



"OFFSHORE WIND TURBINES IN AN OFFSHORE WIND FARM". SOURCE: ©AGRARMOTIVE - STOCK.ADOBE

GERMANY

Wind energy plays an important role for the successful energy transition to renewable energies in Germany. In 2020 wind energy had the biggest contribution to power generation from renewables. With an amount of 131 TWh electricity from wind power has reached an all-time record (126 TWh in 2019). Special attention should be drawn to February 2020, where more than 20 TWh of wind energy power have been generated, what excels the previous record from March 2019 (15,5 TWh). [6]

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Market Development Targets and Policy

- With the amendment of the Renewable Energy Sources Act 2021 (EEG 2021) which was adopted in December 2020, renewable energy targets were updated to reach 65 % of electricity share by 2030. To

TABLE 1. KEY NATIONAL STATISTICS 2020: GERMANY

Total installed wind power capacity*	62.167 GW
Total offshore capacity	7.747 GW
New wind power capacity installed	1.650 GW
Decommissioned capacity (in 2020)	0.211 GW
Total electrical energy output from wind	130.97 TWh
Wind-generated electricity as percent of national electricity demand	23.7 %
Average national capacity factor**	24.3 %
Target (all renewable sources)	65 % (by 2030)
National wind energy R&D budget (new projects 2020)	65.32 million € (79.89 million USD)

*Installed wind power capacity: Use nameplate power ratings of the installed wind turbines. **Average National Capacity Calculation. Only include turbines in operation the whole year: (MWh production/8,760 +24 hrs) / MW installed capacity MWh total electrical production from wind turbines operating January 1 through December 31 divided by 8,760 hrs divided by the total installed wind capacity (in MW) at the beginning of the year. [You can also use an estimate based on the average installed capacity during the year: (installed 1st Jan + installed 31st Dec)/2. But in that case, state that it is how the estimate is calculated.]

achieve this, the targets for land-based wind energy are set at 71 GW by 2030 and for offshore wind energy at 20 GW by 2030 and 40 GW by 2040. The latter values correspond to the also amended Wind Sea Act (WindSeeG) in 2020. [18]

- Furthermore, Germany strives for greenhouse gas neutrality by 2045, five years earlier than originally planned, and which is backed by the national hydrogen strategy from June 2020. So-called “green hydrogen” that has been produced using renewable energy will play a key role in enhancing and completing the energy transition by being an energy storage medium or enabling sector coupling. Recently, 62 major project ideas within the IPCEI framework (Important Projects of Common European Interest) were selected by the Federal Ministry for Economic Affairs and Energy (BMWi) and the Federal Ministry of Transport and Digital Infrastructure (BMVI) to enable a hydrogen market launch and to focus on the generation and deployment of hydrogen as well as on the application of hydrogen in industry and mobility. Wind Energy plays a crucial role in scaling up green hydrogen production. [16, 17, 19]

Progress and Operational Details

- In 2020 investments and economic impact in onshore and offshore wind energy were 4.93 billion € (6.46 billion€ in 2019). While investments in land-based installations have shown an increase to 1.97 billion€ (1.48 billion € in 2019), offshore investments dropped by almost 97 % to a very low 70 million € (2.13 billion € in 2019). Meanwhile

economic benefits of 2.89 billion € (2.85 billion € in 2019) from wind energy operations stayed stable. Costs for operation and maintenance slightly decreased to 22.09 €/MWh onshore (22.64 €/MWh in 2019) and 21.98 €/MWh offshore (22.63 €/MWh in 2019). Land-based installation costs for 2020 are 1377 €/kW (1373 €/kW in 2019). [1]

- In the course of 2020, two offshore wind power projects (OWPs) were commissioned. As of 31 December 2020, a total of 27 projects are in operation and the expansion phase of the projects that were implemented before the introduction of tenders is complete, compare Figure 1.

Wind power supplied more than half of all renewably generated electricity strengthened its position as the most important renewable energy source in the German electricity mix.

- Wind energy provided almost 131 TWh (125.9 TWh in 2019) of electricity to the energy system. Land-based wind and offshore wind energy again contributed more than 52 % to the shares of renewable energy sources of gross national electricity consumption (52.17 % in 2020, 51.93 % in 2019). The capacity factors increased slightly to 22.0 % (21.9 % in 2019) onshore and 40.7 % (40.4% in 2019) offshore and are in line with the 5-year averages of 20.58 % onshore and 39.79 % offshore. [1]



FIGURE 1: "CAPACITY OF OFFSHORE WIND TURBINES IN THE GERMAN NORTH AND BALTIC SEA (END OF 2020)", GERMAN OFFSHORE WIND ENERGY FOUNDATION

Matters Affecting Growth and Work to Remove Barriers

The build-up of wind turbines in Germany has declined compared to 2016 and before. This drop has several reasons with regard to land-based and offshore wind:

- In 2017 there has been a transition towards offshore tender offers, leading to anticipatory effect in the years before this change. The last turbines of the old compensation and permitting system (until EEG 2014) were connected to the grid in 2020. The next offshore wind farms to be realized in Germany are the projects from the 2017 and 2018 transitional tenders. Seven projects are scheduled to be commissioned from 2022 to 2025. With the amendment of EEG 2021 and WindSeeG, see above, the increased offshore targets support offshore wind energy deployment and interlink grid connection in the future. [7], [22]
- For land-based wind, there has been a massive curtailment in availability of space in individual onshore regions due to regulations by the federal state administrations. Additionally, regional development plans have not been finalized in time. Lastly, other reasons for the deceleration in the wind power expansion are protection of species, air

traffic control, weather radar or military issues. To counteract these inhibiting issues there have been several resolutions by the Federal Government like shortened permission procedures for wind turbine installations or support of repowering projects. [8], [21], [23]. To support the ambitious expansion paths for new targets, higher tender volumes including financial participation of communities, cost efficiency for renewables, system and market integration as well as measures for social acceptance are important elements of EEG 2021. [18]

Record wind generation, 131 TWh, means covering nearly a quarter of Germany's gross electricity consumption in 2020.

R,D&D Activities

National R,D&D Priorities and Budget

Germany pursues a very broad R&D programme (7th Energy Research Programme), rather than focusing on a specific subject. Two of the main goals are to reduce

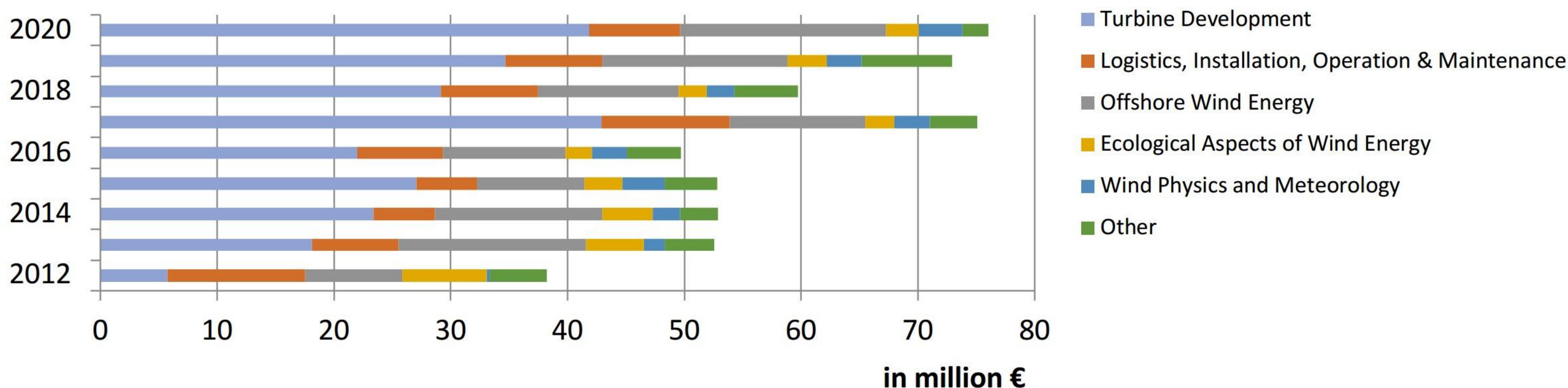


FIGURE 2: "DEVELOPMENT OF YEARLY NEW PROJECT FUNDING IN GERMANY", FEDERAL MINISTRY FOR ECONOMIC AFFAIRS AND ENERGY (BMWi)

the cost of energy and to increase turbine reliability. While onshore wind turbine design with new materials and innovative control strategies as well as precise prediction of electricity generation are subject of research and development, the challenges of offshore research is maintenance and logistic issues but also increased turbine availability to ensure cost-effective operation. The Federal Ministry for Economic Affairs and Energy BMWi has provided a funds flow of 76.06 million € to fund 488 active and ongoing research projects in the field of wind energy in 2020. Additionally, 99 new research projects with a new funding amount of 65.32 million € have been approved in 2020, see Figure 2. Another donor of subsidies for wind energy research are the federal states, who provided an additional fund's flow of 5.64 million Euros. [6]

New targets for wind: 71 GW onshore and 20 GW offshore by 2030.

National Research Initiatives and Project Results

- Besides the above-mentioned National Hydrogen Strategy, in 2020 a Lightweight Construction Technology Transfer Program was launched by the Federal Ministry for Economic Affairs and Energy (BMWi), based on a lightweight construction strategy for Germany's industrial sector. Two yearly calls are foreseen to establish lightweight construction as a future technology with approximately 70 million € of funding per year. Synergies with wind energy technology are expected. [20]
- Within the ongoing 7th Energy Research Program of the Federal Government for renewable R&D projects the following new projects started in 2020 amongst many others:

- **SeeOff**

At the end of their operational life offshore wind farms need to be decommissioned. To contribute to the transformation of the national energy system, there is a need for cost efficient and environmentally friendly decommissioning strategies. The research project SeeOff aims to support stakeholders to develop and assess efficient, project specific decommissioning strategies. Decommissioning strategies are efficient, if they are cost-minimizing, comply with legal requirements, ensure safety at work and environmental protection, and are publicly accepted. The Federal Ministry for Economic Affairs and Energy (BMWi) is funding this project with 1.27 million Euros. [9]

- **X-Wakes**

The main objective of the project X-Wakes is the assessment of the change of wind conditions for the operation of offshore wind farm clusters under large-scale offshore wind farm installation. Extensive measurements with airborne vehicles, satellites and LiDAR at various offshore locations within the German Bight. The findings on interactions of wind farm clusters, which will be investigated with large-eddy simulations in addition to the measurements, will be implemented in industry as well as in a mesoscale weather prediction model. This will allow the definition of a more realistic energy yield for future wind farm installation scenarios. The Federal Ministry for Economic Affairs and Energy (BMWi) is funding this project with 4.68 million €. [10]

- **DigMa**

The research project DigMa (Digitalization of Maintenance Information) aims to standardize and automate the acquisition, management, and communication of maintenance information in the wind industry. Uniform interfaces and consistent information flow between relevant stakeholders is ensured by technical standards. The communication

during maintenance as well as upstream and downstream business processes are in focus. The Federal Ministry for Economic Affairs and Energy (BMWi) is funding this project with 1.69 million €. [11]

- **VISSKA**

In the VISSKA project the innovative installation method “vibratory pile driving” is assessed and verified whether it can be a low-noise and sustainable alternative to impact hammering with respect to duration and underwater noise emission. Measurements are conducted during the installation of the offshore wind farm “KASKASI II” in the German North Sea. The development and validation of prediction models for installation and noise emission as well as the investigation of the reaction of harbor porpoises to continuous noise shall promote the transfer of the innovative installation method to a state-of-the-art installation method. The Federal Ministry for Economic Affairs and Energy (BMWi) is funding this project with 1.66 million €. [12]

- **InterWind**

The project InterWind aims at understanding and mitigating annoyance of residents by immissions from wind farms. To this end, the mechanisms that lead to annoyance are analyzed. Data obtained during operation of wind turbines are investigated and noise reducing operation modes identified. The focus is on low mountain ranges; specifically, the WINSENT test site and the wind farms Tegelberg and Lauterstein in the Swabian Alb are under examination. Relations between acoustic and seismic emissions and immissions as well as meteorological conditions with the annoyance of residents are looked at. The Federal Ministry for Economic Affairs and Energy (BMWi) is funding this project with 1.37 million €. [13]

Further information on renewable project highlights can be found here: <https://strom-forschung.de/en/> [14]

Collaborative Research

- The Federal Ministry for Economic Affairs and Energy (BMWi) is contracting party in the IEA Wind TCP for Germany. In 2021, German research institutions and industry representatives are involved in 18 of 23 active research tasks (11, 19, 25, 26, 28, 30, 31, 32, 36, 37, 39, 40, 42, 43, 44, 45, 46 and 47), the German participation on the new task 48 is planned. Task 32 is jointly led by German Operating Agents University of Stuttgart and 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 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 supports co-operation on European level by providing input to the SET-Plan Implementation Plan for offshore wind energy and by participating in the EU SETWind project. In addition, Germany is working to participate in the European Clean Energy Transition Partnership (CETP) and contribute to its Transition Initiatives according to the CETP Strategic Research & Innovation Agenda.

Impact of Wind Energy

Environmental Impact

- The generation of around 131 TWh of wind energy led to a reduction of greenhouse gas emissions of almost 101 million tons of CO₂-equivalent [24].
- The above mentioned VISSKA and InterWind RD&D projects in Germany focus on environmental and societal issues.

Economic Benefits and Industry Development

- NORDEX had its 35th anniversary as a company in 2020. Despite the COVID-19 pandemic Nordex could install almost 1,500 wind turbines with a combined capacity of 5.5 GW. Projects have been realized in 23 countries. Over 80 % of the 6 GW order book are based on Nordex’ Delta 4000 series. Company’s sales increased by 41.6 % to 4.65 billion € (3.28 billion € in 2019) [3]. The most frequently approved turbine type in 2020 nationwide was the Nordex N149, for which 114 construction permits were issued, followed by 100 Vestas V150 and 69 Enercon E-138 turbines [4].
- In December 2020 the Aloys Wobben Foundation (AWS), sole shareholder of the Aurich-based wind turbine manufacturer ENERCON, and the Oldenburg-based energy service provider EWE signed a corresponding shareholder and investment agreement. Each side holds 50 percent of the shares and existing wind farms and onshore projects of ENERCON and EWE. Investments with a total volume of around 4 billion € are planned up to 2030. The company named Alterric is to be headquartered in Aurich - and the plan is for the approximately 200 employees in the core markets to work decentralized at several locations. The transaction has been completed in spring 2021. Alterric will have more than 2,300 MW of installed capacity in its portfolio and a project pipeline of over 9,400 MW making it the market leader in onshore wind in Germany. The aim is to add more than 200 MW annually and to increase the installed base to up to 5 GW in 2030 [5].

- In 2020, Enercon's market share stayed at a stable 32.3 % (31.6 % in 2019), while Vestas' market share decreased to 35.1 % (43.6 % in 2019) and Nordex could grow to 15.4 % (10.1 % in 2019). The three most installed turbine types (V126, E-115, E-92) account for 26 % of all installations in 2020. In total, 29 different types of turbines were commissioned. Of the 420 new wind turbines, approximately two percent can be assigned to the power class up to 2 MW and a quarter to the 2 to 3 MW class. Half of all new turbines have power ratings between 3 and 4 MW. Turbines with more than 4 MW power capacity were installed in 22 percent of the new plants. [4]

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 onshore barriers and on strengthening offshore deployment. Especially regarding offshore wind energy, the installation targets were updated to 20 GW by 2030 and 40 GW by 2040 according to the amendment of the Wind Energy on Sea Act (Windenergie-auf-See-Gesetz). Furthermore, the amended EEG 2021 ensures a steady and in the future increasing land-based as well as offshore deployment of wind energy. To reach these targets permitting procedures shall be shortened.

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 production.

Co-operation on European level and in IEA Wind TCP is supported by Germany. German research institutes and industrial partners intend to continue the active participation in existing and new research Tasks within the next term.

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