Center for Strategy and Scenario Planning

FUTURE SCENARIOS

for the European and German Wind Energy Industry

TABLE OF CONTENTS

1 Foreword

"Trying to predict the future is like trying to drive down a country road at night with no lights while looking out the back window." Peter Drucker

Rarely has the outlook for the German energy market been so bleak and dominated by so much uncertainty as today. This is particularly true for the wind energy markets. Will ambitious political goals eventually lead to significantly increased installed capacity? Or will regulatory hurdles prevent the expansion? How will the supply side ecosystem in the industry develop? Will the wind turbine manufacturers continue to experience low EBIT margins or even losses? In this study, we try to provide answers to these questions and offer “food for thought” not only for managers of energy providers.

Today’s business environments are becoming increasingly complex, volatile, and uncertain. Changes arrive faster than ever, and many developments are impossible to forecast. Particularly, linear projections from the past are not helpful. Nevertheless, managers need to take decisions and commit resources. This is only possible if uncertainty is accepted and made an integral part of strategic decisions. Conventional strategic planning tools tend to be inadequate under these conditions because they do not sufficiently take uncertainty into account. Scenario planning differs fundamentally from conventional strategy tools in this respect, as it attempts to capture a broad range of alternative developments, thus encouraging strategic decision makers to consider influence factors they might otherwise ignore.

Our scenario study on the European and German wind energy markets supports managers in this endeavor. We have developed four scenarios for the industry in 2033 based on several key uncertainties and important industry trends. We hope that these scenarios will inspire you and help you manage the opportunities and threats in this dynamic industry.

We wish you an insightful journey through the current situation and the potential futures of the European and German wind energy markets.

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2 Executive Summary

The current situation on the European wind energy market seems highly ambivalent and uncertain. On one hand, as fighting climate change has become a political priority, Europe and Germany have committed to ambitious climate goals, which call for a significant and fast expansion of renewable energy generation (European Commission, 2022; Bundesregierung, 2023a, 2023b, 2023c). Ambitious political plans have emerged, particularly for wind energy, such as the goal stated in the Ostend declaration of having 120 GW of wind energy installed in the North Sea by 2030 (European Commission, 2023). On the other hand, the actual expansion of wind energy, notably in Germany, has been slow in recent years, and leading European wind turbine manufacturers reported significant losses last year (Tagesschau, 2023; Vestas 2023b).

In general, the energy trilemma encompasses the need for secure and reliable energy, affordability, and minimal environmental impact (Sommer, 2015). Unlike for example the United States, Europe traditionally faces a scarcity of domestic fossil energy sources, resulting in high import costs and supply vulnerabilities. Europe's energy vulnerability became evident during the ongoing energy crisis, triggered by post-covid energy demand in Asia and disruptions in cheap gas supplies in course of Russia’s invasion in the Ukraine. Consequently, energy prices skyrocketed, contributing mayorly to the high inflation in 2022 (Energy Institute, 2023).

Renewable energy sources, especially wind and solar power, appear as the ideal solution for Europe´s domestic energy dilemma due to availability and scalability. In addition, renewable energies are nowadays usually cheaper than fossil fuels. The electricity generation costs for wind power in Germany is now about only 4-8 cents per kilowatt hour (IRENA, 2022). Consequently, the renewables sector in Europe should be booming. However, the wind energy industry and especially turbine manufacturers have experienced limited expansion and financial troubles in recent years, despite its enormous potential for growth (WoodMackenzie, 2023).

All players along the value chain as well as other stakeholders such as banks or politicians must find answers to critical questions: Can we achieve our climate goals? How quickly can turbine production be sustainably scaled? When will supply chains run more smoothly again? What about competition from abroad? How consistently will society and politics support the energy transition? When will there be faster approval processes? How quickly can power grids be adapted to a system based on renewable energy? Is there enough land for wind turbines? Will the local population accept them even near their homes? Overall, it currently seems very difficult to answer whether positive winds will be blowing that support European Greentech or whether we are facing a lull for this promising industry.

To address these challenges and help managers in the energy industry plan for the future, we created this study using our innovative approach to scenario-based strategic planning, jointly developed by HHL and the strategy consultancy Roland Berger. Our scenarios are based on extensive research and industry-wide surveys considering various stakeholder groups. This has helped us gain a holistic picture of the relevant trends and influence factors in the industry and ensures the quality of the scenarios and resulting strategy implications

The four scenarios we have created evolve around two critical uncertainties identified in our survey of industry experts:

- **Design of the regulatory framework**
- **Development of the supply side ecosystem**

Based on these critical uncertainties as well as additional trends and influence factors, four plausible scenarios emerge on how the European wind energy market could fare until 2033. These four scenarios are the following:

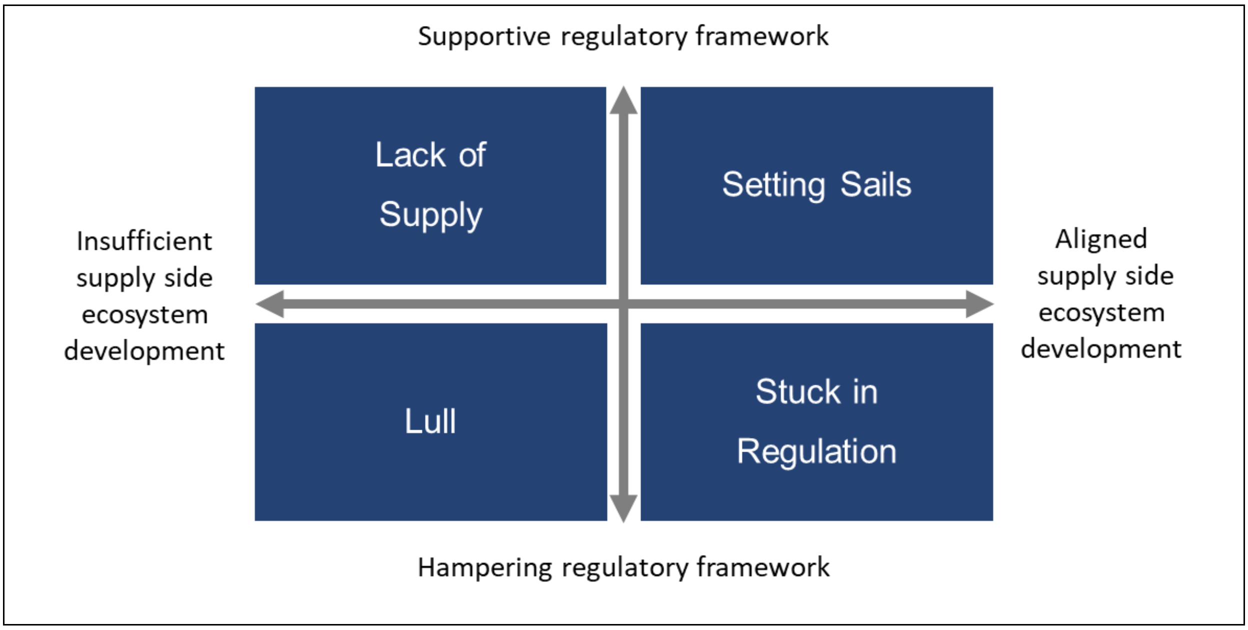


Figure 1: Scenario Matrix for the European and German wind energy market

Source: Own illustration

"**Setting Sails**" portrays an energy transition in Europe that has gained momentum by the mid-2020s with the "Fit for 55" and "REPowerEU" plans. By 2033, renewables accounted for 45% of Europe's energy, led by Germany achieving 80% renewable electricity, primarily from wind power. This success is attributed to positive political support, societal backing, efficient approval processes, and increased international cooperation. The wind energy sector, deeply integrated into local communities, has played a pivotal role in achieving these goals. Europe's commitment to sustainability and strategic collaboration has not only driven progress but also yielded solid profits throughout the wind energy value chain, offering a promising future for the green energy sector.

"**Stuck in Regulation**" shows Europe's slow energy transition impeded by bureaucratic barriers, making 2050 climate neutrality uncertain. By 2033, renewables contributed 30% of Europe's energy, with also Germany missing its targets. Wind power formed 35% of German electricity, facing resistance and regulatory delays. Geopolitical cooperation improved, yet labor shortages and weak immigration policies still posed hurdles. Wind turbine manufacturing and European developers face challenges in scaling and pricing and struggle with competition outside the European market resulting in limited growth and profitability.

"**Lull**" paints a grim picture for the European wind energy sector and depicts Europe's faltered energy transition after the mid-2020s, making climate neutrality by 2050 appear out of reach. Ambitious plans lacked momentum, and by 2033, renewables provided only 25% of Europe's energy, with close-to-zero green hydrogen adoption. Germany´s power mix shows just 50% renewables and continues to rely heavily on coal and gas. Wind power faced numerous obstacles including regulatory hurdles and geopolitical tensions causing instable supply chains. European wind energy firms ceded market share to international rivals, resulting in some manufacturer bankruptcies.

"**Lack of Supply**" presents Europe's sluggish energy transition, decelerated by ongoing supply sided challenges. By 2033, renewables accounted for 30% of Europe's energy, with Germany falling also short of its ambitious goals. While political support for wind energy improved and approval processes sped up, persistent geopolitical tensions and supply-side challenges like raw material scarcity and labor shortages hindered progress. Despite an advantageous regulatory framework, many companies along the value chain show limited growth and, especially manufacturers, struggle to turn a profit.

3 European and German Wind Energy Market

Renewable energies are playing an increasingly important role in the energy supply. Wind energy is a major pillar of the energy transition with a share of over 20% in the German electricity mix (Energy Institute, 2023). This section aims to provide an overview of the state of renewable energy and the wind energy industry in Europe. The initial chapter introduces the European energy markets, followed by a summary of the growth of renewables. Then energy transition policies and regulatory aspects are examined before we have a closer look on the development of the European wind energy industry and is key players. Finally, current trends and a market outlook are provided.

Structure and Evolution of European Energy Markets

According to the Energy Institute's annual Statistical Review of World Energy Data (2023), Europe accounted for 13.2% of global primary energy consumption in 2022. In this report, Europe is defined as including Turkey but excluding the CIS countries Russia and Belarus. This geographical demarcation of Europe will be adopted for this study. European primary energy consumption in 2022 was around 22,170 TWh. Germany accounted for around 15% (3,420 TWh) of this and was therefore the federal state with the highest energy consumption in this region.

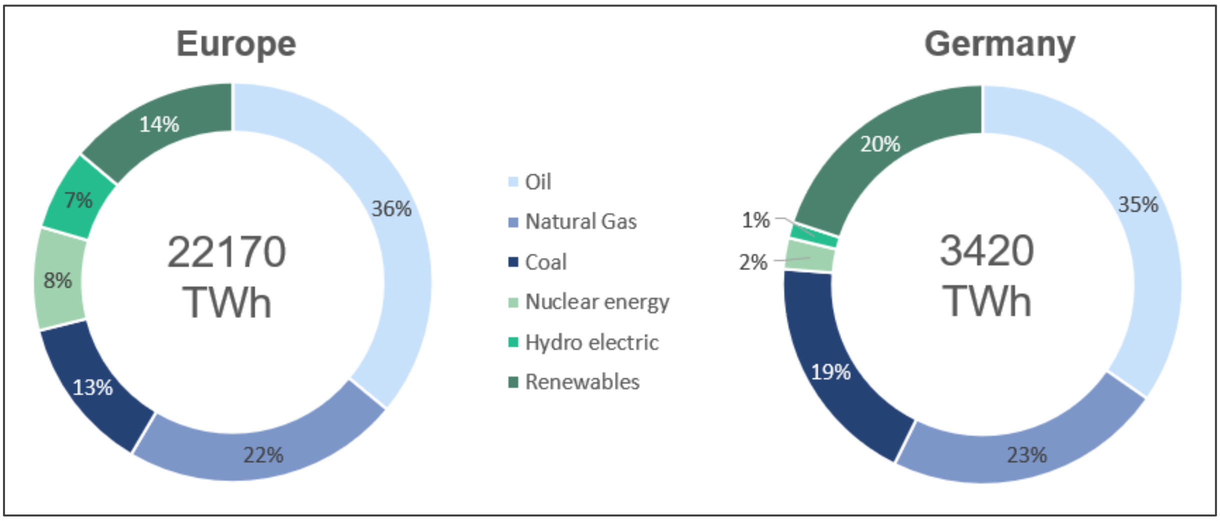


Figure 2: Energy consumption by energy type

Source: Own illustration; data from Energy Institute (2023)

As Figure 2 shows, both in Europe and in Germany, the fossil fuels oil, gas, and coal account for the lion's share of primary energy consumption at around 70-75%. The main reason for oil having the highest share is the reliance of the transportation sector on oil products, which account for more than 90% of the energy used in the transportation sector (Umweltbundesamt, 2023a). Part of the primary energy source, natural gas, and most of the coal and renewable forms of energy (wind, solar, but also biomass) as well as hydropower and nuclear energy are used to generate electricity (secondary energy).

A special characteristic of Europe in a global comparison is that the peak of energy consumption seems to have been overcome (Energy Institute, 2023). In Europe, the energy demand has been declining slightly since the late 2000s, while it is still growing worldwide, especially in Asia. In Germany, this trend started even a few years earlier than in the rest of Europe.

Because the topic of this study is the wind energy industry, the focus will now be on electricity. Still, it is important to consider general energy demands in Europe and Germany, since in the future with the pursuit of decarbonization, fossil fuels will have to be reduced and replaced by low-carbon emission forms of energy (especially renewables). This includes, for example, low-CO_2 electricity instead of mineral oil for the transportation sector and green gases (i.e., hydrogen and other gaseous fuels produced with power from renewables) instead of natural gas for the industrial sector (BCG, 2021).

Schiffer (2019) describes that until the mid-late 1990s, the European electricity markets were characterized by monopolistic market structures. In five of the EU-15 countries at the time, including France and Italy, 90 percent of the electricity supply in each market was provided by a single state-owned company. In Germany, there was a pluralistic system with many individual companies, but due to the regional monopolies being covered by antitrust laws free competition was impossible. It should also be noted that at that time power generation, trading, and sales as well as the operation of the grids were not separated causing a high degree of vertical integration.

The monopolistic market structure was liberalized in several steps starting in 1996 based on the EU Directive 96/92/EG (Europäisches Parlament, Rat der Europäischen Union, 1996). During the liberalization, there was also a (partial) privatization of state-owned companies. In some cases, such as the French electricity supplier Électricité de France (EDF), however, it was later re-nationalized.

Around the turn of the millennium, power exchanges were opened in Europe as part of the liberalization, such as the European Energy Exchange (EEX) in Leipzig (Schiffer, 2019). In the increasingly liberalized market, new players first appeared in electricity trading and sales. Soon, however, new players also entered the area of electricity generation, the so-called independent power producers (IPP), who operate power plants and feed the electricity into the grid. They sell the electricity either via bilateral contracts, usually referred to as over the counter (OTC) or on the electricity exchange.

However, most of the large, often formerly state-owned, electricity companies still have very high market shares despite the liberalization. In Germany, the five largest companies have a combined market share of around 2/3 (Bundesnetzagentur, 2023a) whereas in France the re-nationalized giant EDF alone had a market share of over 80% (Fraunhofer ISI, 2015). In contrast to power generation, trading and sales, the power grids are natural monopolies. Accordingly, during liberalization, the large power companies had to split off or sell their power grids. Nowadays, in most European countries there exist only one national transmission system operator (extra high and high voltage lines). Germany forms an exception and is divided into four zones of different transmission system operators (Tennet, Amprion, TransnetBW and 50hertz) (Schiffer, 2019).

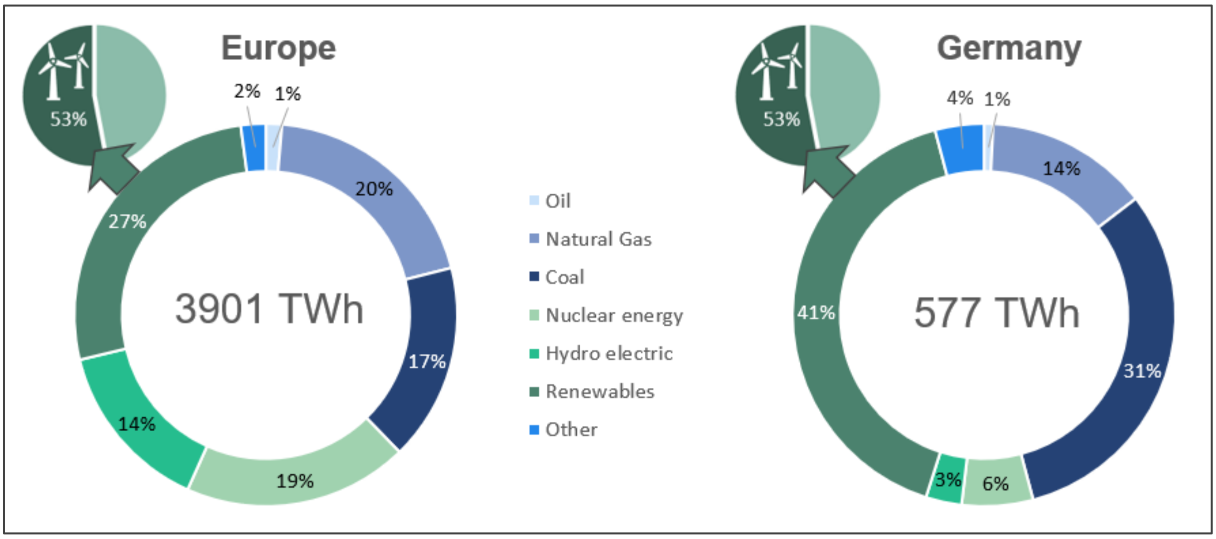


Figure 3: Electricity generation by energy type

Source: Own illustration; data from Energy Institute (2023)

While the proportions of primary energy sources, such as oil, are relatively similar everywhere in Europe (compare Figure 2), the sources of electricity generation in Europe differ widely. As can be seen in Figure 3, Germany had a significantly higher share of coal and renewables in 2022 than the European average, but a smaller share of nuclear and hydropower. The reasons for this are of geographical, historical, and political nature. In Germany large lignite resources can be found, while it´s topography and population density are not suitable for high-yield dams like in Norway or Austria, countries which generate most of their electricity from hydropower (Energy Institute, 2023). In opposition to France that relies mainly on nuclear power generation, the German society traditionally has a more critical attitude towards nuclear energy, at latest since the Chernobyl catastrophe. Eventually, the reactor accident in Fukushima in 2011 led to Germany's decision for a final nuclear phase-out (Gasch & Twele, 2013; Sommer, 2015).

In general, there always have been changes in the energy sector due to external factors. A current example is the 2021 energy crisis soon followed by Russia's attack on Ukraine, which has caused gas prices in Central Europe and especially in Germany to rise extremely. Consequently, in the short term the price of electricity rose sharply. This was due to the merit order principle of the electricity exchanges, according to which the marginal costs of the last connected power plant determine the electricity price on the exchange (Bundesnetzagentur, 2023a; Schiffer, 2019). In the medium term, the share of gas in the electricity mix in Europe has fallen noticeably (Energy Institute, 2023).

The high proportion of renewables in Germany (see Figure 3) can be explained by the fact that the country was one of the pioneers in application of green technologies in Europe (Kammer, 2011). As Figure 3 shows, today, wind accounts for over 50% of renewable electricity in Germany as well as in Europe. Due to the generally higher proportion of renewables in Germany, wind power accounts for almost 22% of the entire electricity mix, while in Europe it averages at 14%. The following chapter covers renewables, which are the source of energy whose share has been growing the most in recent years in more detail (Energy Institute, 2023).

Rise of Renewables and Associated Challenges

This section provides an overview of the growth of (new) renewable energies in Europe and Germany and the challenges associated with this development. Renewables include all energy sources that are practically inexhaustible on the human time horizon, such as wind and solar energy, or can be renewed in a relatively short period of time, such as biomass (Quaschning, 2013). In some statistics, hydropower is included among renewable energies. In this study, however, hydropower is excluded from the data on renewables, and we will center on “new renewables” with the focus on wind.

The idea of using more renewable energy instead of fossil fuels is not new. Even in the past, crises were often the trigger for changes: About a hundred years ago the German physicist Albert Betz wrote that the "general shortage of coal" during the First World War triggered investigations into the use of wind energy (Betz, 1926). However, it still took several decades before new renewable energies were used on a relevant scale to generate electricity. The modern era of renewables and especially wind energy began in Europe in the emergence of the oil crises of the 1970s (Bruns & Ohlhorst, 2011). A major reason for this is the scarcity of fossil fuel resources in Europe. At that time, the leading pioneer in wind energy, Denmark, had to import almost all its energy due to a lack of own fossil resources, thus shaping its energy policy (Sommer, 2015).

Renewables in Europe experienced a significant boost in the early 2000s. This was closely related to the sharply rising prices for fossil energy. While the oil price was around $25 per barrel in 2001/2022, it was over $95 per barrel in 2008 (Energy Institute, 2023). This upswing for renewables stopped with the onset of the global financial crisis in 2008. The price of oil fell again, and wind turbine manufacturers were affected by the global crisis tendencies from 2008 (Sommer, 2015). From around 2011, the upturn in renewables continued and wind as well as solar power increased the most (Energy Institute, 2023; Umweltbundesamt, 2023b).

With the expansion of renewable energies, there has been a strong experience curve effect, and the levelized cost of energy (LCOE) has fallen considerably. In 2021, the International Energy Agency stated (IEA) in their World Energy Outlook that “In most markets, solar PV or wind now represents the cheapest available source of new electricity” (IEA, 2021, p. 15). “New electricity” means the levelized cost for newly built power plants. For example, the LCOE for nuclear power from plants that have already been written off can be cheaper (IEA, 2020). The International Renewable Energy

Agency (IRENA, 2022) specifies the global average LCOE for onshore wind power for 2021 as only 0.033 USD/kWh. The rapid fall in costs for the new renewables is remarkable. In 2010, the global LCOE for onshore wind was still at 0.102 USD/kWh.

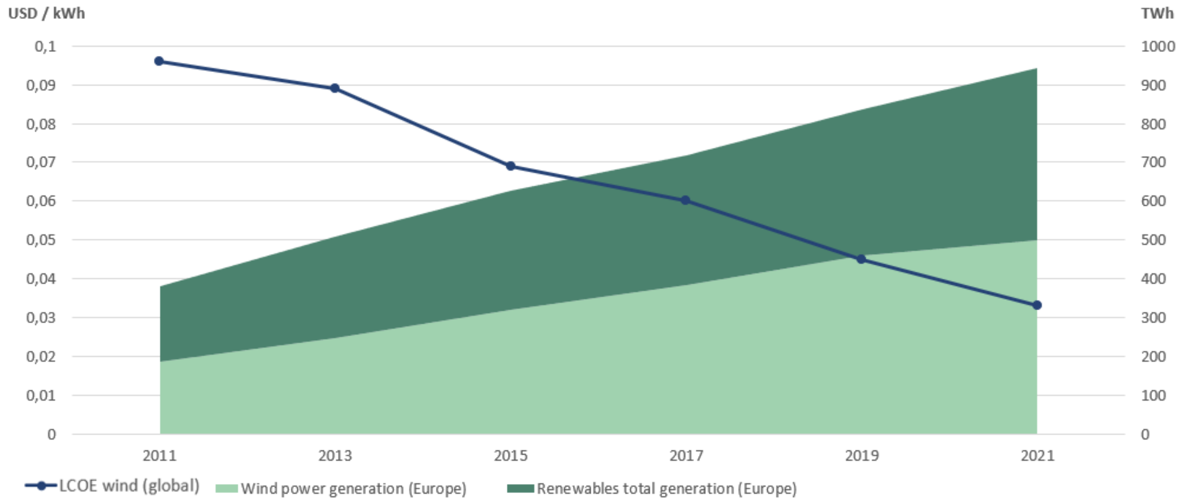


Figure 4: LCOE and power generation from renewables and wind 2011-2021

Source: Own illustration; data from IRENA (2022) and Energy Institute (2023)

As Figure 4 illustrates, in line with declining LCOE, electricity generation from renewables in Europe has more than doubled in ten years. Wind energy even increased by around 150% from 2011 to 2021. Of course, there are significant differences in the LCOE between regions and individual wind farms, since this value ultimately depends on many factors such as capital costs, service life and significantly on local wind speeds and the resulting utilization. The US investment bank LAZARD (2021) estimates the LCOE for wind in the Europe region with a range of 0.033-0.050 USD/kWh. For Germany, Fraunhofer ISE (2021) states LCOE for onshore wind energy at 0.039 EUR/kWh for advantageous coastal locations, but up to 0.083 EUR/kWh was calculated for locations with poor wind conditions. Nevertheless, when comparing costs of renewables with conventional power plants, it is important to note that the LCOE does not consider storage costs that may be required (Fraunhofer ISE, 2021).

However, the new renewables also come with several challenges that are of a social and technical nature. Sommer (2015) describes that the acceptance of wind turbines faced a lot of social headwinds, especially during the first boom in the early 2000s. There were and are many organized local opponents of wind power not only in Germany, but also in other European countries. For example, in the United Kingdom, despite good wind conditions, few wind turbines were built for a long time, until the growth of offshore wind farms with a relatively high distance from the coast.

The technical challenges are primarily due to the discontinuity, more precisely the weather dependence, of wind and solar energy. In contrast to power generation from (fossil) fuels, new renewable energies cannot be regulated according to power requirements. Wind power generation is much stronger in winter when energy consumption is higher in Europe while solar energy is naturally only available during daytime and is mostly generated in summer (Heide, von Bremen, Greiner, Hoffmann, Speckmann & Bofinger, 2010). Quaschning (2013) describes the problem of storing electricity from renewable sources as a major challenge. Pumped-storage power plants are the cheapest solution, but there is hardly any potential left in Germany due to topography and population density. Therefore, batteries and green hydrogen (and other green gases) are crucial as a storage medium for an energy economy based on renewable energies. However, the rapidly growing global battery production is faced with the challenge of raw material shortages and green hydrogen from electrolysis is scarcely available to date and still expensive at around 7 EUR/kg (BDEW & EY, 2023).

Renewable energies also require a significant expansion and redesign of power grids. In Germany, for example, new high-voltage lines (SuedLink) urgently need to be completed to bring wind power from the windy north to consumers in the south of the country. In addition, the Federal Network Agency emphasizes that a significant expansion of (H2-ready) gas-fired power plants is necessary for peak load times (Bundesnetzagentur, 2023b). However, the capacity expansion is not to be equated with a generally higher level of gas-fired power generation. Consequently, investments in flexible gas peak load capacities are difficult to realize since they must be refinanced with only a few operating hours per year.

In summary, wind energy has the highest potential for the energy transition in Germany and other countries in Central and Northern Europe. The main reason for this is that solar energy has a very low yield in winter while there is a higher demand for energy during this season, and hydropower and biomass are no longer significantly scalable in this region. Wind energy is therefore the most promising power generation technology for northern Europe, even though the political net-zero goals, which are discussed in the next section, can only be achieved with a combination of different renewables and a strong development of the ecosystem, especially regarding grid and storage.

Energy Transition Policies and Regulatory Aspects

Energy markets are market environments fundamentally influenced by politics. This also applies to electricity markets which can be explained by the importance of electricity prices as one of the most elementary influential factors for the industrial competitiveness and for cost of living and thus for the economy of a state. Therefore, a reliable but at the same time cost-efficient power supply is in the national interest of every country (Kammer, 2011; Sommer, 2015). With an emphasis on wind energy, this chapter aims to briefly look at some of the political climate goals in Europe and regulatory aspects using Germany as an example. The following table summarizes policies, declarations and laws on EU and German level.

Level	Policy / Declaration / Law	Targets
EU	European Climate Law (2021)	• Climate neutrality by 2050
EU	Fit for 55 Legislation (2021)	• - 55% carbon emissions compared to 1990 • Target of 40% renewable energy by 2030
EU	REPowerEU Plan (2022)	• Target of 45% renewables of energy consumption by 2030 • 10 Mio t green H2 production in EU + 10 Mio t imported green H2
EU	Reinforcement of EU Renewable Energy Directive (2023)	• Binding target of min. 42,5% renewable energy by 2030 • Buildings: Renewable energy benchmark of 49% for energy consumption • Industry: Binding target of 42% renewable H2 of total H2 consumption • Transport: 29% share of renewables in final energy consumption
GER	EEG 2023	• 80% of power consumption from renewables by 2030
GER	Windenergie-an-Land-Gesetz (onshore wind energy law)	• 2% Area designation by the end of 2032
GER	Windenergie-auf-See-Gesetz (offshore wind energy law)	• 30 GW Offshore until 2030 • 70 GW Offshore until 2045
North Seas countries	Ostend declaration (04/2023)	• Aim of 120 GW in the North Seas by 2030 • Aim of 300 GW in the North Seas by 2050

Table 1: Overview German and European climate goal policies

Sources: EU Commission (2022, 2023); Bundesregierung (2023a, 2023b, 2023c)

In recent years, the objectives of European climate policy have become progressively more ambitious and concrete. In 2021, The European Climate Law established a legally binding long-term framework for climate neutrality in the EU by 2050. At the national level, some nations have already committed to achieving climate neutrality before set date. For instance, Germany has legally enshrined carbon neutrality by 2045 (Bundesregierung, 2022). As a result of the Russian invasion in Ukraine in February 2022 and the subsequent cessation of reliable and inexpensive natural gas supplies from Russia, the EU has increased its climate targets with the REPowerEU and has set particularly ambitious goals for the production and use of green hydrogen. In March of 2023, the Reinforcement of the EU Renewable Energy Directive bolstered and specified the climate targets. The legally binding target of 42.5% renewable energy by 2030 was established, and specifications as seen in Table 1 were established for the buildings, industry, and transportation sectors (European Commission, 2023).

A central instrument for implementing these goals is the European Emissions Trading System (EU-ETS), introduced in 2005. The objective is to use market incentives to reduce CO2 emissions in participating sectors, which so far are the energy industry, energy-intensive manufacturing, and intra-European air traffic (Umweltbundesamt, 2022). Since the end of 2021, the price per ton of CO2 has exceeded EUR 80, which should encourage the development of low-carbon production.

In Germany, the Renewable Energy Sources Act (EEG) has been the legal framework for renewable energies since its introduction in 2000 and has since been revised and updated several times. With the 2014 reform, the law included specific expansion objectives for the first time. The most recent 2023 reform sets a target for 80% electricity from renewable sources by 2030 (Bundesregierung, 2023a). In addition, legislation has been enacted, that set a binding area designation and concrete expansion targets for offshore wind parks. A further increase in goals occurred in April 2023 with the multilateral Ostend declaration, in which the countries bordering the North Seas agreed to improve cooperation and set the North Seas expansion target at 120 GW by 2030 (BMWK, 2023).

While the climate goals mentioned above provide a political direction, regulatory aspects on different administrational levels are crucial for project implementation and in general of great influence in the energy industry (Schiffer, 2019; Kammer, 2011). This applies to the planning, construction, and operation of wind parks, as will be briefly shown using the example of Germany. The main goal of regulatory frameworks should be to ensure a high level of fairness and planning security, as this enables the investor to estimate the costs and income of the project that typically has a life cycle of at least 20 years (Gasch & Twele, 2013). On the other hand, regulatory framework conditions can also be a hindrance for planned wind turbines since they also represent other interests such as the local population or nature conservation.

In Germany, the feed-in of electricity from renewable energies has been promoted since 1991 with the introduction of the "Stromeinspeisungsgesetz". This law was replaced by the EEG in 2000, which, like the previous law, guaranteed a fixed feed-in tariff for electricity from renewable sources (Sommer, 2015). Depending on the year of commissioning, this was around 0.089-0.102 EUR/kWh fed in between 2000 and 2016 for onshore, and between 0.15-0.187 EUR/kWh for offshore wind turbines (Schiffer, 2019). The costs of the subsidy were largely borne by end consumers through an EEG surcharge, which rose sharply in the 2010s.

With the EEG 2017 there was a system change and the guaranteed feed-in tariff stopped. Instead, direct marketing of electricity has been the main principle since then and subsidy levels are determined in tendering procedures. The volume of the tenders is determined by the Federal Network Agency and the last offer that was awarded a contract determines the amount of funding. In the first ever round of tenders for onshore wind energy in May 2017 this was 0.0571 EUR/kWh and has varied since then, with some tenders also being undersigned (Schiffer, 2019). The system change to the tendering process and the associated uncertainty is one of the reasons why the expansion of wind power in Germany collapsed from around 4-5 GW newly installed capacity per year in the years 2014-2017 to only 1 GW in 2019 (Deutsche Windguard, 2023).

Twele and Liersch (2013) describe that certain bureaucratic regulatory aspects on the other hand can severely impede the expansion of wind energy. In Germany, the approval process is the responsibility of municipality, but relevant federal laws as well as rules set by the federal states must still be followed. At the level of federal legislation, these include the Federal Nature Conservation Act, the Federal Emission Control Act and the Aviation Act. At the federal state level, height and distance regulations must be observed, which are much stricter in Bavaria than in northern Germany, for example. Finally, the administration at the community level is responsible for the local land use plan and the granting of the building permit. These complex approval processes lead to long process times, which have taken up more and more time in recent years. According to an analysis by the Fachagentur Wind an Land (2023), the average duration of the emission control approval process alone has increased from 14 months on average in the years 2011-2017 to 23 months in the period 2018-2022. From the start of this process, up to 50 months were required before commissioning of the plant.

Finally, it should be noted that Europe does not have a single regulatory framework, but rather a variety of regulatory frameworks. Germany and Denmark, for example, rely on grid priority for green electricity and subsidies that are determined by tendering processes, whereas in the UK, subsidies are based on a quota model for renewable energy, in which the green electricity produced is linked to certificates that can be traded (Sommer, 2015). The average approval times also vary significantly in Europe, however the Europe-wide industry association WindEurope (2020) notes that permitting generally represents a major bottleneck for the expansion of wind power throughout Europe due to complex regulations, slow processes, and understaffed authorities.

Development and Status Quo of the European Wind Energy Industry

The wind turbine industry has its roots in Europe (Kammer, 2011). Since its beginnings with small experimental systems in the low-kilowatt range, it has shown periods of remarkable growth, but new challenges have also emerged. A first surge of industrial growth in the wind-industry set off in the 1970’s when established mechanical engineering companies such as Vestas (Denmark) or MAN (Germany) expanded into the wind power sector (Sommer, 2015). Back then, the geographic focus was on Denmark, Germany, and the Netherlands. Later, in the 1990s, Spain experienced a wind energy boom with cluster formations in the north of the country. From these core European regions, in which supplier clusters had evolved around the turbine manufacturers, the industry first expanded into neighboring European countries and later into the USA, China and India. Internationalization usually took place gradually, first with export and later with joint ventures and direct investments (Kammer, 2011).

From the 1990s, a process of consolidation of wind turbine manufacturers began. Particularly smaller companies, but also the wind energy division of the industrial conglomerate MAN, left the market or were taken over by expanding companies such as Vestas (Sommer, 2015). At the beginning of the 1990s, a new business field emerged with the first commercial offshore wind farms in Denmark (Gasch & Twele, 2013). Later, offshore also spread to the UK and France, which previously had very little wind energy industry. Around the year 2000, global players in the technology sector such as Siemens (since 2004) and General Electric (since 1997) entered the arena by acquisitions and mergers and have since then competed with original wind turbine manufacturers such as Vestas, Enercon or Nordex (Kammer, 2011).

Not only the manufacturers were gradually growing, but also the wind turbines themselves. At the beginning of the 1990s, mass-produced wind turbines had a rotor diameter of approx. 40 meters and an output of around 0.5 MW. By the mid-2000s there were already systems with significantly more rotor diameter (100m) and 5 MW power (Gasch & Twele, 2013). The most recent turbines, especially for the offshore sector, achieve rotor diameters of over 220m and 15 MW output (Siemens Gamesa, 2023; Vestas, 2023a). As turbine size increases, transport and construction of the plants become correspondingly more complex (Twele & Liersch, 2013).

The value chain of the wind energy industry consists of three major businesses. At the center of the chain is the production of wind turbines, which account for most costs over the entire project life cycle of a wind farm (Kammer, 2011). The wind turbine manufacturers and their suppliers are embedded in the value chain between wind farm development and plant operation. After the strong consolidation described, today five large turbine manufacturers dominate the European and the German market as shown in Figure 5.

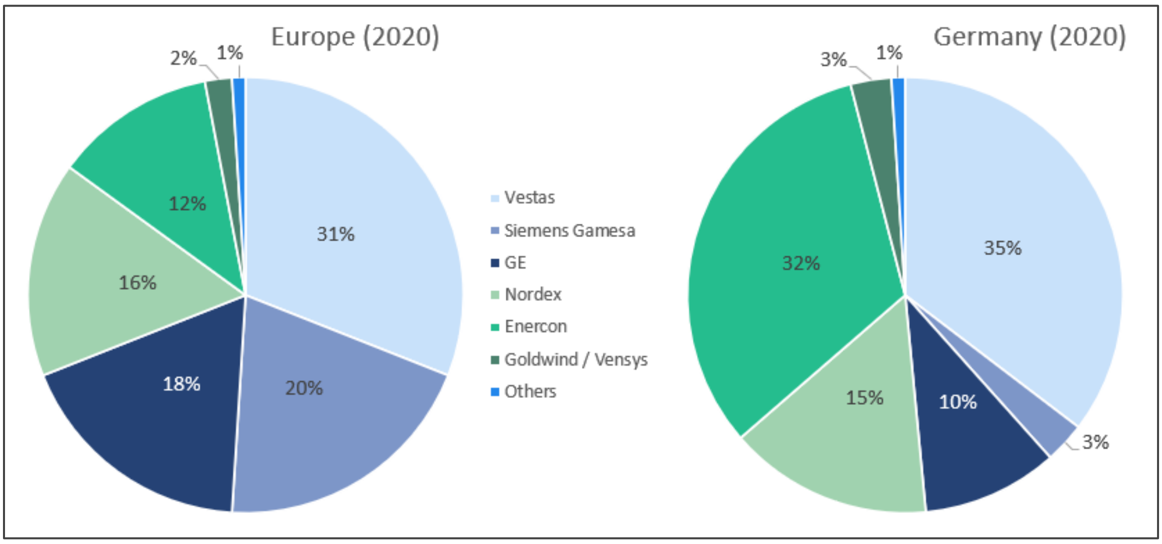


Figure 5: Market share of turbine manufacturers by installed onshore capacity

Source: Own illustration, following Enercon (2021)

Vestas, Siemens Gamesa, General Electric, Nordex and Enercon together had a market share of over 95% for onshore wind turbines in 2020 (Enercon, 2021). The market share is measured in the capacity installed in the respective year, which is why it fluctuates from year to year, depending on when turbines are commissioned. It should be noted here that Siemens Gamesa's market share was higher in other years, and that the company is more active in the international offshore market. Vestas is the market leader both in Germany and in Europe. Globally, Vestas ranks second behind the Chinese manufacturer Goldwind in terms of installed capacity (BloombergNEF, 2023). China is also the world's largest market for wind energy. In Europe, Goldwind, its German subsidiary Vensys, and other Chinese manufacturers have not yet been able to gain large market shares but have become more present in recent years.

The picture is much more heterogeneous among project developers and other service providers. There are several smaller, regional project developers. Yet larger, internationally oriented development offices such as WPD and PNE are increasingly gaining market share (Sommer, 2015). In particular, complex offshore projects are being driven forward by large development offices or directly by specially created departments of energy companies, which operate the parks. In the implementation phase they usually cooperate with specialized offshore companies, if only because the weather conditions at sea pose a great challenge.

The operators also differ in terms of type and size. While in the past a large part of the wind farms, which often consisted of just a few wind turbines, was operated by local public utilities or cooperatives, later large energy companies entered the arena (Kammer, 2011). Especially in the offshore sector, the players are large energy companies, often backed by banks, since the dimensions in terms of installed capacity and costs are similar to conventional power plants. According to data from EurObserv'er (2023), the largest European operators in 2022 were all traditional energy supply companies such as RWE (approx. 11 GW installed capacity), EDF (approx. 8 GW) or Iberdrola (approx. 21 GW). These are also very active internationally, for example the Italian utility Enel operates 12.5 of its total capacity of 17.5 GW abroad.

In terms of profitability, there is an enormous imbalance along the value chain. As Figure 6 demonstrates, the manufacturing part of the value chain struggles with being profitable. Especially the OEMs suffered significant losses last year. In contrast, developers and other service providers as well as operators generate robust 15-20% EBIT margins. Renewable energy consultancy WoodMackenzie (2023) cites supply chain issues and increased commodity costs as the main drivers. Chinese manufacturers, on the other hand, are less affected and are making profits. Even the European market leader Vestas, which had been profitable in previous years, had to post losses of more than EUR 1.5 Bn in 2022 (Vestas, 2023b). Currently, the situation among the manufacturers seems to remain tense. Recently, Siemens-Gamesa reported unexpected additional cost for quality defects amounting to EUR 1 Bn, which caused the stock of the parent company Siemens Energy to crash by 35% (Tagesschau, 2023).

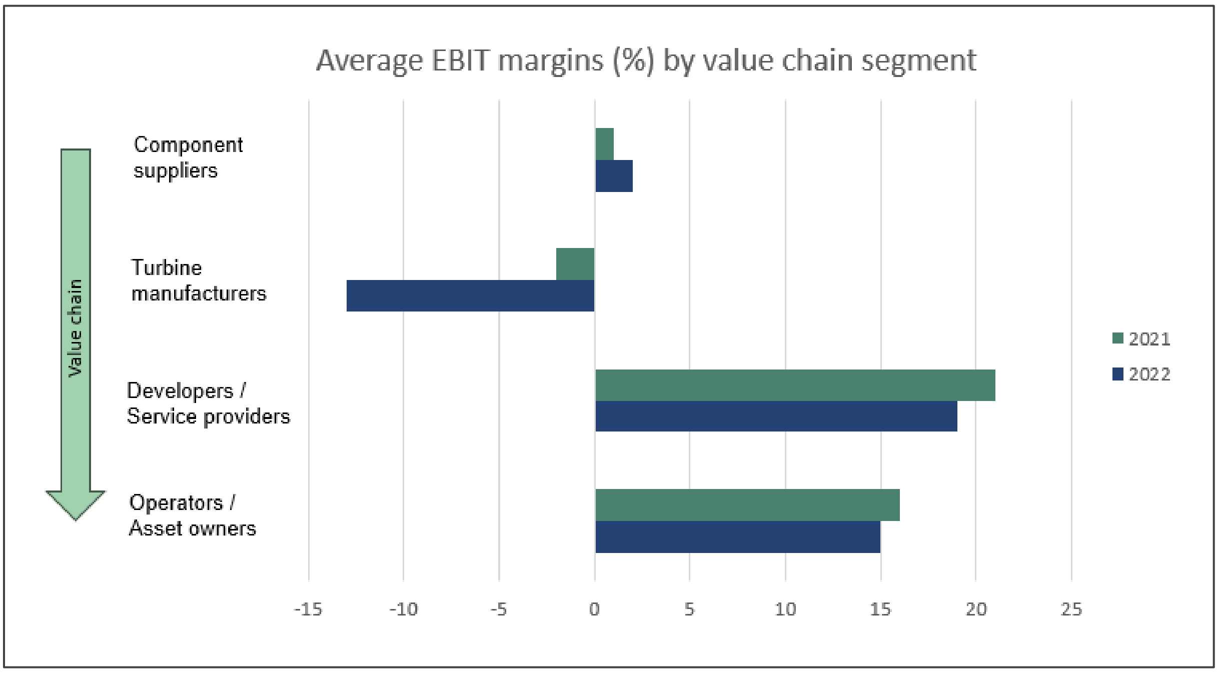


Figure 6: Profitability imbalances along the value chain

Source: Own illustration, following The Economist (2023) and WoodMackenzie (2023)

In summary, it can be said that there was a strong consolidation in the last decades and today market entry barriers are high, as the capital intensity and the technical and logistical complexity have increased due to the size of the plants. In contrast to the production of solar modules (which are mostly imported from China now), manufacturing of wind turbines still provides significant added value in Europe. However, in recent years financial pressure endangers manufacturers while wind farm developers and operators make robust profits.

Current Trends and Market Outlook

To conclude this overview, we will examine briefly current developments in the wind energy market, including new opportunities in the wake of the decarbonization megatrend as well as threads like rising raw material prices and competition from Far East.

In contrast to the public perception, large-scale offshore projects have only been implemented in Europe for a few years. Recently, offshore business segment has finally slowly picked up speed, particularly in the North Seas. In the EU, offshore now accounts for around 8% of the total wind power capacity, but due to significantly more full load hours for 12% of the gross electricity production. Also, onshore construction speeded up as around 40% more capacity was installed in 2022 than in the previous year (EurObserv'er, 2023). A considerable part are now repowering projects, i.e., the replacement of old systems (for which the funding period has usually expired) with newer, more powerful ones. In Germany, the repowering share of gross new construction was almost 18% in 2022 (Deutsche Windguard, 2023).

Decarbonization and the electrification required in many areas represent a megatrend (BCG, 2021; McKinsey, 2022). The need for green energy is high as businesses pursue decarbonization strategies, no less because of the European energy policies discussed earlier. For example, Deutsche Bahn, Germany's largest electricity consumer, has announced to only use electricity from renewable sources by 2038. To achieve this, they have concluded a PPA with RWE on offshore wind power (DB, 2023). In addition to electrification, green gases and sustainable liquid fuels will also play a role in decarbonization efforts. Demand for hydrogen is likely to increase significantly and will play an important role in hard-to-abate industries like the steel and concrete production while the demand for e-fuels is anticipated to be greatest for aviation and shipping (McKinsey, 2022; TotalEnergies, 2022).

Subsequently, Green power-to-x, i.e., the conversion of electrical power from renewable sources into a synthetic energy carrier, such as hydrogen (and derivates), is currently very present in the media. However, green hydrogen is currently hardly available and expensive at around EUR 7/kg (BDEW & EY, 2023). Fraunhofer IEE (2020) stated that the (green) electrolysis capacity available in Germany in 2019 was only 0.036 GW. According to the umbrella organization HydrogenEurope (2022), hydrogen capacities almost doubled between 2019 and 2022. Despite this increase, we are still a long way from the goals of the EU hydrogen strategy (see Table 1). Considering the EU climate targets, the potential for power-to-x and thus for additional wind turbines is very high. Wind power competes with solar for green power-to-x production, as the LCOE is a crucial factor in the final price of hydrogen. An argument in favor of wind is that electrolysis is more utilized due to the higher full load hours, especially when considering offshore wind or a combination of wind and solar.

Another important trend in recent years has been the strongly fluctuating energy and raw material prices. Supply chain disruptions caused by the 2020 Corona Pandemic, the energy crisis which took off in 2021 and the Russian invasion of Ukraine have resulted in generally higher prices, but above all in increasing volatility on the markets. The average German gas price has increased six-fold between 2020 and 2022, and raw materials such as steel had enormous price increases of more than 100% (Energy Institute, 2023; Deutsche Rohstoffagentur, 2023). As a measure against the economic effects of these multiple crises, programs have been launched by several countries. At this point, the US Inflation Reduction Act (IRA) deserves a special mention, as it provides substantial funding for the expansion of renewable energies in the USA, from which the solar and wind energy sectors will benefit (bp, 2023).

One last aspect, which needs to be mentioned is the growing competition from Chinese wind turbine manufacturers on the European market. Their presence in Europe is still rather small (see Figure 5), however it is growing as a matter of fact. A good example for their meddling in the European market is, what occurred in 2022, when Italy's first offshore wind farm was eventually installed wind turbines from the Chinese manufacturer Minyang, because the originally planned German manufacturer Senvion had gone bankrupt (Orsted, 2023).

Concluding this chapter, one can bear in mind, that there are currently several positive drivers for the renewable energy sector and in particular the wind energy sector. There is an unquestionable demand for green energy, if only because electrification will lead to a significant increase in the demand for electricity. The German federal government projects demanding electricity will increase by more than 25% by 2030 (Bundesregierung, 2023). Nevertheless, despite these trends, the expansion rate for wind turbines in Germany has collapsed in recent years and European manufacturers are experiencing challenging economic conditions. Due to the high level of uncertainty the industry is confronted with, the creation of various scenarios is advisable.

4 Scenarios

Based on the market situation and the various trends in the European and German wind energy market described above, we have developed four scenarios that present different possible pictures for the future of the European and German wind energy market in 2033. These scenarios are determined primarily by the two critical uncertainties, which form the dimensions of our scenario matrix – *the development of the regulatory framework* and *the development of the supply side ecosystem*. We have named the resulting scenarios "Lack of Supply", "Setting Sails", "Stuck in Regulation", and "Lull" (see Figure 7). They are described in the following, first briefly and then in more detail.

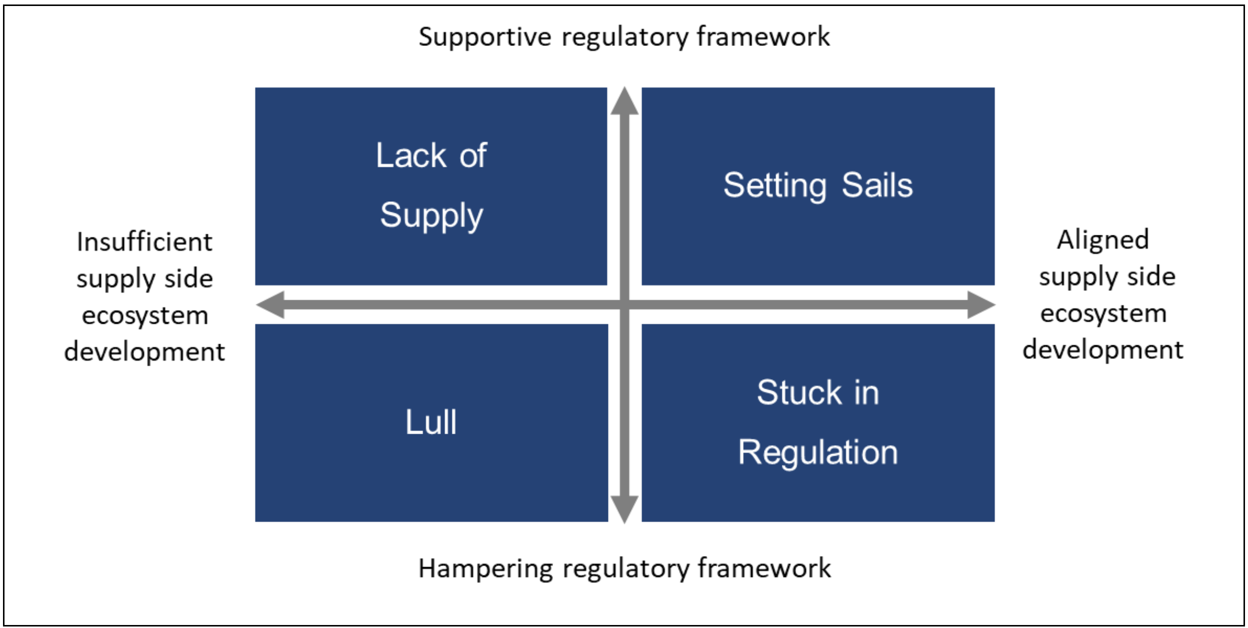


Figure 7: Scenario Matrix for the European and German wind energy market

Source: Own illustration

Overview

Setting Sails describes a so far successful energy transition in Europe, gaining momentum in the mid-2020s and making the ambitious EU government climate goals seem achievable. By 2033, renewables accounted for 45% of Europe's energy, with Germany at the forefront, achieving over 80% renewable electricity. Wind power played a vital role, contributing 45% to Germany's electricity mix and ensures competitive power prices due to low LCOE in absolute terms, the growth of wind power is even greater, as the amount of electricity required has increased significantly due to rapidly advancing electrification in all sectors. The success in the energy transition was bolstered by positive political frameworks and growing societal support for climate protection. The wind energy sector thrived, benefiting from involvement and acceptance within local communities, even near residential areas. Efficient approval procedures enabled wind turbines to receive timely clearance, further driving progress. Geopolitical tensions eased, leading to strategic cooperation in resource procurement and resolving supply chain bottlenecks. Successful immigration policies mitigated skilled labor shortages, and the growing renewables industry can attract the urgently needed workforce. Overall, Europe's energy transition sailed towards a greener future, anchored by determination, cooperation, and a commitment to sustainability and all players along the wind energy value chain earn solid profits.

Stuck in Regulation describes Europe's moderate progress in the energy transition since the mid-2020s, making it unlikely to achieve climate neutrality by 2050. By 2033, renewables contributed 30% of Europe's energy, while Germany also fell short of its climate goals. Wind power accounted for 35% of Germany's electricity, facing resistance and lengthy approval processes due to regulatory obstacles. On the other hand, supply side development improved as geopolitical tensions diminished, fostering cooperation in resource procurement and supply chain resolution. However, skilled labor shortages and ineffective immigration policies posed challenges in Europe. Wind turbine manufacturers faced hurdles in scaling production capacities, struggle with competition from abroad, and thus struggle to break even. Similarly, European wind developers faced international price competition, limiting expansion possibilities. Despite challenges, wind park developers and operators maintained slight growth but experienced decreased profits due to complex projects and reduced subsidies. Overall, regulatory barriers hindered Europe's energy transition progress.

Lull describes Europe's energy transition facing persistent challenges since the mid-2020s, leading to doubts about achieving climate neutrality at any point. The "Fit for 55" and "REPowerEU" plans' ambitious goals seem unrealistic, as decarbonization across sectors lacked momentum. By 2033, renewables provided only 25% of Europe's energy, with green hydrogen remaining a niche technology due to dominance by conventional energy sources. Germany also failed to meet its climate goals from the EEG 2023. Expansion of renewable energies has stagnated in recent years and is now contributing just about 50% to the German power mix. Wind power, the second-largest contributor (not even 25%) after coal, faced obstacles with limited designated areas and stalled infrastructure projects. Regulatory hurdles, influenced by influential industries, hindered the wind energy sector, leading to conflicts and negative sentiment. Geopolitical tensions intensified, impacting global economic interconnectivity and skilled labor availability, strongly affecting the energy transition progress. Along the whole value chain European wind energy companies have lost significant market share to Chinese and American competitors and European manufacturers suffered a wave of bankruptcies. Overall, the "Lull" scenario depicted a challenging landscape for the wind energy sector, constrained by unfavorable regulations, geopolitical complexities, and limited growth opportunities.

Lack of Supply describes Europe's limited progress in the energy transition since the mid-2020s, why climate neutrality by 2050 appears unlikely without more favorable economic conditions and even more increased efforts. By 2033, renewables accounted for 30% of Europe's energy, and green hydrogen production remained low. Germany fell short of its climate goals from the EEG 2023, with renewables contributing 65% to its electricity mix in 2032, primarily from wind power (32% of mix). In general, political support for wind energy improved, for example approval processes have been successfully accelerated. However geopolitical tensions persisted and thus supply side factors such as scarcity of raw materials and skilled labor shortage, affecting LCOE, electrification progress and the wind energy industry's growth. At least a protective regulatory framework protects European players from foreign competition, however many companies, especially manufacturers struggle to reach profitability. Overall, the negative development of the supply side ecosystem impedes the wind energy industry to thrive, and the achievement of the goals set in the political framework.

Scenario 1: Setting Sails

The European and German Wind Energy Market in 2033

September 2, 2033

Wind Power: The Driving Force Behind Europe's Clean Energy Revolution

In the heart of Europe's relentless pursuit of climate neutrality by 2050, the mid-2020s witnessed a remarkable transformation in the energy landscape. Backed by ambitious climate policies, by early 2033, the continent had achieved an impressive milestone, sourcing 45% of its energy from renewable sources. Germany, a frontrunner in this green revolution, recently announced that over 80% of its electricity mix was from renewables, with wind power emerging as the star contributor at 45%.

According to the CEO of a European wind energy association *"Wind power has proven itself as the driving force behind Europe's clean energy revolution. Our industry's rapid growth, combined with strategic planning and strong public support, has brought us closer to our climate goals. We've harnessed the winds of change and are well on our way to a greener, more sustainable future."*

State of wind power

Europe's energy transition, initially faced with challenges, has gained significant momentum in the mid-2020s, paving the way for the continent to achieve its climate neutrality goal by 2050. Bolstered by the "Fit for 55" and "REPowerEU" plans, the region made remarkable progress, albeit with a slight delay. By the beginning of 2033, Europe successfully sourced 45% of its energy needs from renewable sources. Only green hydrogen production at currently 5 Mt/year falls short of Europe`s ambitious targets, nevertheless extreme growth in this branch is impressive.

Germany, a frontrunner in the transition, has also reached its climate targets outlined in the EEG 2023, although with a minor delay. The country's Economics Minister (Green Party) recently announced that in 2032, over 80% of Germany's electricity mix came from renewable energies. Wind power emerged as the primary contributor, accounting for 45% of the total electricity generation in Germany. This achievement was made possible thanks to the designation of 2% of areas and land for wind power installations. Furthermore, the expansion of the power grid enabled the transmission of constant wind power from the North Sea, where 30GW of offshore wind farms now supply the country's inland.

The German wind energy sector has flourished in recent years, thanks to positive political frameworks and an increasing societal prioritization of climate protection. This shift is evident in election results and a consistent political determination to drive the energy transition forward. Furthermore, by involving local communities, acceptance of wind turbines, even in close proximity to residential areas, has increased. Conflicts with remaining wind energy opponents are only of short duration and often resolved outside of court. The “Deutschlandgeschwindigkeit", previously observed in the construction of LNG terminals from 2022, has made its way into the approval procedures for wind turbines. On average, wind turbines now receive approval within a mere nine months. The population, as well as the wind energy sector, express great satisfaction with the reliable and supportive regulatory framework.

Geopolitical tensions, which prevailed at the beginning of the last decade, have significantly diminished since 2024. The world has experienced greater economic integration, fostering strategic cooperation in resource procurement, and resolving supply chain bottlenecks. While skilled labor shortage remains a challenge in Europe, successful immigration policies have helped alleviate the issue. The mentioned factors helped in driving the electrification efforts across the continent. Smart solutions, combined with network expansion and large-scale storage systems, have created the necessary infrastructure for the energy transition. In response to high demand and stabilized interest rates at around 3% from 2025 onwards, wind turbine manufacturers have made substantial investments in expanding their production capacities. Industry experts, as well as leading consultants and researchers, recognize the positive and aligned supply-side development occurring within the energy sector.

Wind turbine manufacturers

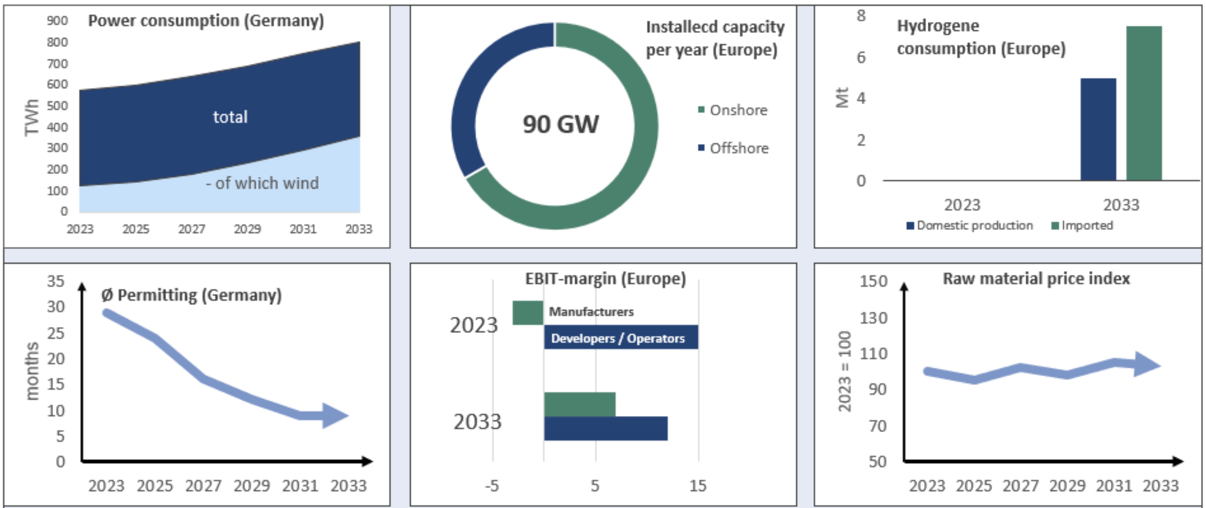
After a challenging start in the 2020s, the wind energy industry has regained momentum. Major European manufacturers swiftly responded to the growing demand by expanding their production capacities, positioning themselves to meet the growing market needs. Last year, Europe set a record with the installation of 90GW of wind power, out of which 30GW were offshore. A notable development in the industry is the allocation of approximately 10% of installations for hydrogen production facilities within Europe. Furthermore, a sizeable increase in orders from abroad is registered, notably for hydrogen projects of European developers in Latin America.

Thanks to sustained growth, manageable raw material costs, and long-term framework contracts with compelled higher selling prices, wind turbine manufacturers have achieved a solid average EBIT of 7% in recent years. Due to the EU's high sustainability and social standards, which protects the domestic wind farm industry, Chinese manufacturers have struggled to enter the European market.

Wind park developers and operators

Developers and operators have not only benefited from the growth in the European home market but have also used their experience and reputation to expand to overseas markets. Both smaller independent power producers (IPPs) and larger energy conglomerates operating wind parks have witnessed an upswing in revenues, fueled by the high demand for electricity.

Compared to the beginning of the previous decade, profits have somewhat decreased as a result of companies having to give up part of their margins to manufacturers who have forced through higher pricing. Developers and operators, however, can cope well with this development because the new long-term, partnership-based contracts with manufacturers provide supply certainty and their EBIT still amounts to a solid 12%.



- Thanks to a supportive and effective regulatory framework and a positive development of the ecosystem, wind energy is booming
- Europe's ambitious interim targets for 2030 on the way to becoming a climate-neutral continent were achieved with a slight delay
- Germany has also largely achieved its climate targets with now over 80% renewables in its electricity mix; phase-out of coal was completed in 2030
- LCOE of wind energy averages 0.05EUR/kWh onshore and 0.07EUR/kWh offshore; Households and companies benefit from low electricity prices
- European wind energy companies generate robust profits and expanded internationally; Chinese failed to establish outside Asian markets

Figure 8: Scenario fact sheet A "Setting Sails"

Source: Own illustration

Scenario 2: Stuck in Regulation

The European and German Wind Energy Market in 2033

September 2, 2033

Wind Energy's Potential Hampered by Regulatory Gridlock in Europe

Europe's push for a cleaner energy future faces a significant challenge as regulatory barriers continue to impede the growth of wind power. Despite ambitious renewable energy goals, lengthy approval processes, bureaucratic obstacles, and local resistance have hindered the expansion of wind energy projects across the continent, slowing the pace of Europe's transition to a greener and more sustainable energy landscape.

A leading wind park developer comment the situation: "*The potential for wind power in Europe is enormous, but the cumbersome regulatory hurdles are slowing us down. We need streamlined processes and better community engagement to harness the full potential of clean energy. It's not just about business; it's about combating climate change and securing a cleaner future for all*."

State of wind power

In the second scenario, the progress of the energy transition has continued to be moderate since the mid-2020s. It is unlikely that Europe will achieve the goal of climate neutrality by 2050, even with significant increased efforts it is hardly possible before 2065. The ambitious goals of the "Fit for 55" and "REPowerEU" plans are highly unlikely to be met. By the beginning of 2033, Europe obtained 30% of its energy demand from renewable sources. The domestic green hydrogen production in Europe with currently 1 Mt/years is still far from the EU's target.

Germany has also failed to achieve its climate goals set in the EEG 2023. At the beginning of the year, the Minister of Economy (Conservative Party) announced that renewable energy accounted for over 65% of the electricity mix in 2032. Wind power contributed 35% to the total electricity generation, surpassing the combined contribution of fossil fuels. Onshore still only about 1,5% of land areas are designated for wind power as bureaucratic hurdles are still high. Offshore there is more progress. In the North Sea, wind farms with a capacity of 20 GW now supply the inland with a constant supply of wind power.

The political framework in recent years has not been very favorable for wind energy. While climate protection in general has gained higher priority in society, there is still resistance to concrete and more profound measures. Local acceptance of wind turbines has hardly increased, and organizations opposing wind energy continue to form. The approval processes for wind turbines are still lengthy and bureaucratic, with an average approval time of 30 months. Overall, the wind energy industry remains dissatisfied due to cumbersome and insufficiently ambitious government regulations.

In contrast, the supply side ecosystem developed more positive. Geopolitical tensions that prevailed in the early part of the last decade have diminished since 2024, with no major wars involving global economic and military powers. The world has become economically more interconnected again. Strategic collaborations on raw materials and the resolution of supply chain bottlenecks have been largely achieved. However, the shortage of skilled workers remains a challenge in Europe, with regulatory obstacles and ineffective immigration policies being contributing factors. Electrification in Europe is progressing steadily as smart solutions, network expansion, and large-scale storage systems provide the necessary infrastructure for the energy transition. Considering the increasing power demand and interest rates stabilizing around 3% from 2025, there is increased planning security, although wind power providers benefit less from this than other industries. Overall, industry representatives, leading consultants, and scientists speak of a positive and coordinated supply-side development.

Wind turbine manufacturers

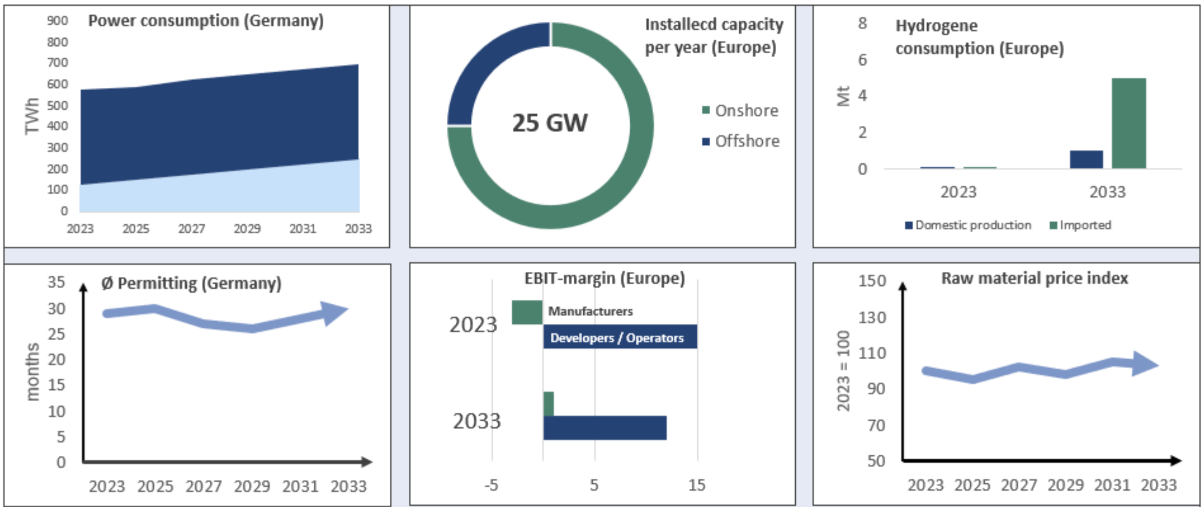
After facing challenging years in the early 2020s, the wind energy sector in Europe continues to grapple with regulatory obstacles and fierce international competition. While major European manufacturers recognized the trend of a sharp increase in demand, they struggled to effectively scale up their production capacities. Last year, Europe achieved a remarkable installation of 25 GW wind power, including 6 GW offshore. However, these figures still fall short of government objectives for rapid decarbonization. Approximately 3% of the installations are dedicated to hydrogen production in Europe. However, there have been limited orders from abroad, as for example hydrogen projects in Latin America are being implemented by Chinese manufacturers.

Mainly due to challenging regulatory conditions, wind energy manufacturers achieved an average EBIT of only 1% in recent years, lagging other industries of the renewable energy sector. Chinese and American manufacturers have gained substantial market share in Europe, as the EU has not adequately supported domestic industry and has focused primarily on upfront costs in tenders for wind farms.

Wind park developers and operators

Although there is steady growth in the domestic market, European companies struggle to withstand price competition in foreign markets and have limited expansion opportunities abroad, despite their experience and good quality. Their revenues experience only marginal growth. However, energy companies can capitalize on the growing demand for electricity and conduct profitable business operations.

While the industry faces challenges, profits have slightly decreased compared to the beginning of the last decade, primarily due to increasingly complex projects and the inability to maintain high levels of subsidies. Nevertheless, long-term, collaborative contracts provide delivery security, and the capital markets offer favorable conditions. Thus, the sector is generating stable profits resulting in an average EBIT of 11%.



- Supply chains and other supply side factors have developed in a positive way; however, inefficient regulations are slowing down the energy transition
- Europe's interim climate targets for 2030 have not been achieved yet; with this path climate neutrality before 2065 will be hardly possible
- Germany has also failed to achieve its climate targets as it achieved only 65% renewables in its power mix; coal plants are still needed in winter season
- LCOE of wind energy averages 0.07EUR/kWh onshore and 0.10EUR/kWh offshore
- Many European wind turbine manufacturers still struggle to break even; Growing price pressure from Chinese manufacturers

Figure 9: Scenario fact sheet B "Stuck in Regulation"

Source: Own illustration

Scenario 3: Lull

The European and German Wind Energy Market in 2033

September 2, 2033

Manufacturing Exodus: Wind Energy Industry in Europe Faces Crisis

In a disconcerting turn of events, Europe's energy transition has hit a significant roadblock, progressing at a pace far slower than anticipated. This lamentable situation has cast a shadow of uncertainty over the European wind energy industry, triggering a crisis aggravated by a regulatory framework that hinders growth and setbacks in the supply side development.

The CEO of one of the remaining big European manufacturer shouts out for help*: "The European wind energy industry is facing its most challenging period in recent history. Regulatory obstacles have created an environment of uncertainty, while setbacks in the supply chain have disrupted operations. Much like the solar industry, we've seen production shift to China, impacting our domestic capabilities. We urgently need coordinated efforts from governments and industry stakeholders to navigate through this crisis and ensure a sustainable future for wind power."*

State of wind power

In this most unfavorable scenario for the wind energy sector, the difficulties in the energy transition have remained unresolved and, in some cases, worsened. As a result, achieving climate neutrality by 2050 for Europe is no longer feasible, as decarbonization across all sectors has failed to gain momentum. The ambitious political targets set 10 years ago were deemed unrealistic in the late 2020s. By the beginning of 2033, Europe only obtained 25% of its total energy demand from renewable sources. Green hydrogen production in Europe remains a niche technology, as conventional energy sources dominate the market and impede research investments and innovation.

Germany, too, has been unable to achieve its climate goals outlined in the EEG 2023. At the beginning of the year, the Minister of Economy (Conservative Party) announced that renewable energy accounted for 50% of the electricity mix. However, in recent years, this percentage has seen little increase. Wind power contributed only 23% to the overall electricity generation, while coal was the largest contributor. Still there are limited areas designated for wind parks, and in the North Sea, there is currently only 8

GW of offshore wind capacity installed. The expansion of infrastructure projects to supply energy across all of Germany has stalled or failed to materialize.

The political framework in recent years has not been conducive to the wind energy sector. Climate protection continues to have a lower priority in society, partly due to the influential positions of Pro-carbon lobbies. The sensitivity of the population to climate-related issues is evident in election results, further dividing society and making consistent decarbonization policies largely unattainable. Despite efforts to involve local communities for the acceptance of wind turbines, many conflicts with wind opponents and local politics persist. This plus bureaucratic hurdles causes the approval processes for wind turbines remain lengthy. On average, it now takes 32 months to obtain approval. Overall, the wind energy sector continues to struggle with complicated and unsupportive regulatory conditions, leading to a negative sentiment within the industry.

Geopolitical tensions that persisted in the early part of the last decade have not resolved but have intensified. Free trade has been reduced, and tariffs have become a common political pressure tool. These geopolitical dynamics have damaged international economic interconnectivity and supply chains, resulting in high raw material prices and supply shortages. The shortage of skilled workers remains a significant challenge in Europe. While there is a large influx of refugees worldwide, there is limited capacity and willingness to integrate them into the labor market. Consequently, the energy transition has stagnated, and electrification in Europe has made little progress, with insufficient investments in network expansion and research for smart solutions. High interest rates, at around 6%, result in limited planning security and reduced investments in wind energy expansion. Overall, industry experts highlight the considerable challenges associated with supply-side development in the wind energy sector.

Wind turbine manufacturers

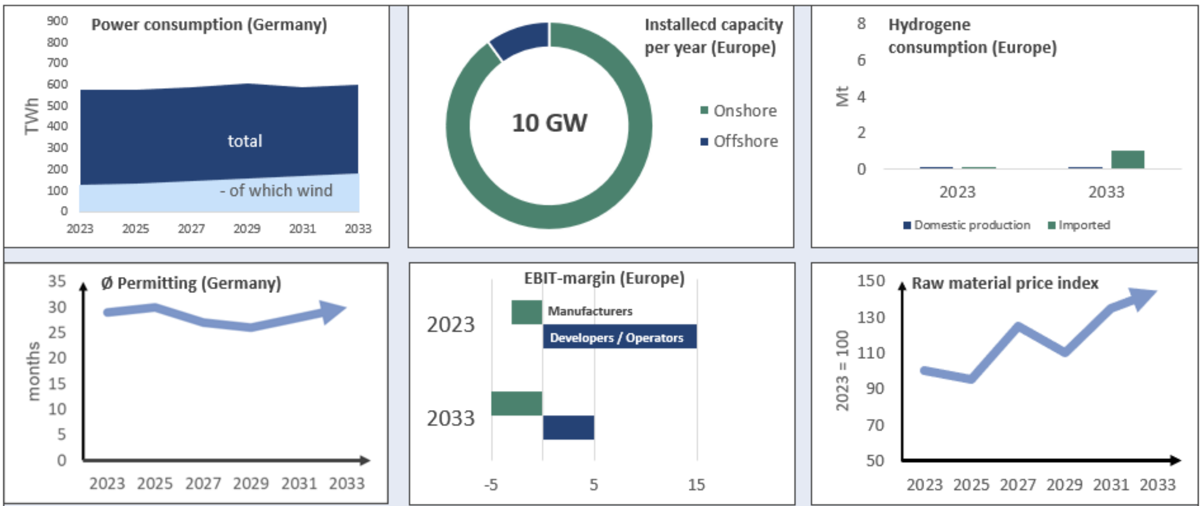
While the wind energy sector has experienced significant contraction worldwide, American, and especially Chinese manufacturers are now global market leaders. Despite recognizing the increasing demand for electricity, European states have failed to establish the necessary regulatory framework to stimulate the organic growth of their wind energy sector. Price competition has increasingly favored foreign manufacturers in recent years. In Total, Europe installed 10 GW of wind energy capacity last year, of which 1 GW was offshore. These figures fall significantly short of governments' expectations, and only a small portion of the investments remain within the region. Only approximately 0.5% of the installations in Europe are specifically dedicated to hydrogen production. The number of orders from abroad is very limited, primarily confined to specialized solutions, as the reputation of European engineers remains strong.

Due to high raw material costs and competition pressure, European wind energy manufacturers have been recording negative EBITs and only a few are still operating. Chinese and American manufacturers have managed to gain significant market share in the European market, primarily due to lower production cost, facilitated by government subsidy programs, lower energy prices and better availability of raw materials.

Wind Park developers and operators

European wind park developers and operators also face challenges in the international market due to the limited growth in the domestic market. In fact, revenues of developers are declining as the industry perceives little expansion potential within Europe. Only energy multinationals, benefiting from stable returns in the fossil fuel sector, can continue to achieve good profit margins.

Foreign developers now hold a leading position due to their better relationships with manufacturers. European developers are under significant pressure, with many facing bankruptcy. The remaining players in the market are experiencing low average returns, with an EBIT of 5%.



- Both, regulatory framework and supply side issues have developed extremely negatively
- Europe's interim climate targets for 2030 have not been achieved yet; with the current path climate neutrality before 2090 will be hardly possible
- Germany has also failed to reach its climate targets as it achieved only 50% renewables in its power mix; most coal plants are still needed
- LCOE of wind energy averages 0.09EUR/kWh onshore and 0.13EUR/kWh offshore
- European wind turbine manufacturers suffer from operative losses and growing competition from Chinese manufacturers; Industry expert fear a decline similar to that of the German solar industry

Figure 10: Scenario fact sheet C "Lull"

Source: Own illustration

Scenario 4: Lack of Supply

The European and German Wind Energy Market in 2033

September 2, 2033

Supply Chain Challenges Overshadow Regulatory Success

In a complex turn of events, Europe's wind energy industry stands at a crossroads, where improved regulatory frameworks have been overshadowed by persistent supply chain issues. While strides have been made in creating a more conducive environment for the sector, the industry now grapples with challenges on the supply side that threaten to jeopardize its progress.

"*The regulatory improvements have provided some much-needed optimism for the industry. However, we're facing a significant crisis on the supply side, which has translated into skyrocketing costs. As wind park operators, we're grappling with unprecedented challenges that threaten our ability to deliver clean energy efficiently*" comments the CCO of a leading German utility company.

State of wind power

The progress of the energy transition since the beginning of the 2020s still lacks momentum. Thus, achieving the goal of climate neutrality in Europe by 2050 is very unlikely without significant increased efforts and favorable economic conditions. Rather, climate neutrality might be reached at earliest 20 years later with the current path. By the beginning of 2033, Europe obtained 30% of its total energy demand from renewable sources. Despite general progress, the green hydrogen production in Europe at 0.5 mt/year, is still far from the EU's desired level and no game changer for decarbonization of the industrial sector yet.

Germany also fell short of its climate goals outlined in the EEG 2023. At the beginning of the year, the Minister of Economy (Liberal Party) announced that renewable energy accounted for more than 65% of the electricity mix, still far from the aimed +80%. Wind power contributed 32% to the total electricity generation, surpassing slightly the combined contribution of fossil fuels. Currently, almost 2% of land areas are designated for wind power, with additional wind parks planned. In the North Sea, 14 GW of off-shore wind power is now supplying the inland with a consistent source of wind-generated electricity.

The political framework in recent years has evolved positively for the wind energy sector. Climate protection has gained higher priority in society, leading to increased subsidies and more government investments in energy infrastructure. Acceptance of wind turbines has also increased, with reduced resistance to local wind farm development, largely due to political mediation. This is reflected in the accelerated approval processes, averaging now around 10-12 months. Overall, the wind energy industry is increasingly satisfied with the regulatory framework; however, the political efforts of recent years have not led to the hoped-for breakthrough.

On the other hand, geopolitical tensions that prevailed in the early part of the last decade have not been resolved, and conflicts and wars persist between global powers. These confrontations sometimes result in war economy conditions, disrupting economic interconnectivity and supply chains. The significant rise in raw material prices and shortages of important rare metals have dramatic consequences for the energy transition. Also in this scenario, the shortage of skilled workers remains a huge challenge in Europe, exacerbated by ongoing conflicts and ineffective immigration policies that hinder the integration of refugees into the job market. Smart solutions and network expansion are progressing slowly, and the EU is still far away from a harmonized energy market. Given the global tensions, capital markets are restless, and interest rates are relatively high, around 6%. Overall, industry representatives, leading consultants, and scientists acknowledge the significant challenges associated with supply-side development in the wind energy sector.

Wind turbine manufacturers

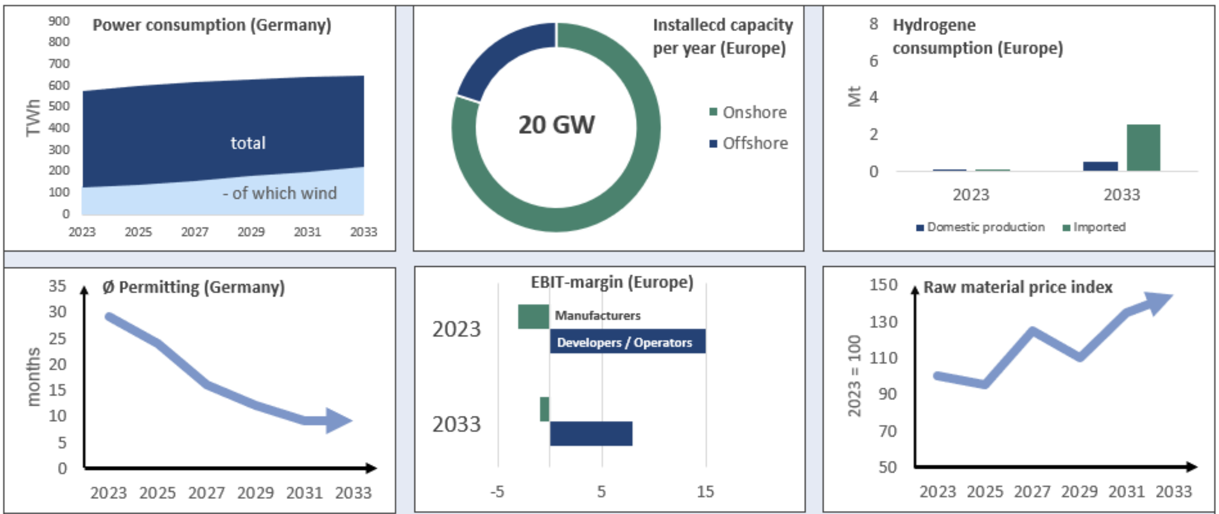
After facing challenging years in the early 2020s, the wind energy sector is now dealing with a better regulatory framework, but with an economically depressed environment. The European market for wind energy is growing, but much more slowly than hoped 10 years ago, which is why manufacturers are still struggling with overcapacities. Last year, Europe installed 20 GW of wind turbine capacity, including 4 GW offshore. However, these figures still fall short of government expectations and the necessary capacities for rapid decarbonization.

Due to high production costs, European manufacturers have been recording losses, with an average EBIT of -1% in recent years. However, the industry can still benefit from obligations to purchase green electricity and further government support. Outside Europe, Chinese and American manufacturers have managed to gain significant market share, primarily due to lower production costs in these countries, facilitated by government subsidy programs and better availability of raw materials and cheaper energy.

Wind Park developers and operators

While the wind energy sector experiences still growth in the European domestic market, international developers face challenges in staying competitive due to price pressure and protectionism. They can only expand into a limited number of countries outside of Europe with whom the EU maintains favorable relationships, which further limits their growth potential. Also, operators perceive limited expansion potential, but energy companies continue to generate good profit margins driven by high energy prices.

The wind energy developers, however, face relatively low profits as growth is slow and cost pressure is getting more intense. While long-term partnership contracts provide a certain level of delivery security, securing capital investment becomes challenging due to high-risk premiums. Overall, industry is characterized by a landscape where only the major players can thrive, achieving an average EBIT of 7%.



- Regulatory framework has improved in the right direction; however, supply chain problems and slow grid expansion create difficulties for the industry
- Europe's interim climate targets for 2030 have not been achieved yet; with this path climate neutrality before 2070 will be hardly possible
- Germany also failed to reach its climate targets as it achieved only 60% renewables in its power mix; some coal plants are still needed all year round
- LCOE of wind energy averages 0.08EUR/kWh onshore and 0.11EUR/kWh offshore
- European wind turbine manufatcurers still struggle to break even, one big manufacturer recently went bankrupt; At least, the protective regulatory framework protects from Chinese competition

Figure 11: Scenario fact sheet D "Lack of Supply"

Source: Own illustration

5 Implications

The four scenarios are not meant to predict the future development of the European and German wind energy market. Instead, they provide alternative pictures of the state of the industry in 2033. Common to all scenarios is the far-reaching scope of changes to be expected. It is therefore essential for European and German energy providers to start preparing today. In this chapter we thus highlight a few strategy implications for respective players. Detailed strategy recommendations, however, can always only be derived in the light of the specific situation of each individual company.

Strategy Corridor

The strategy corridor summarizes in a clear way the direction of the trends and critical uncertainties to the shapes of the dimensions for the desired, positive scenario and thus offers help in developing the core strategy. Figure 12 shows the strategy corridor for the desired "Setting Sails" scenario. The influencing factors outlined in green are those that the industry can actively and directly impact the most, making them vital for the formulation of the strategy. Other variables, such as geopolitical stability, cannot be significantly influenced by neither individual players nor industry associations. Nevertheless, these important factors should of course also be monitored.

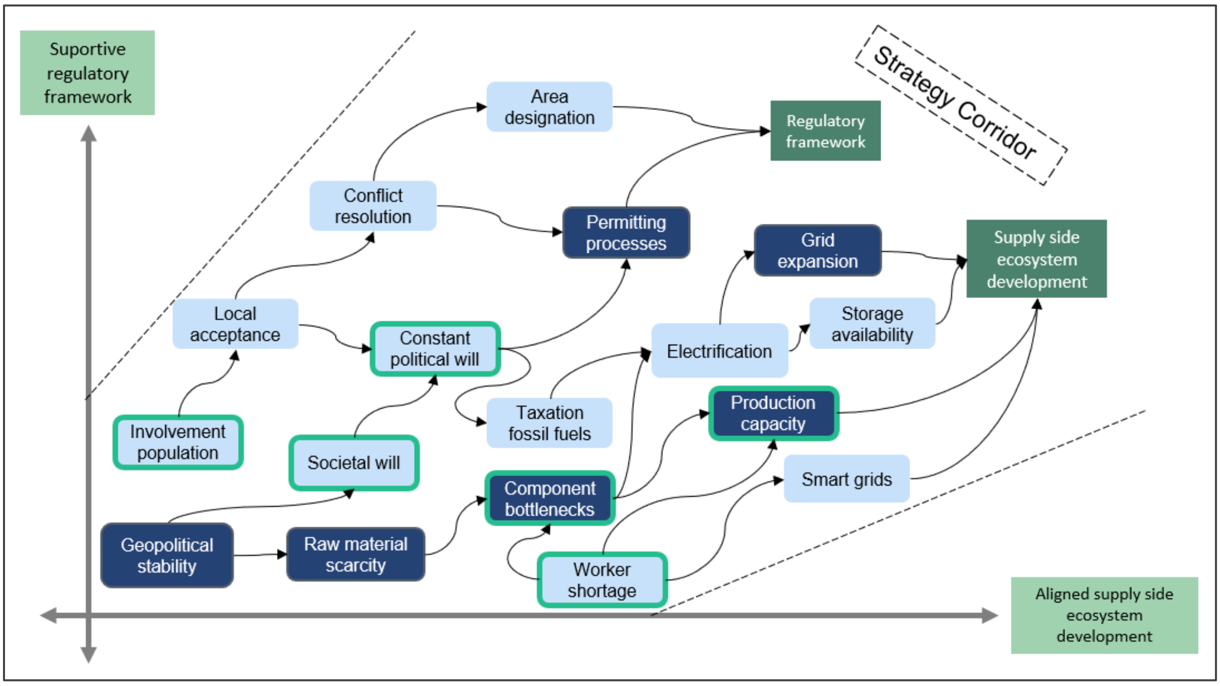


Figure 12: Strategy corridor for wind energy industry

Source: Own illustration

Core Strategies

The core strategy for the European wind energy industry consists of generic strategic recommendations that apply to all four future scenarios described earlier but position companies for the best-case scenario. To work towards the desired "Setting Sails" scenario, it is advisable for all stakeholders to follow the following principles as a robust core strategy for the entire wind energy value chain: 1) Align production with market trends, 2) Cooperate with upstream and downstream players establishing long-term partnerships, and 3) Engage in policy and directly in society. These principles not only help to achieve the desired future scenario, but also work in the case of less positive future outcomes and can easily be remembered as “ACE principles." However, since the initial situation as well as the business model of wind turbine manufacturers and the developers and operators are vastly different, a distinction is made between the two groups when describing the core strategy for the desired scenario in more detail.

Core Strategy for Wind Turbine and Component Manufacturers

To work towards the desired scenario, the following strategic measures embedded in the "ACE Principles" are recommended for manufacturers:

(1) Expand capacities: To meet the increasing demand, the aligned expansion of production capacities is of crucial importance. In view of the higher demand for electricity due to electrification and the additional demand for green hydrogen, manufacturers of wind turbines should increase their production capacities at an early stage. It is advisable to have coordinated efforts within associations and seek external expertise to avoid temporary or regional overstepping.

(2) Global manufacturing facilities and collaborations: To enter new markets with great potential, European manufacturers should consider setting up manufacturing facilities abroad. They may find promising emerging markets in South America, due to the region's favorable conditions for wind power, and in the long term, in Africa due to its exponentially increasing demand for electricity. In the near term, manufacturers should consider opening facilities in the US. The demand for energy in the US not only presents an opportunity for growth, but also serves as a potential foundation for developing markets in Central and South America.

(3) Clear orientation through standardization and specialization: Depending on their strength, manufacturers should offer large systems for utility scale wind parks or specialize in smaller wind turbines for decentralized power supply. Specializing in either offshore or onshore wind turbines can also reduce complexity.

(4) Long-term partnership contracts with both suppliers and customers instead of "race to the bottom" pricing: Long-term agreements reinforce loyalty and increase planning security on both sides, which is necessary in a market that is expanding but is now experiencing supply side challenges.

(5) European positioning: Manufacturers should distinguish themselves from Chinese manufacturers and emphasize their European origins. This can be achieved through a focus on product and service quality, as well as creating jobs domestically and prioritizing sustainability. This includes implementing high rates of recycling and minimizing CO2 production. At the local level, manufacturers should collaborate closely with their partners to engage with communities.

Core Strategy for Wind Park Developers and Operators

For the developers and operators, the following strategic recommendations are available, depending on their company size:

A) Energy conglomerates and international developers

(1) Focus large scale projects, especially offshore parks, and long term also on hydrogen facilities: Benefit from the capital-intensive nature and similarities to conventional power plants of offshore projects. For opportunities in large scale green hydrogen production, consider better locations abroad, such as South America.

(2) Secure Power Purchase Agreements (PPAs), especially with bulk consumers, to ensure project stability and long-term planning.

(3) Engage in lobbying and stay involved in political affairs to advocate for favorable policies.

B) Smaller operators and local developers

(1) Focus on decentralized models and adopt a hybrid approach by integrating solar energy and storage for seasonal balance.

(2) Offer direct local supply to SMEs and households with long-term transparent contracts.
(3) Strengthen community acceptance for onshore wind parks in rural areas by participation options.

Regardless of the group, it is important to establish long-term partnerships with suppliers, landowners, and other stakeholders due to the wind farms' lifecycle of over 20 years. Doing so can create favorable conditions for future repower projects and may prove lucrative if the turbines continue to operate effectively beyond the intended 20-year lifespan through proper maintenance and management.

Monitoring & Tipping points

The actual developments of relevant influence factors should be continuously monitored to identify whether scenarios other than the favored one might occur. Table 2 lists examples of indicators that can be used to monitor the development of the influence factors and thus the meta-dimensions. If the future sees a decline in election results for green parties, insufficient area designation, and on-going delays in permitting processes, the regulatory framework has developed in a negative direction. If the supply side ecosystem development is positive at the same time, the strategy should be geared towards Scenario B "Stuck in Regulation".

Influence factors		Indicators
Regulatory framework	Societal will for energy transition	Election results (Percentage of votes for green parties)
	Permitting processes	Average approval duration
	Area designation	Percentage of land designated for wind turbines
	Fossil fuels taxes & CO2 price	EU-ETS certificate price (EUR / t CO2)
Supply side ecosystem development	Electrification	Number of e-vehicles registrations (Kraftfahrtbundesamt)
	Grid expansion	Yearly investment in grid infrastructure (BNetzA)
	Storage availabillity	Lithium battery storage cost per MWh
	Interest rates	ECB interest rate policy
	Raw material scarcity	Metals price index

Table 2: Indicator table for the European wind energy industry

Source: Own illustration; data own estimation

6 Methodology

HHL-Roland Berger Approach to Scenario-Based Strategic Planning

Our scenario study is based upon the approach to scenario-based strategic planning that was jointly developed by HHL and Roland Berger. The approach does not only allow creating scenarios but also enables companies to integrate scenarios into their strategic planning processes.

Our approach consists of six consecutive process steps for each of which we have created a specific tool that eases strategic planning with scenarios in practice (see Figure 13). The approach thus enables managers to plan for multiple options. At the same time, it allows managers to integrate and align external and internal perspectives to challenge existing assumptions and mindsets (Schwenker & Wulf, 2013).

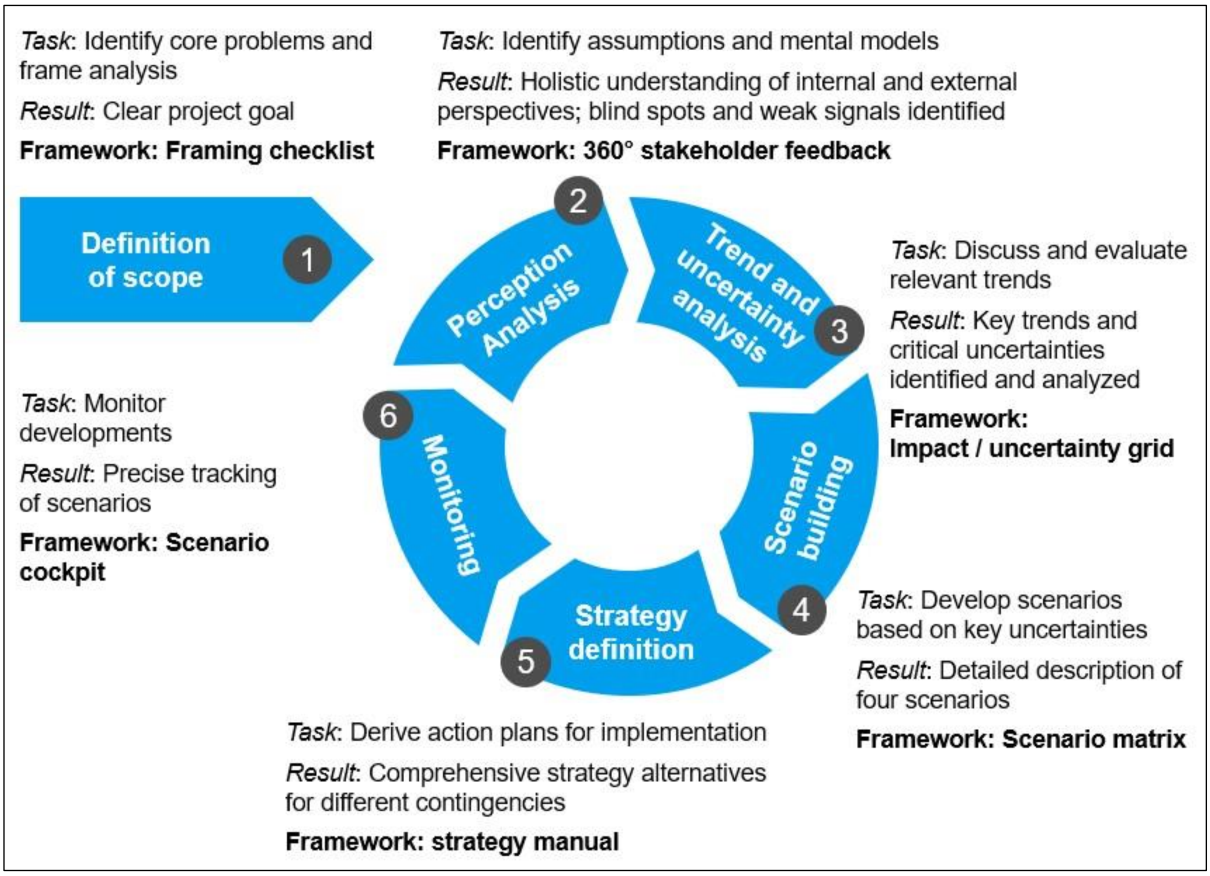


Figure 13: HHL-Roland Berger Scenario-Development Process

Source: Schwenker & Wulf (2013).

Description of process steps

Definition of Scope

The first step of the scenario development process is to define the project scope. Experts of our Center for Strategy and Scenario Planning and project partners meet to agree upon the core goal of the project. This includes identifying core problems and framing the analysis. Our Framing Checklist tool makes sure that every important aspect is covered and that all project partners share a common understanding of the steps ahead.

To create the four scenarios for the European and German wind energy market we applied the Framing Checklist. We defined the goal of the analysis to be the development of scenarios for the wind energy industry in 2033. The present study targets the European and German (energy) market geographically. Due to the complexity and dependency, the analysis will further encompass all frequent energy sources as limiting to a specific energy source results in incomplete scenarios for energy producers using different resources to generate electricity.

Perception Analysis

In the second step of the scenario development process, we apply our 360° Stakeholder Feedback tool to identify assumptions and underlying mental models of different players in the industry as well as of external stakeholders. This reveals important influence factors, but also possible blind spots and weak signals.

To identify important influence factors for the future development of the European and German wind energy market, we sent out two questionnaires to managers of major energy suppliers as well as to external industry experts from research institutions, to consulting companies and to customers to get an overview on their assumptions as well as the trends and factors they considered important for the future of the industry.

After conducting the 360° stakeholder feedback, all factors were consolidated and analyzed. The aim of the so-called trend and uncertainty analysis is to identify the most important driving forces affecting the industry and the corresponding uncertainties behind these factors. These factors were mapped on an impact/uncertainty grid to identify the critical uncertainties.

Trend and Uncertainty Analysis

In the third step of the scenario development process, we determine and analyze trends that are likely to impact the project partner in the future. With the help of our Impact/Uncertainty Grid tool, we cluster the trends according to their degree of impact and their level of uncertainty. Factors which score high on both dimensions are then transformed into 'key uncertainties', the basis of the next step in our scenario development process.

Afterwards, different influence factors that were gathered and rated by the experts in the previous process step were transferred into the Impact/Uncertainty Grid and clustered into critical uncertainties, trends, and secondary elements (Figure 14).

Furthermore, two key uncertainties building the basis for the scenario development in the next process step were identified. For this we clustered three and five factors respectively into two meta-categories, which we call critical uncertainties or scenario dimensions. The first meta-category/ scenario dimension is a cluster consisting of three critical uncertainties. These are:

(1) Permitting process (political)
(2) Predictable legal framework (legal)
(3) Conflict resolution with wind power opponents (legal)

Together they form the scenario dimension **"Regulatory framework"**.

The second scenario dimension, **"Supply side ecosystem development"** is composed of four subcomponents. These uncertainties are:

(4) Raw material supply shortages (economic)
(5) Component bottlenecks (economic)
(6) Production capacity manufacturers (economic)
(7) Grid expansion (technological)

These four subcomponents mainly capture the economic pressure and technological obstacles the European wind energy industry faces.

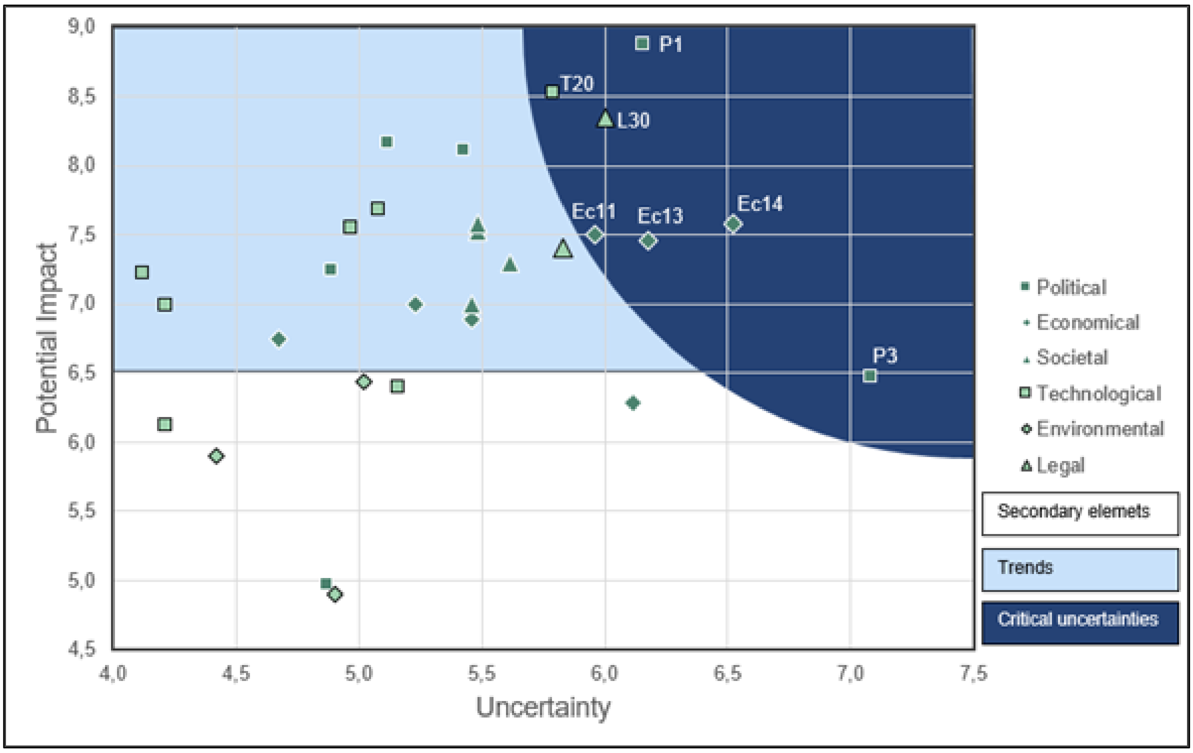


Figure 14: Impact/Uncertainty Grid for the German Energy

Source: Own illustration

Scenario Building

In the third step of the scenario development process, the scenarios themselves are created. Using the scenario dimensions determined in the previous step, we derive possible pictures of the future and describe them in detail. Typically, four plausible and distinct scenarios are developed. Our Scenario Matrix tool guides this process step. To speed up the process and to make the scenarios as accurate as possible, we also use the know-how of global scenario experts assembled in our Scenario network for this step.

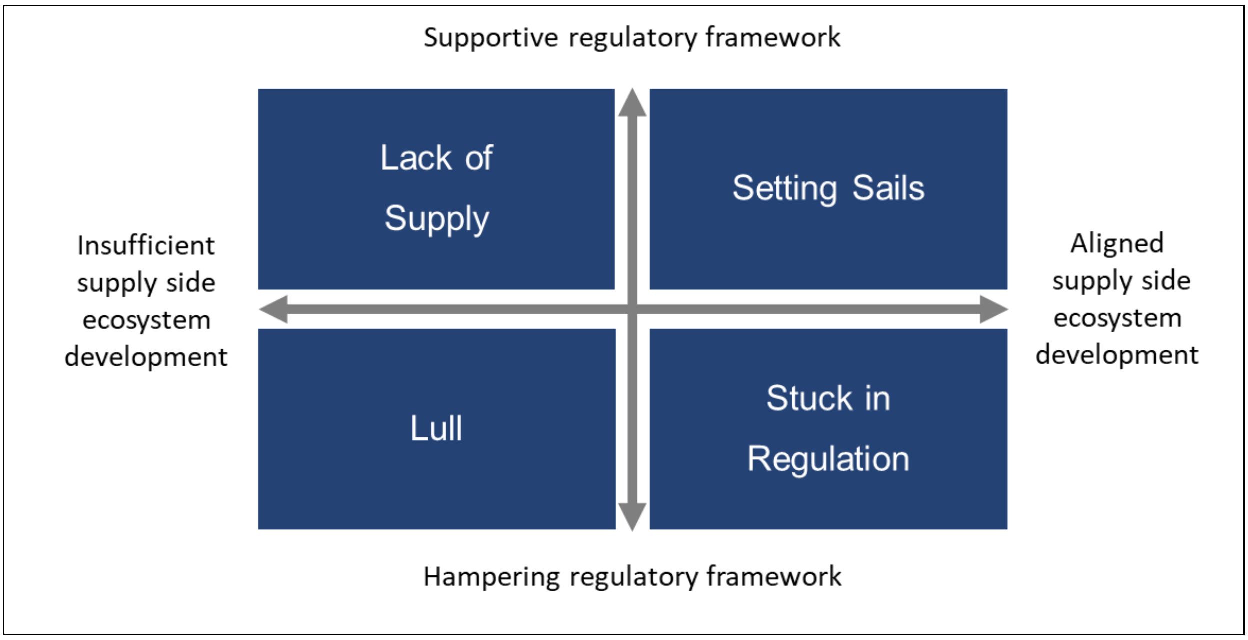


Figure 15: Scenario Matrix for the Wind Energy Industry

Source: Own illustration

In the present scenario project, the creation of the scenario matrix resulted in four scenarios for the German energy market as described above (see Figure 15). We named these scenarios “Setting Sails”, “Stuck in Regulation”, “Lull”, and “Lack of Supply”. To describe these scenarios in more detail, we created an influence diagram. This diagram displays all trends and critical uncertainties as a chain of causes and effects which lead to the two scenario dimensions. This influence diagram forms the basis for the detailed description of the four scenarios presented below (16).

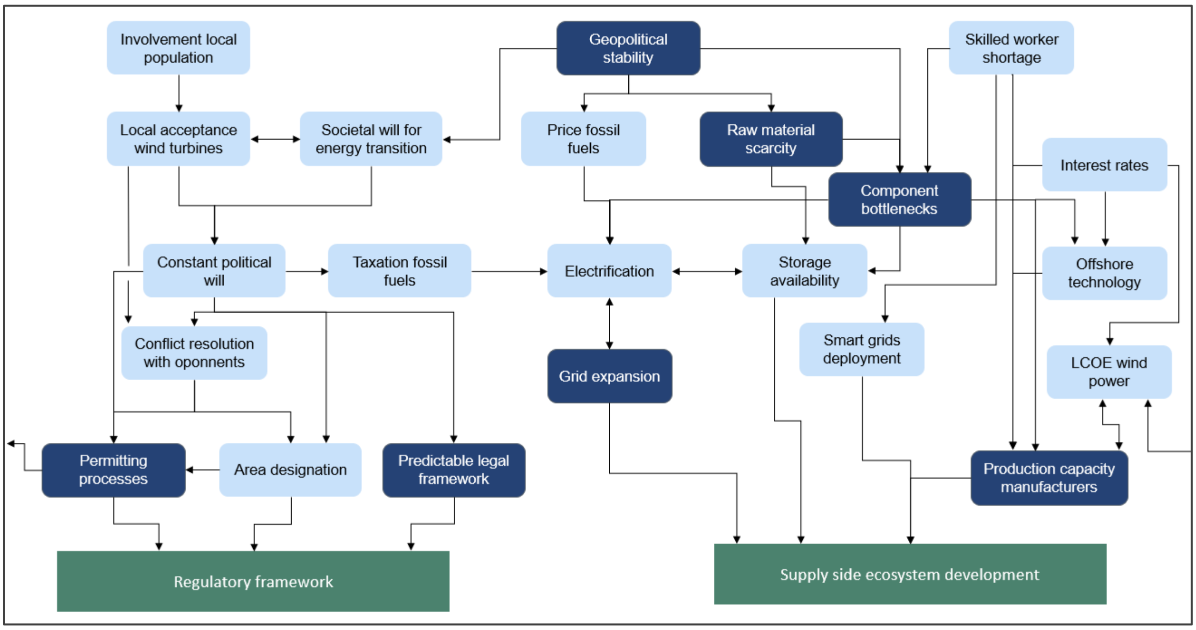


Figure 16: Simplified Influence Diagram for the Wind Energy Industry
Source: Own illustration

Strategy Development

The main goal of this step is to develop ideal-typical portfolios businesses or products and services for each of the four scenarios. For the strategy definition we use the scenario-based portfolio matrix as a tool. The scenario matrix serves as a basis for the portfolio matrix. In each of the four quadrants of the scenario matrix, we now display one ideal-typical portfolio that is most adequate for this scenario. To arrive at the ideal-typical portfolios, we first list all existing businesses of the company in question. Then, we go back to the scenarios that we developed. For each scenario we ask two questions:

1. Which of our current businesses, products or services seem particularly promising under the conditions of this scenario?
2. Which new businesses, products or services are promising under the conditions of this scenario?

These two questions are discussed as part of a top management workshop and yield one ideal portfolio for each of the four scenarios. Certainly, specific businesses, products or services can also appear more than once in this portfolio matrix if they fit to different scenarios.

Monitoring

The main goal of this step is to constantly track the development of the company's environment and its influence factors and to allocate or reallocate resources to the most appropriate scenario-based portfolio. For the monitoring step we use the scenario cockpit as well as scenario-based portfolio management as tools. The scenario cockpit is a strategic controlling tool that comprises several indicators which help us to determine which scenario is most likely to occur. The scenario cockpit lays the essential basis for scenario-based portfolio management. The company's management needs to decide which of the four scenario-based portfolios, which have been defined in step 5, the company should focus on. Scenario-based portfolio management helps to take this decision by answering two questions:

1. Which scenario is the dominant one, that is: which scenario is most likely to occur?
2. How far are we from reaching certain tipping points, that is: Is the transition from the presently dominating scenario to a different one likely?

After having formulated a company’s core strategy as well as coping strategies, the scenario planning process supports managers with a monitoring approach, referred to as *Scenario Cockpit* (Wulf et al., 2012). The *Scenario Cockpit* supports the management in identifying critical indicators for changes in the market environment. Based on defined values for each scenario, a regular assessment enables the management to choose the right strategy for the respective developments. Therefore, the senior management must get reports regularly to align their perception with objectives, focusing on a few objectively measurable indicators to simplify monitoring (Schwenker & Wulf, 2013).

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8 HHL Center for Strategy and Scenario Planning

The HHL Center for Strategy and Scenario Planning creates knowledge and acts as an impetus to change the way decision makers think about the future and organizations plan their future. We provide a platform for the exchange of ideas with leading scenario experts. The Center's activities focus on four areas:

1. Research

We advance knowledge about scenarios by developing new methods and tools for strategic planning, exploring the cognitive and behavioral implications of using scenarios in strategic decision making, and developing new scenarios across a broad range of domains.

2. Teaching

We teach scenario planning to business leaders and strategic planners in executive seminars and workshops, to graduate students in summer seminars, and to MBA and MSc students at HHL studying strategic management.

3. Consulting

We advise corporate, public, and civil organizations on establishing scenario planning structures and processes, reviewing, and adapting existing planning processes, and communicating effectively with all stakeholders in times of uncertainty.

4. Networking

We provide a platform and act as a facilitator to bring together scenario experts from around the world, bridge the gap between theory and practice, and share ideas about what the future will look like.

For more information about the Center, visit *www.scenarioplanning.eu*.

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