Report 2021

Germany

Offshore Wind Turbines with Jacket Foundations in the first German Offshore Wind Park Alpha Ventus.
Source: ©BMWK/Holger Vonderlind

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With the new Federal Government formed in December 2021, wind energy continues to play a major role in the successful energy transition to renewable energies supply in Germany.

WITH THE SO-called "Easter Package", the Federal Ministry for Economic Affairs and Climate Action (BMWK) reforms several important laws to massively speed up the expansion of renewable energies, particularly solar and wind power. It declares that for Germany, the build-up of renewable energies is of great public interest, and plans to provide at least 80 % of its energy consumption from renewable sources by 2030 [1]. Research projects that are directly related to increasing the speed of the extension of wind energy production and deployment have come to the fore from 2022 on. Furthermore, the offshore expansion will be significantly increased in the future; by 2030, there shall be 30 GW of installed offshore capacity, 40 GW by 2035 and 70 GW by 2045 (starting from 7,8 GW in 2022).

Table 1. Key National Statistics 2021: Germany [0a] [0b]

Total (net) installed wind power capacity*	63.677 GW
Total offshore capacity	7.798 GW
New wind power capacity installed	1.949 GW
Decommissioned capacity	0.233 GW
Total electrical energy output from wind	111.734 TWh
Wind-generated electricity as percent of national electricity demand	19.6 %
Average national capacity factor**	20.6 %
Target	80% renewable energies by 2030
National wind energy R&D budget	54.031 million EUR (61.487 million USD

Highlight(s)

- New "Easter package" laws make use of renewable energy, overriding public interest.
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- New targets for reaching 80% share of renewables of electricity in 2030.

Market Development

Targets and Policy

Against the backdrop of an escalating climate crisis and Russia's war of aggression against Ukraine, Federal Minister for Economic Affairs and Climate Action Robert Habeck has presented a comprehensive immediate action package for energy in April 2022, the so-called "Easter Package", which has been adopted in July 2022. [2] [3]

At the heart of the package is the principle that the use of renewable energy is in the overriding public interest and serves public security. The expansion of renewable energy on land and at sea will be raised to an entirely new level so that the gross consumption of electricity in Germany will be covered by at least 80 % from renewable energy sources by 2030. A comprehensive package of measures is being adopted to drive forward the expansion of renewables. For example, the participation of the municipalities in the onshore wind will be extended, and more low-wind sites will be developed. Furthermore, the expansion rates of land-based wind energy will be stepped up to 10 GW/year, so Germany's installed onshore wind capacity should total around 115 GW in 2030.

The German Federal Government plans a revision of The Renewable Energy Sources Act (RES Act, or EEG) as well as the amendment of The Wind Energy at Sea Act. In the future, the expansion of offshore wind energy will be based on tender structuring in relation to area use and ideas for speeding up planning and approval procedures. In the case of centrally pre-assessed areas, the preliminary approval procedure is to be omitted entirely and replaced by a more expeditious planning authorisation process. Environmental assessments and participation rights are to be more clustered. Offshore grid connection can, in future be granted directly after the area has been incorporated into the overall site development plan, which will accelerate the award of contracts by several years. [4], [5]. The expansion of renewable energy and the grid will be sped up as barriers are removed, and planning and approval procedures are streamlined. The abolition of the EEG surcharge (granting subsidies for renewable energy via the electricity price) will also massively simplify the rules for the consumption of self-produced electricity and contribute strongly to reduce the amount of bureaucracy in energy law. Furthermore, this will relieve the burden on electricity consumers while strengthening sector coupling. An additional so-called "Summer Package" is prepared to tackle major obstacles in terms of onshore wind (e.g., too few sites) by a separate legislative package to be adopted by the cabinet at a later stage in a second step since they cannot be resolved by the RES Act itself.

The innovation auctions are being continued but switched from a fixed to a floating market premium since the fixed premium has not worked

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well. Also, a new auction segment will be introduced. In order to steady the volatile levels of generation from renewable energy and to trial storage in hydrogen and reconversion in practice, innovative concepts for renewable energy with local hydrogen-based electricity storage will be funded; this will also promote the market rollout of hydrogen technology. To this end, new combinations of installations are being funded, with renewable energy generation installations being complemented by a local chemical electricity storage facility that storages hydrogen.

With regard to offshore wind, in 2021 only zero Eurocent bids were awarded [6]. Onshore, the weighted average values were awarded with 6 Eurocents per kWh by February 2021, 5.91 Eurocents per kWh by May 2021 and 5.79 Eurocents per kWh by September 2021 [7].

Progress and Operational Details

While offshore deployment came to a full stop in 2021 (219 MW in 2020), the onshore wind grew by 1,677 MW (1,227 MW in 2020). In total, wind provided 111.734 TWh (129.644 TWh in 2020), contributing with 19.64 % (23.35 % in 2020) to the gross electricity consumption in Germany. Accordingly, the capacity factors dropped, too. Onshore, only 18.49 % (22.24 % in 2020) could be achieved, while the offshore capacity factor decreased to 35.79 % (40.67 %).

The average onshore capacity of newly installed wind turbines in 2021 was 4 MW. However, turbine manufacturers already show the first installations of next-generation larger machines.

Matters Affecting Growth and Work to Remove Barriers

The approval rate for wind energy projects has remained below the level of previous years for five years now. The main obstacles to the approval or realization of wind energy projects identified in previous surveys as well as in the report of the Federal States Cooperation Committee are the insufficient availability of legally designated areas, the lack of usability of these areas, reasons for nature conservation and species protection as well as air traffic control [8]. With regard to onshore wind energy, the Federal government and Federal states cooperation committee is to monitor the expansion targets of the states for renewable energy and their implementation status, with a particular focus on onshore wind. The body comprises the Federal Ministry for Economic Affairs and Climate Action (BMWK), all 16 states, the Federal Chancellery and the Federal Ministries for the environment, agriculture, transport, finance and building. The members of the committee at state secretary level convene at least twice a year to discuss the status of the renewables' rollout. Their work is based on reports from the states and comprehensive monitoring of the progress. The Onshore Wind Act is to stipulate **that each of the states must provide two per cent of its area for wind turbines.** Existing barriers to the expansion of onshore wind are to be cleared away. In addition to freeing up more sites in order to meet the two-per-cent-target, the act also aims in particular to speed up and simplify planning and approval procedures. Here, the expansion of wind energy and the protection of endangered species must go hand in hand. Intensive debates about the implementation of the two-per-cent-target and possible options for the

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breakdown of the target between the states are going on.

Recently, the Federal Ministry for Digital and Transport (BMDV) and the Federal Ministry for Economic Affairs and Climate Action (BMWK) agreed on a comprehensive package of measures in the field of omnidirectional radio beacons and weather radar stations. It modernizes the existing regulatory framework and uses **new forecasting methods for the impact of wind turbines on radio navigation and omnidirectional radio beacons, opening up the possibility to reduce the required distance from wind turbines by 50%.** This increases the availability of locations for onshore wind energy. The measures are based on results of the "WERAN plus" project, see below. It is planned to extend the project scope to military needs with regard to low-level flight air corridors and needs of preservation order.

The prohibition on the construction of wind turbines in nature conservation areas will be dropped in favour of a case-by-case examination of whether the construction would undermine the protection enjoyed by the protected area. Also, the revision regulates the subsequent use and repowering of existing offshore wind farms, and provides rules on the planning and approval of hydrogen pipelines. [2]

Rising raw material and shipping costs, as well as increasing price competition due to the introduction of auction systems in most of the energy markets, are putting turbine manufacturers under price pressure, leading to changes in the location of production facilities. In February 2022, Nordex informed staff at the Rostock Freight Village (FV) rotor blade site in Germany about considering ceasing the manufacture of rotor blades at that site at the end of June 2022 [9]. This followed earlier decisions by Enercon and Vestas to close their respective German blade manufacturing facilities. Thus, all existing German blade manufacturing facilities have been closed, resulting in the loss of about 4,000 jobs.

RD&D Activities

National RD&D Priorities and Budget

Germany continues pursuing 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 the cost of energy and to accelerate the total amount of wind power capacities. To achieve this, several options are taken into account: Increase the turbine reliability, extension of turbine lifetime, enabling higher wind turbine performance by using bigger rotors or increased hub heights, and identification of new sites for wind turbines. Equally to the building of new wind turbines, the decommissioning of disused wind turbines needs to be examined, e.g. in terms of recyclability and circularity. The Federal Ministry for Economic Affairs and Climate Action (BMWK) has provided a funds flow of 82.87 million EUR (94.306 million USD) to fund 488 active and ongoing research projects in the field of wind energy in 2021, see Figure

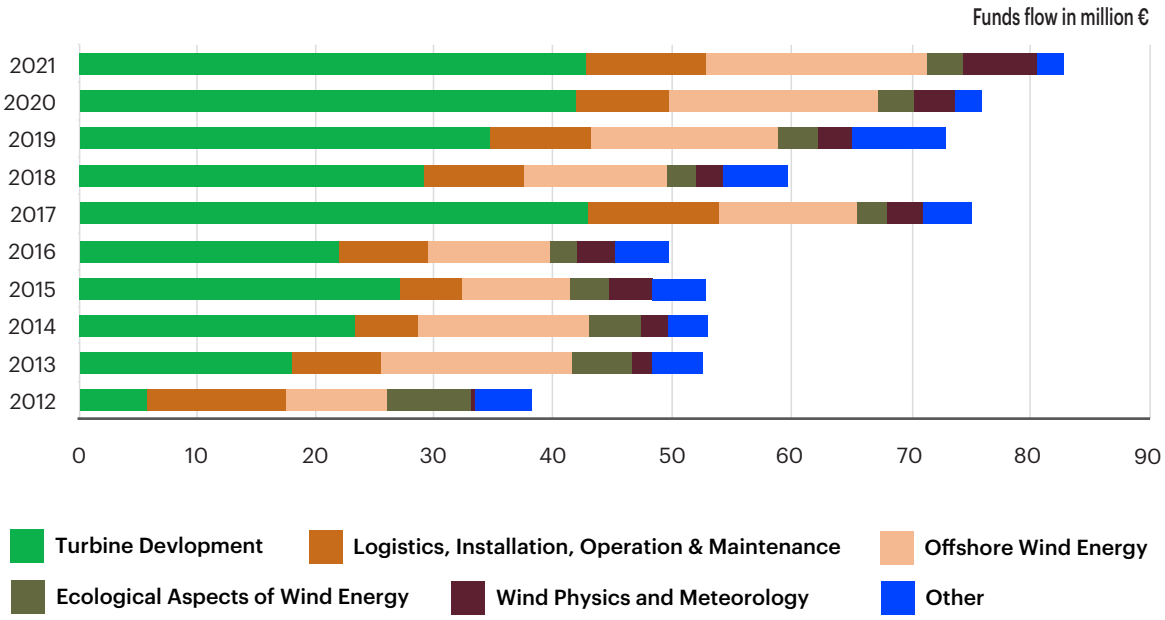

Figure 1: *Development of yearly funds flow in Germany,*
Federal Ministry for Economic Affairs and Climate Action (BMWK) [10].

1. Additionally, 103 new research projects with a new funding amount of 54.031 million EUR (61.487 million USD), including a topping-up amount of 10 million EUR (11.38 million USD) for 19 of these 103 new projects, have been approved in 2021.

National Research Initiatives and Results

- **WERAN plus**
  WERAN plus project scientists have been able to prove that a radius of between six and seven kilometers between omnidirectional radio beacons and wind turbines is sufficient for an assessment in terms of aviation safety. Moreover, the open space surrounding the radio beacons is considered particularly useful since wind turbines, just like radio signals, need an unobstructed "view" in order to be able to sufficiently harness the wind. Scientists have developed a new method – the so-called "Doppler cross bearing. " This method enables them to determine the location of potential disruptors and the intensity with which any given object is reflecting radio signals. The objects identified in this way can be localized on a map. On the basis of the measured data, a complete "clutter map" can be drawn up to make the disruptions visible. New wind energy installations can be added to the map, and it will be easier to tell how potential new installations will impact aviation safety. Also, it is possible to predict with great precision any potential disruptions to the radio signals from omnidirectional radio beacons. These new findings enable wind energy installations in the surroundings of omnidirectional radio beacons without posing a threat to aviation security. [11], [12]

- **BeBeO**
  Within the BeBeO project, the status quo for the demand-driven lighting of offshore wind farms was determined. Suitable wind farms were selected, at which the demand-driven lighting can be implemented, and a suitable system was selected, with radar or transponder-based systems available on the market. In difference from the existing systems, the project chose to use an active radar system covering multiple offshore wind farms. A suitable location for the radar was selected, and a practical test was carried out. With regard to ecological aspects, the influence of demand-driven lighting on nocturnal migrating birds was analyzed, and the feasibility of bird detection by the chosen active radar system was checked as well as how birds are attracted by the turbine lighting at night. Finally, a concept for demand-driven lighting was developed. [13]

  The above mentioned WERAN plus and BeBeO RD&D projects in Germany focus on environmental and societal issues (see also chapter Environmental Impact below).

- **SmartWeld**
  SmartWeld aims to access the lightweight potential for large scale steel structures, exemplarily for offshore jacket foundations, by application of digital tools during the

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design stage as well as innovative welding technologies. Adaptive welding process control schemes are developed, and the applicability of the control algorithms for welding scaled nodes is demonstrated under the constraint to enable a seam shape that agrees with the design found by bionic principles to reduce the stress concentration. The positive effect on the fatigue strength can be transferred into a potential reduction of necessary resources during manufacturing which is mapped onto the corresponding global warming potential by a life cycle assessment. [14]

- **InGROW**
  The project InGROW focused on repowering as an alternative to decommissioning offshore wind turbines after their designated lifetime. The project focused on the consolidation and strengthening of the existing structure to allow a new, bigger, and more efficient wind turbine to be put into operation for the following 20 to 25 years. The chosen concept is a support structure extending and strengthening existing substructures. Experimental model tests, as well as numerical simulations toward the comprehension of this hybrid structural system, have been carried out; the results and the possibility of a future certification has been examined and confirmed by a certifier. [15]

- **HBDV**
  In the HBDV project ("Dimensioning on Highly Loaded Slewing Bearings"), rotary joints were taken under investigation to be used as rotor blade bearings. A guideline that takes all relevant damage mechanisms into account has been developed to design rotor blade bearings for high loads. Hence, rotor blade bearings can be assessed safely and consistently in the future, leading to a reduction in the cost of energy. [16]

Test Facilities and Demonstration Projects

- Within the framework of the **WINSENT** project, a fully functional wind energy test site in complex mountainous terrain is constructed. The WINSENT test site offers both a virtual and a real environment, for example, as the possibility for testing new technologies and control strategies. The open platform supports the use of wind energy in complex terrain through improved prediction of performance and turbine load as well as through yield increase and load reduction. The main topics include: (i) Construction, erection, and operation of the four met masts and the two 750 kW research turbines, including measurement data collection and storage. (ii) Microclimate assessment by the characterization of the complex test site before and after the erection of the two research turbines. (iii) Adaption of the two research turbines by the processing of the geometric and structural turbine data as well as designing a new wind turbine controller. [17] The WINSENT test site will be put in operation at the end of 2022.

- In the project, **DFWind** six partners establish in close collaboration a unique research platform for wind energy. It consists of two 4.2 MW wind turbines (Enercon E-115 EP3 E4) in a downwind siting and a high-performance R&D infrastructure, including a met-mast array for

in-depth wake research. The wind turbines are funded by the Ministry for Science and Culture of the German State Lower Saxony. Based on the multi-disciplinary experience of the partners, the intended research facility shall provide a world-class basis for the comprehensive exploration and advancement of wind energy utilization. The primary research topics are control methods, condition monitoring, meteorology, acoustics, aerodynamics, aeroelasticity, support structures, geotechnics, and wind energy systems. [18]

- In the **Collaborative Research Centre 1463** by DFG (Deutsche Foschungsgemeinschaft e.V.) Several universities and research institutes work together on new structural concepts for **future offshore megastructures** since modern offshore wind turbines can provide a significant contribution to the energy transition. The collaborative will work on structures to enable turbines with over 300 meters in height and rotor diameters of more than 280 meters. [19]

Collaborative Research

- The Federal Ministry for Economic Affairs and Climate Action (BMWK) is Contracting Party in the IEA Wind TCP for Germany. In 2022, German research institutions and industry representatives are involved in 21 of 23 active research tasks (11, 25, 28, 30, 31, 37, 39, 40, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53 and 54). Task 52 is jointly led by German Operating Agents Fraunhofer Institute for Wind Energy Systems (IWES) and the University of Applied Sciences Flensburg, and Task 43 is co-led by Fraunhofer Institute for Energy Economics and Energy System Technology (IEE) together with the US NREL. Most of Germany's task participants also execute nationally funded projects on their related topics, benefitting the mutual worldwide information exchange within their IEA Wind TCP Tasks and, to some extent, between different TCPs.

Impact of Wind Energy

Environmental Impact

The federal government both supports strong nature conservation and swift wind energy deployment. Therefore, the Federal Ministry for Economic Affairs and Climate Action (BMWK) and the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) launched a key issues paper on nature compatible onshore wind energy deployment. Wind turbines shall be approved swiftly and legally watertight, ensuring European ecological standards of protection to solve the conflict of objectives between energy transition and species conservation. Permitting procedures are simplified by establishing national consistent criteria for collision risk significance assessment within the Federal Act for the Protection of Nature (Bundesnaturschutzgesetz, BNatSchG). A list of 16 protected breeding bird species will be applicable for typal mitigation measures and distance rules. The conservation status of (local) species populations is taken into account, and anti-collision risk systems play a crucial role. Furthermore, the repowering of wind turbines shall be simplified. [20]

According to the planned "Wind Energy Area Requirement Act (Windenergieflächenbedarfsgesetz, WindBG)," by 2032, 2 % of the German land area shall be available for onshore wind turbines. To achieve this, wind turbines shall be permissible within landscape conservation areas.

In 2021, the generation of around 112 TWh of wind energy led to a reduction of greenhouse gas emissions of almost 86.5 million tons of CO2-equivalent [21].

Economic Benefits and Industry Development

Investments in construction of wind power plants are on a low level compared to previous years, but slightly increasing over last year's figures: onshore 2.84 billion EUR (2.08 billion EUR in 2020), offshore 0.16 billion EUR (0.07 billion EUR in 2020). Economic stimuli from the operation of wind power plants show a constant level: onshore 2.31 billion EUR (2.3 billion EUR in 2020), offshore 0.62 billion EUR (0.6 billion EUR in 2020). [21] Nevertheless German manufacturer have proceeded in realizing novel meaningful projects.

With the completion of the Metafor project, the German turbine manufacturer Enercon surpassed the 2 GW mark in Turkey [15], while it reached the 1 GW mark in Belgium and installed its 1,000th wind energy converter in Canada [16]. In Western Europe, the company exceeded 10 GW of installed power [17].

A first Enercon E-138 EP3 E2 has been installed in South Korea. It's the first project in Asia to install this type of wind turbine. In the province of Dak Lak in Vietnam, Enercon will deliver 84 wind turbines – a combination of the E-138 EP3 E2 and the E-160 EP5 E2. With a total capacity of 400 MW, the project will be the largest onshore project in Vietnam [16]. Enercon installed an E-160 EP5 E2 prototype (5.5 MW, direct-drive permanent magnet generator, E-nacelle) at the wind energy test facility in Wieringermeer (NL). For this turbine type the installation time can be reduced by using a new blade lifting beam. Also in The Netherlands, Enercon used its Climbing Crane LCC140 for a first installation of an E-136 EP5 turbine. The climbing crane places pre-assembled tower segments on top of each other and proceeds to climb up the modular steel tower bit by bit. The LCC140 is tailor-made for the EP3 and EP5 turbines, climbs hub heights of up to 180 meters and can lift weights of up to 140 tons.

Enercon's sole shareholder Aloys Wobben Stiftung (AWS) and the utility EWE AG have launched a joint venture for the project development and operation of onshore wind energy projects, named Alterric. The AWS and the EWE each hold 50 per cent of the shares in Alterric. [22]

The company also moved into new office premises in Bangalore in the

Photo: Karl Köhler/Unsplash

southwestern Indian state of Karnataka, where it had opened another site for its research and development organization in 2020 [22]. The company started the production of generators in India for international projects. The plant near the metropolis of Bangalore is designed for a maximum production capacity of 250 generators a year. This cooperation with Coral Manufacturing Works is part of the restructuring of Enercon's global production network [24].

In turbine production, the Nordex Group manufactured a total of 1,480 turbines with a total output of 6.7 GW (2020: 1,488 turbines with 5.8 GW) and achieved sales of 5.4 billion EUR. Nordex achieved an order intake of 7.95 GW in the 2021 financial year (6.0 GW in 2020), including an order from Acciona of approx. 1 GW for Australia. By region, this splits into 58 % (Europe), 21 % (Latin America), 9 % from North America, and 12 % (rest of the world) [25]. In April 2021, the 1,000th nacelle of a Delta4000 turbine was produced in the German factory in Rostock [26].
In August 2021 the Nordex group installed the first N163/5.X turbine, a 5 MW class turbine for moderate and light-wind sites [27]. The company announced the expansion of its portfolio and launched the N163/6.X to successfully enter the 6 MW class [28]. Compared to its sister model in the 5 MW class the N163/6.X is able to produce an up to 7 per cent higher annual energy yield. It has a design lifetime of 25 years, but also comes with an extended lifetime for specific sites for up to 35 years. The turbine is designed for moderate and light-wind regions, and focuses on selected core markets in Europe. The start of series production is scheduled for early 2023 [29].

The newly established Nordex Germany GmbH is uniting its customer activities in Germany in one company. In the future, sales, project management and technical support service for Nordex wind turbines in Germany will all be handled by Nordex Germany GmbH [30].

On a much smaller level, SkySails Power announced the start of its Airborne Wind Energy Systems (AWES) series production in Seevetal, Lower Saxony [31]. The companies test site at Klixbüll in Schleswig-Holstein is also used for AWES social acceptance research.

Next Term

Wind energy continues to be central to the German Energy Transition as one of the main supporting pillars. Federal and State Governments are working on removing barriers specifically for onshore wind and on strengthening offshore deployment, backed up by a planned set of law amendments dubbed "Summer Package".

Further wind energy research on technology improvement is needed to enhance offshore wind energy cost-efficiency, also in order to provide competitive electricity for green hydrogen (aiming for 10 GW of electrolyzers by 2030) production, as well as to reach a higher share of land-based area for onshore wind energy deployment. In the near future, the Federal Ministry for Economic Affairs and Climate Action (BMWK) plans to accelerate approval and permitting procedures for new wind turbines and enhance the grid development. By 2032, 2 % of the German land area shall be available for onshore wind turbines. [9] The above-mentioned "Easter Package" of the Federal Ministry for Economic Affairs and Climate Action is paving the way towards this goal.

Germany plans to continue participating in the IEA Wind TCP, and German institutions intend to take part in prolonged and new research tasks within the next term. Germany also supports cooperation on European level.

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