2) **National Governments must ensure their wind auction design addresses the challenges of the supply chain by:**
   - Indexing auction tariffs to reflect possible increases in commodity prices.
   - Avoiding negative bidding where the industry pays for the 'privilege' of building a wind farm.
   - Using non-price criteria in auctions to reward the added value that European manufacturers bring in terms of energy system integration, sustainability, European jobs and community engagement.
3) **The EU and National Government must support the expansion of the wind supply chain by:**
   - Making use of the flexibility in the State aid guidelines that allow national Governments to give CAPEX support to production.
   - Improving the Net Zero Industry act so that it delivers the support that the industry need.
   - Developing fit-for-purpose Funding and Financing instruments at EU level through reforming the Innovation Fund to focus on scaling up clean tech supply chains and focusing the new EU Sovereignty Fund on the technologies that deliver net zero and energy security.
   - Establishing new trading routes for the raw materials that we need through the Critical Raw Materials Act. This includes sourcing from reliable third countries, recycling and mining in Europe. To support this, the EU must coordinate trade defence measures to ensure that European manufacturers remain competitive globally.

With only 7 years to go until 2030, the time is now to make the necessary improvements so that Europe's energy transition can be built at home. We need to see the quick adoption of supporting measure that are manufacturer friendly and for permitting processes that to work in Europe's favour rather than against it. Only then will we see the significant levels of investment needed at home.

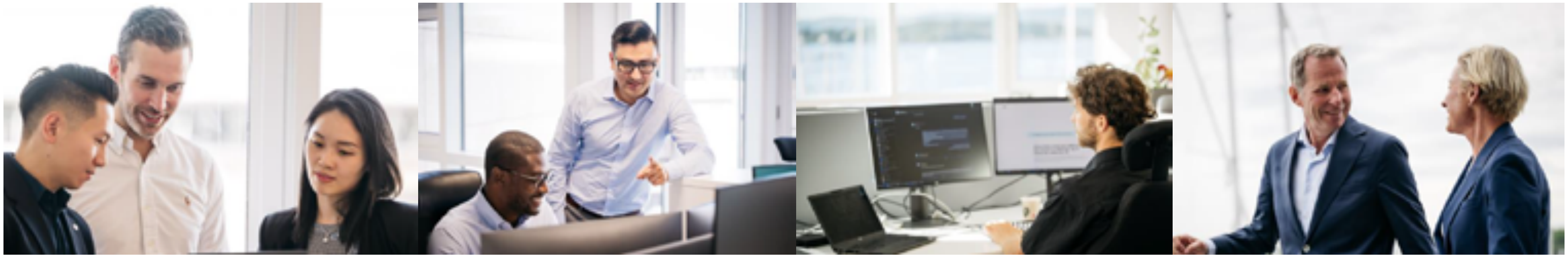
Source: WindEurope

About Rystad Energy

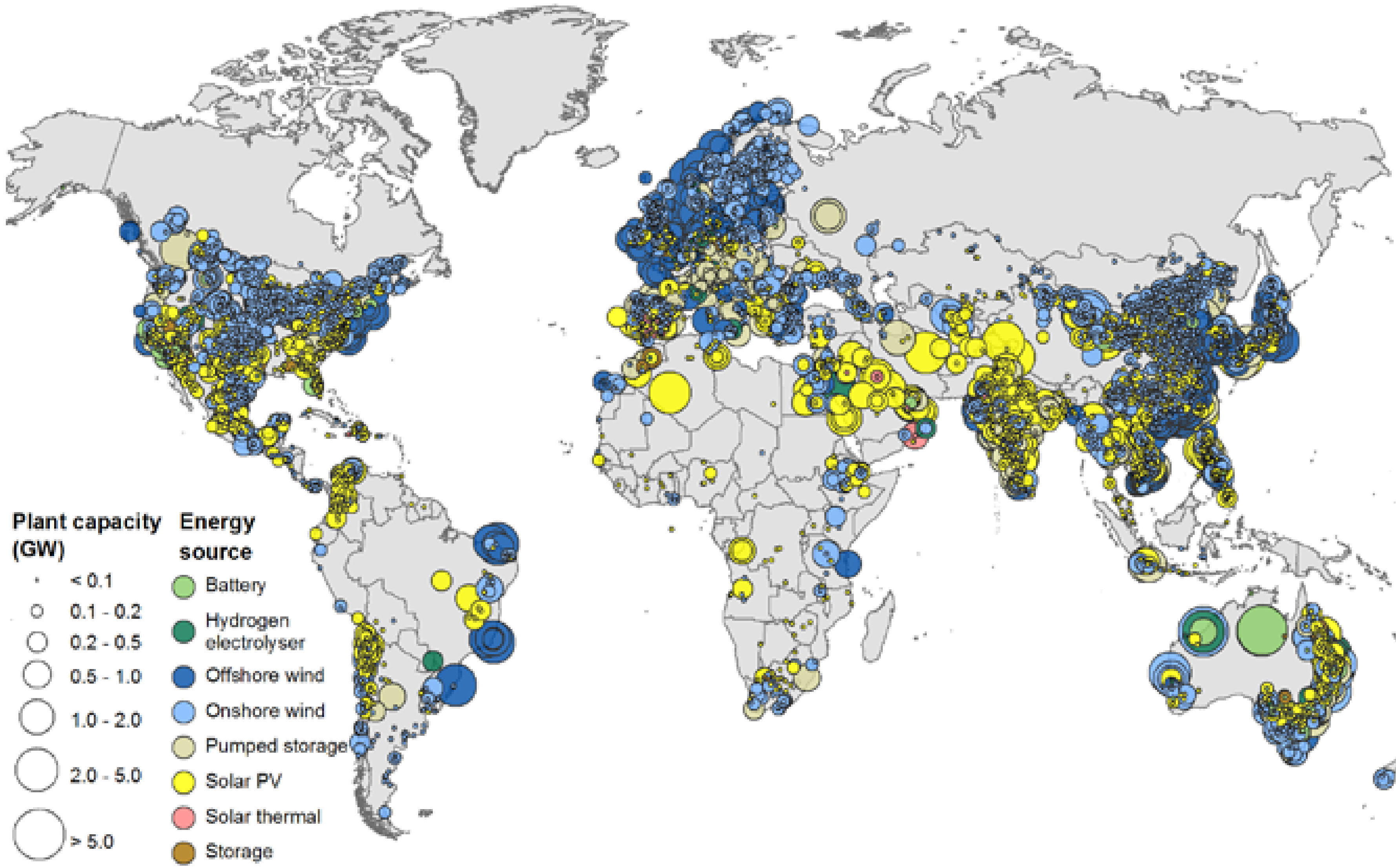
We are
a global independent **energy research and business intelligence** company covering all energy sources and energy markets globally

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**



Rystad Energy covers more than 100,000 utility-scale renewable assets globally



Methodology overview

Figure 49: Component/service demand model overview

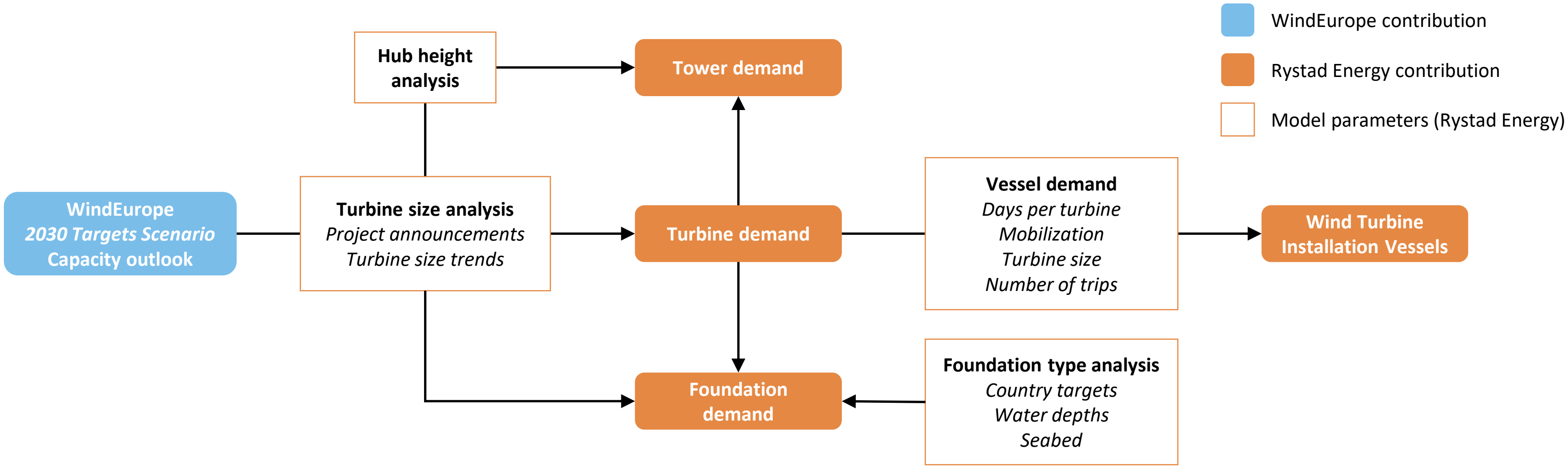
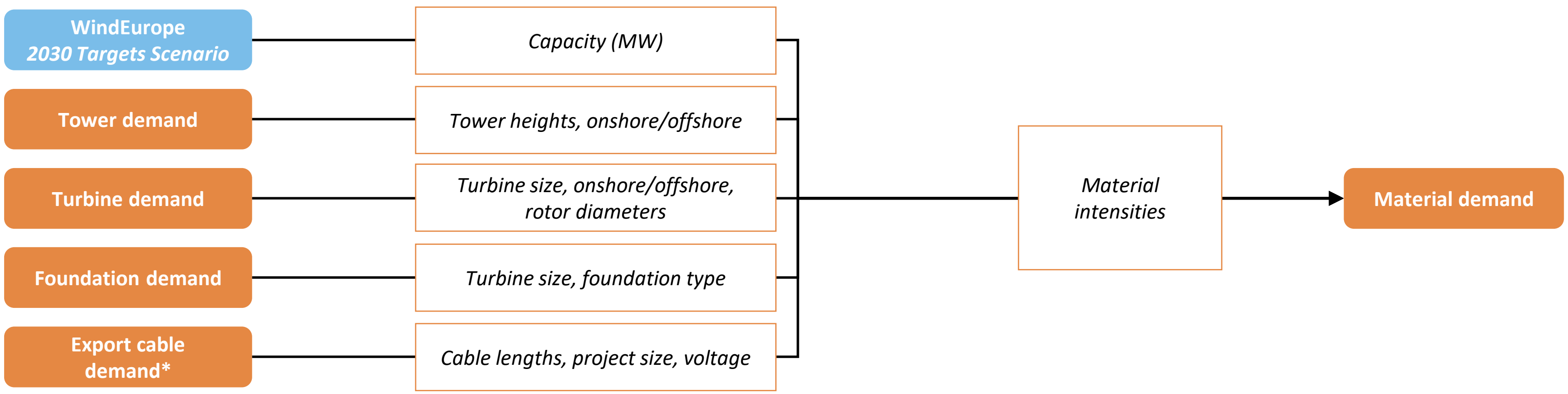


Figure 50: Material demand model overview



*Only used for material modeling purposes

Appendix

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