Report 2022

# Germany

**Land-Based Wind Turbines.** *Source: ©whitcomberd – stock.adobe.com*

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**Germany continues to value wind energy as a main contributor to the green energy transition and a key supply of renewable energy. In lieu of the energy crisis caused by the war against Ukraine, the transition towards renewable energy has become a greater strategic focus.**

To support this transformation, the Federal Ministry for Economic Affairs and Climate Action (BMWK) has developed the so-called Land-Based Wind Energy Strategy [1], which aims to develop a land-based wind power capacity of 160 GW by 2035. The main aspects of this strategy are to accelerate the installation of wind turbines (WT), increase WT reliability, reduce the cost of energy, improve acceptance among the public, educate skilled personnel, facilitate transportation, and continue to support further research. Another pillar of the German energy supply will be the significant expansion of offshore wind energy, where a target of 40 GW is to be installed by 2035 and 70 GW by 2045, according to the Offshore Wind Energy Act (Wind-SeeG) [2].

**Table 1. Key National Statistics 2022: Germany.**

| | |
|---|---|
| Total (net) installed wind power capacity | 66.344 GW |
| Total offshore capacity | 8.116 GW |
| New wind power capacity installed | 2.745 GW |
| Decommissioned capacity (in 2022) | 0.266 GW |
| Total electrical energy output from wind | 125.287 TWh |
| Wind-generated electricity as percent of national electricity demand | 22.8% |
| Average national capacity factor | 22.0% |
| Target | 80% renewable energies by 2030 |
| National wind energy R&D budget | 68,657 million USD |

## Highlight(s)

- New Land-Based Wind Energy Strategy with a demanding target for onshore wind power of 160 GW by 2035, supported by solutions for barriers in 12 relevant action fields.
- The Wind Energy Area Requirement Act (WindBG) intends to speed up the installation of land-based wind energy through binding area targets in the Federal States.
- 40 GW of offshore wind energy capacity is to be installed by 2035, and 70 GW by 2045 is projected by the Offshore Wind Energy Act (WindSeeG) [2].

## Market Development

### Targets and Policy

Germany continues its rapid transition towards renewable energies with ambitious new goals. The Federal Ministry for Economic Affairs and Climate Action (BMWK) has developed the so-called Land-Based Wind Energy Strategy [1], which sets a target of 160 GW of land-based wind power capacity to be installed by 2035. The Offshore Wind Energy Act (WindSeeG) [2] supports the massive expansion of offshore wind energy by setting a goal of 40 GW in installed capacity by 2035 and 70 GW by 2045.

To reach these goals within their deadlines [2], the Federal Government continuously adapts its strategies to stay on track. For instance, the Wind Energy Area Requirement Act (WindBG) has been introduced. This places a target requiring wind generation facilities to cover 1.8% of the German land area by 2027 and up to 2.2% by 2033. For each Federal state, the exact values vary between 0.5% and 2.2% due to their individual landscapes [3] [4].

Furthermore, as one of several European signatories of the Ostend Declaration, Germany is delivering cross-border projects and anchoring the renewable offshore industry in Europe to strengthen cooperation in offshore wind energy in the North Sea region [30].

### Progress and Operational Details

In 2022, wind energy continued as the largest contributor to renewable electricity generation. Wind energy constituted 22.8% of gross electricity consumption, while renewable energies collectively contributed 46.2%. The amount of new added capacity amounted to 2.75 GW in 2022, which is an increase compared to the previous year where 1.95 GW was installed. The additional capacity in 2022 increased partly due to the 342 MW from newly installed offshore wind turbines [16].

In regard to offshore turbines, the average nameplate capacity of newly added turbines is 9 MW, with 167 m rotor diameter and 108 m hub height. The average capacity of onshore wind turbines increased by 10% in comparison to 2021 to 4.4 MW, while the average hub height of 138 m and rotor diameter of 137 m remained mostly unchanged. It must be noted that these averages are impacted by the large proportion of 132 turbines with relatively low average hub heights of 109 m and rotor diameters of 128 m. However, Germany's most northern state, Schleswig-Holstein, has an average tip height above 200 m [32].

With the installation of a total of four E-138 EP3 E2 WT in Lower Saxony, ENERCON has surpassed 25 GW of total installed capacity in Germany. The company also installed an E-160 EP5 E3 WT in Lower Saxony as the first WT with a built-in electrical system. In this nacelle type, converters and transformers are placed directly behind the generator. The new design achieves a significant simplification of processes in production, transport, and installation, saving resources. The E-nacelle marks the end of a multi-year transformation process away from the iconic 'egg' design of traditional ENERCON WTs and towards a rigorous 'form follows function' design [5]. The first E-160 EP5 E3 5.5 MW turbine in North America was successfully commissioned and put into operation at the end of January 2023 in Alberta, Canada. These three projects feature 55 WTs, constituting a total capacity of 303 MW [6].

Following the EP5, the EP3 WT platform is the next to incorporate the box-shaped machine house design, where the interior houses the most recent ENERCON power electronics. These electrical systems will also be used in the E-nacelle versions to come [7].

The company also announced an expansion of the EP5 WT class with improved performance and yield. The new E-175 EP5 WT type is projected to rank above the current E-160 EP5 E3 and supplement the product portfolio. The E-175 EP5 will be designed for wind class S (IEC); the rotor diameter will be 175 metres with a nominal power output of 6 MW. The E-175 EP5 builds on the E-nacelle platform of the current E-160 EP5 E3. The mechanical components and the supporting structure of the E-nacelle are largely identical for both WT types. The goals of the new WT type include substantial yield increases above the current EP5 WTs, requiring a plus of at least 18% increase in yield compared to the E-160 EP5. Spanning 86 metres, the E-175 EP5 will exhibit the longest one-piece rotor blade designed by ENERCON. The market launch and scaling of series production have been scheduled for the beginning of 2024 [7].

With the official deployment of the Asia-Pacific region (APAC), ENERCON is completing its regionalisation project from the turnaround. In addition to the European regions, North America, Central Asia/Middle East/Africa, and Latin America, APAC has also been working with the new organisational model since the beginning of June 2022. Regionalisation is considered to be one of the most important reorganisations in the course of the reorientation of ENERCON to its core business in international markets [7].

In May 2022, the Nordex Group installed its first N163/6.X turbine in the Delta4000 series in the province of Flevoland in the Netherlands. The N163/6.X is designed for moderate and light-wind regions. However, the model may be customised for different markets. For example, the height can be built up to 164 metres, a bespoke version for cold climates with an advanced anti-icing system can also be commissioned. Series production of the N163/6.X is scheduled to start at the beginning of 2023 [8]. In early 2023, Nordex Group had already received orders for the supply and installation of N163/6.X WT, which will amount to more than 1.1 GW [9].

German wind farm developer UKA and the Nordex Group continue their collaboration by extending their framework agreement for another two years. The existing partnership covers a total of 80 WTs, representing a capacity of around 500 MW. The first orders for a volume of 100 MW have already been initiated under the new framework agreement and are due to start operation in 2023. The Nordex Group will manufacture the turbine nacelles at its production facility in Rostock [10].

In September, the Nordex Group announced another new turbine. With its single-piece, newly designed 85.7-metre-long rotor blade, the N175/6.X will yield between 7 to 14% more compared to its preceding models, the N163/5.X and N163/6.X. This additional yield is achieved particularly during times of light wind speeds where the turbine produces up to 22% more energy than its predecessors. The turbine will initially be offered with hub heights between 112 and 179 metres and is designed for an operating lifetime of 25 years. In some site-specific circumstances, it can reach a life-cycle of up to 35 years. Series production of the N175/6.X is scheduled for the end of 2024. The nacelle will be produced at the company's German production facility in Rostock [11].

Siemens Gamesa announced that a number of the 38 SG 8.0-167 DD WTs of RWE's Kaskasi offshore wind farm will be equipped with handcrafted Siemens Gamesa B81 Recyclable Blades, each with a length of 81 m. The 342 MW project is located 35 km north of the island of Heligoland in the German North Sea. Utilising Siemens Gamesa's recyclable blade technology enables a full reclaim of the blade's components at the end of the product's lifespan. Separating the resin, fibreglass, and wood, among other materials, is achieved using a mild acid solution. The materials can then be reused in the circular economy, creating new products [12].

The company also received a 913 MW order from Borkum Riffgrund 3.50 km off the coast in the German North Sea. The SG 11.0-200 DD WT that will be used features a capacity of 11 MW with a 200 m rotor. It utilises 97-metre-long Siemens Gamesa B97 blades. In addition to the installation of the 83 SG 11.0-200 offshore direct drive WTs, Siemens Gamesa has been awarded a multi-year contract to service the turbines. The installation of Borkum Riffgrund 3 is expected to begin in 2024, with commissioning anticipated to be completed in 2025 [13].

### Matters Affecting Growth and Work to Remove Barriers

Almost simultaneously with the incursion of Russian troops on the 24th of February 2022, satellite communications with thousands of WT in Central Europe went silent. Remote monitoring and remote control were no longer possible; service control centres and operators/owners lost their remote access. In total, the disruption affected 5,800 ENERCON WTs in Germany, Austria, France, Benelux, Italy, Greece, the UK, Lithuania, and Scandinavia, equalling a total power loss of more than 10 GW. The disruption was caused by a cyberattack on the KA-SAT network. ENERCON customers use this infrastructure to connect wind farms to service communications at sites where broadband is unavailable or would entail excessive costs for operators/owners. Grid operators continued to have unrestricted access to the WTs in order to regain control of their behaviour on the power grid. The WTs ran reliably in automatic mode and continued to generate green electricity. In response to this incident, ENERCON developed optional backup solutions and prepared LTE-based retrofit packages for the affected SAT systems [5].

The Nordex Group detected a cybersecurity incident on the 31st of March 2022 and in response, initiated security protocols, immediately shutting down various IT systems across different business units. To safeguard customer assets, remote access from Nordex Group IT infrastructure was disabled for WTs under contract. Nordex turbines continued operating without restrictions and wind farm communication with grid operators and energy traders was unaffected. As part of the immediately initiated business continuity measures, alternative remote control services have been set up and are now successfully implemented for most of the fleet [14]. Due to the cybersecurity incident, weather-related delays, and component bottlenecks, the Nordex Group's installations were lower than in the previous year: 1,129 WTs in 19 countries, compared to 1,619 in 22 countries in 2021. The total nominal output constituted 5.2 GW, opposed to the 6.7 GW generated in 2021. Despite these factors, the company gained market share, improved its operating structure, and reinforced its financial structure [15].

## RD&D Activities

### National RD&D Priorities and Budget

Germany continues to pursue a very broad R&D programme (7th Energy Research Programme of the Federal Government), rather than focusing on a specific subject. Two of the main goals are to reduce energy costs and accelerate the increase of wind power capacities. To this end, several options are considered: Increasing turbine reliability, extending turbine lifetime, enabling higher wind turbine performance by using bigger rotors or increased hub heights, understanding wind physics, optimising system engineering, identifying new onshore sites for wind turbines, and inciting more dialogue on offshore logistics and maintenance topics. As well as building new wind turbines, the decommissioning of end-of-life wind turbines needs to be examined in terms of recyclability and

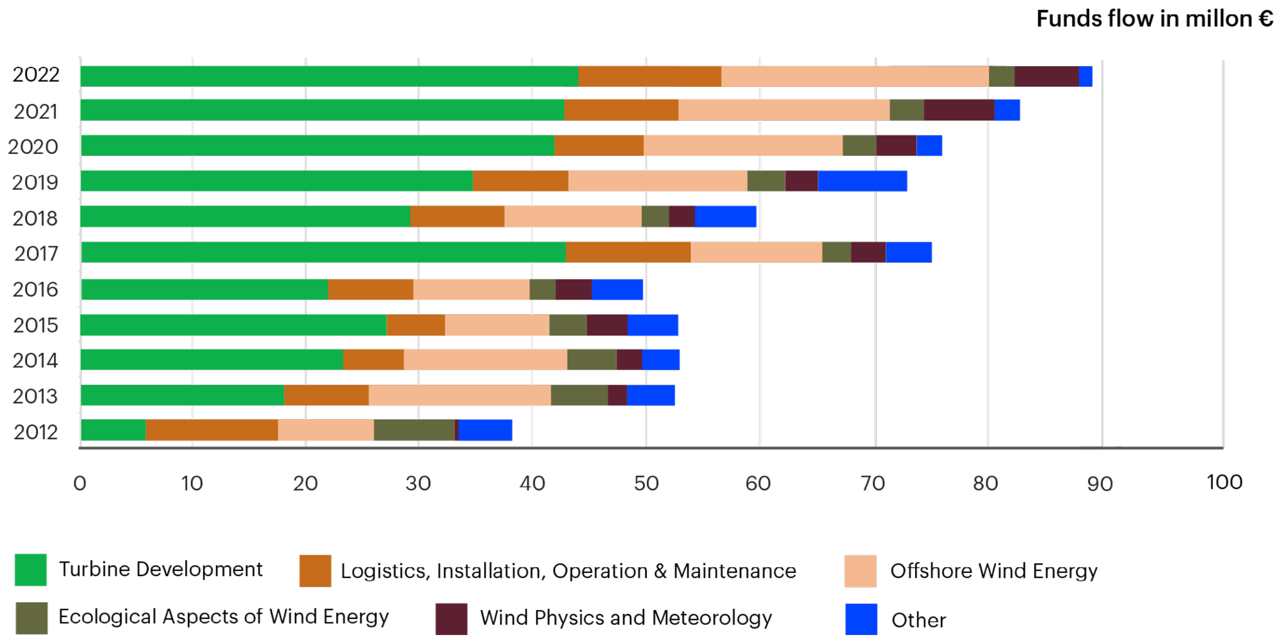


**Figure 1:** "*Development of yearly funds flow in Germany*", Federal Ministry for Economic Affairs and Climate Action (BMWK) [16].

circularity, as well as social acceptance. The Federal Ministry for Economic Affairs and Climate Action (BMWK) has provided 89.19 million EUR (95.70 million USD) to fund 469 active and ongoing research projects in the field of wind energy in 2022, see Figure 1. Additionally, BMWK started 107 new research projects with a new funding amount of 63.99 million EUR (68.66 million USD), including an additional supplementary amount of 4.24 million EUR (4.56 million USD) for ten projects that started in the years before.

## National Research Initiatives and Results

- In the project **CompactWind II**, scientists focused on the development and industrial testing of concepts for wake control in wind farms. The goal is to develop more economical, efficient, and environmentally friendly use of the limited onshore locations. Another aim was to improve the control and synchronisation of individual wind turbines. Therefore, experiments in the field with real turbines, as well as highly developed wind tunnel tests and numerical simulations, have been undertaken. By now, the investigation to increase the power output in closely spaced wind farms through self-learning databased wind park control by wake deflection will be continued in the recently started project **SmartYaw** [17] [18].
- The project **FoKO-Wind** focused on theoretical and experimental investigations on the development and qualification of a foil-based system for protecting surfaces of offshore wind tower segments, as well as the development of an application technique in the tower manufacturing phase. The team of researchers was able to develop polymer-coating foil, proving its usability in laboratories as well as in outdoor storage assessments [19].
- The purpose of the project **AgileDataDev** was the development of a guideline to agilise the product development process for system engineering. This is done by using the example of a wind turbine manufacturer integrating agile methods and data-based assistance. Achieved benefits are the increase of effectiveness by specifically addressed requirements, the improvement of efficiency by reduction of unintended iteration steps, the provision of data-based decision support, and the reduction of time-to-market and improvement of market-fit of products [20].
- The project **REWA** investigates the relationships between acceptance and regional added value, considering the effects of different participation models in renewable energy projects in selected energy municipalities. The effects of acceptance are surveyed at different levels of actors in the energy communities. Additionally, the correlation with a perceived regional added value, as well as the different forms of participation, are examined. Scientific results are prepared in a short and concise manner for a broad target group for practice transfer [21].

## Test Facilities and Demonstration Projects

At the Coastal Research Centre (Forschungszentrum Küste, FZK) in Hannover, a Large Wave Flume (GWK – Großer WellenKanal) built in the 1980s, has recently been upgraded during the **MarTech** project. It now features a powerful current system, a deeper area for examining foundation structures and a more powerful wave generator. The newly renovated infrastructure has been dubbed **"GWK+"** and enables the examination of waves on a variety of structures, such as offshore foundations [22] [23]. The new GWK+ started its operation in the first half of 2023.

Furthermore, at the National Metrology Institute (Physikalisch-Technische Bundesanstalt, PTB), a unique torque measuring system with 5 MNm was inaugurated in June 2023 within the Competence Centre Wind Energy (CCW) [24].

## Collaborative Research

- The Federal Ministry for Economic Affairs and Climate Action (BMWK) is the German Contracting Party in the IEA Wind TCP. By the end of 2022, German research institutions and industry representatives were involved in 19 of 21 active Research Tasks (11, 25, 28, 30, 37, 39, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53 and 54). Task 52, "LIDAR", is jointly led by the German Task managers, Fraunhofer Institute for Wind Energy Systems (IWES), and the University of Applied Sciences Flensburg. Task 43, "Digitalisation", was co-led by the Fraunhofer Institute for Energy Economics and Energy System Technology (IEE) until March 2023 in collaboration with the US, NREL. Most of Germany's Task participants also execute nationally funded projects in their related topics, benefitting the mutual worldwide information exchange within their IEA Wind TCP Tasks and to some extent between different TCPs.
- Furthermore, Germany has been a Federal partner in the Clean Energy Transition Partnership (CET Partnership) since the first joint call that was launched in 2022 within the Transition Initiative (TRI) 2 "Enhanced zero emission power technologies". Here, wind energy-related research topics are included amongst a variety of technologies and system solutions. Yearly calls are projected until 2028. The CET Partnership is a multilateral and strategic partnership of national and regional research, development and innovation (RDI) programmes in the EU/EEA

Member States and non-EU/EEA Partner Countries. The aim is to substantially support the implementation of the European Strategic Energy Technology Plan (SET Plan) [25].

## Impact of Wind Energy

### Environmental Impact

In 2022, the generation of around 125 TWh of wind energy led to a reduction of almost 94.92 million tons of CO2-equivalent greenhouse gas emissions [26].

In the research project, **BirdVision**, a camera system for the detection and protection of wind power-sensitive bird species as well as nocturnal flying animals has been developed. The classification/species differentiation has been extended to bird species occurring throughout Germany, such as the Red Kite, the Common Buzzard, and Rooks by collecting and incorporating additional data into the Deep Learning Network. Additionally, a new camera and server hardware are in use, enabling the timely detection of fast-flying wind power-sensitive bird species by means of an adapted detection distance. A reduction of false triggers for the protection of the plant technology and for yield optimisation has been achieved as well. In addition, a detached monitoring and protection system with a self-sufficient power and data supply has been established [27].

With regard to life-cycle analyses (LCAs), the Nordex Group published two new LCAs for the Nordex N155 and N163 turbines, demonstrating onshore wind turbines' very low energy-generation environmental footprint, with 5.5 and 2.7 grams of CO2-equivalent per kWh respectively [28].

### Economic Benefits and Industry Development

Investments in the construction of new wind power plants are still below the long-term average but have increased significantly compared to the last three years. Onshore, this equalled 3.6 billion EUR (3.8 billion USD) (2.84 billion EUR; 3 billion USD in 2021), while offshore generated 1.25 billion EUR (1.34 billion USD) (0.29 billion EUR; 0.31 billion USD in 2021). Economic stimuli from the operation of wind power plants remain at a constant level: Onshore 2.29 billion EUR (2.46 billion USD) (2.31 billion EUR; 2.48 billion USD in 2020), offshore 0.65 billion EUR (0.69 billion USD) (0.62 billion EUR; 0.66 billion USD in 2021) [26].

Concerning one example of turbine manufacturers in Germany, Nordex SE, whose sales in the projects segment rose slightly by 2.7% to 5.1 billion EUR (5.4 billion USD) (5.0 billion EUR; 5.3 billion USD in 2021). The service segment increased its

**Figure 2.** Worker on land-based Wind Turbine. *Source: ©Tarnero – stock.adobe.com*

sales by 22.7% to 574 million EUR (617 million USD) (468 million EUR; 503 million USD in 2021) to comprise 10.1% of consolidated sales. By the end of 2022, the Nordex Group serviced 10,599 wind turbines with a total output of more than 31 GW, most of them on long-term contracts (2021: 9,765 turbines, 27 GW). The order book grew by 7.2% to 3.3 billion EUR (3.5 billion USD) in the service segment (3.0 billion EUR; 3.2 billion USD in 2021) and by 5.8% to 6.5 billion EUR (6.9 billion USD) in the projects segment (6.2 billion EUR; 6.6 billion USD in 2021) [31].

## Next Term

Wind energy continues to be central to the German Energy Transition as one of its main supporting pillars. Federal and State Governments are working on removing barriers specifically for onshore wind and strengthening offshore deployment. To achieve the 160 GW target by 2035, the land-based wind energy capacity target, the so-called Wind Energy Area Requirement Act (WindBG) has been introduced [4].

Furthermore, the Federal Ministry for Economic Affairs and Climate Action (BMWK) has announced the launch of the 8th Energy Research Programme of the Federal Government. Alongside cross-cutting aspects that will help optimise the energy system, it is expected that the transformation of the energy system will be built on research for the electricity transition, the heat transition, and a progression of the hydrogen economy. The 8th Energy Research Programme will serve as a further instrument of energy and climate policy and clearly identify ways to support existing programmes in these policy fields and create synergies [29].

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