

Status of Onshore Wind Energy Development in Germany

Year 2023



On behalf of



Power Systems

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Notes

The analysis within the scope of the Status of Onshore Wind Energy Development is based on the data of the core energy market data register (German: Marktstammdatenregister or MaStR) of the Federal Network Agency (German: Bundesnetzagentur or BNetzA) as well as on the announcements of the BNetzA regarding the tenders for onshore wind energy. The data was partially validated and corrected with regard to various details and supplemented with unrecorded dismantling and repowering properties of projects. Only wind turbines with a installed capacity of over 100 kW are included in the analysis.

The publication of the Status of Onshore Wind Energy Development takes place before the reporting deadline for commissioning in the year 2023. Further reports increasing the quantity added and decommissioned as well as permits are possible. Furthermore, changes or subsequent reporting of existing turbines to the MaStR may result in deviations from the cumulative portfolio shown.

Some of the figures in the text and illustrations are rounded values. Their addition may therefore result in slight deviations from the total values.

Photo on Title Page

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Wind Energy Development and Status

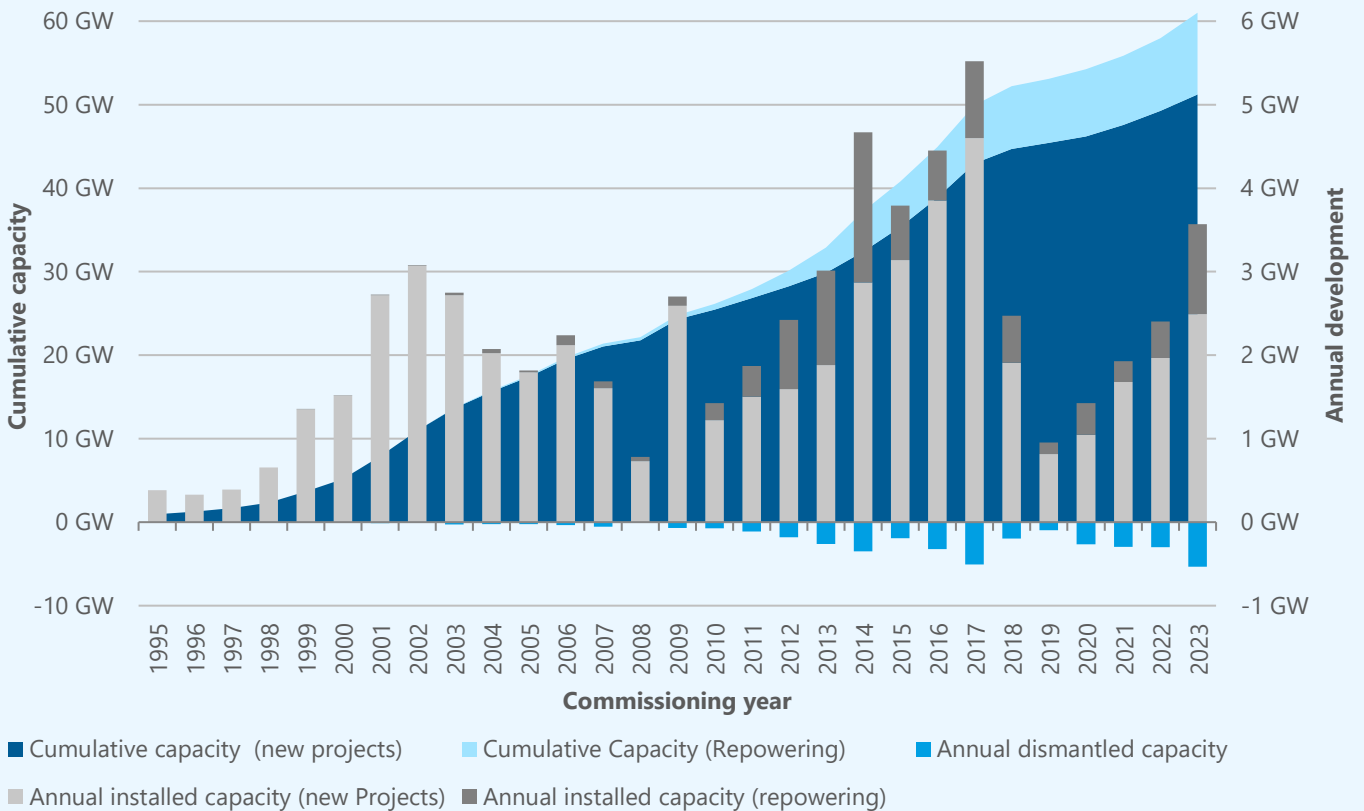
Onshore wind energy in Germany achieved an expansion of 745 new wind turbines with a total capacity of 3,567 MW in 2023. This corresponds to an increase of 48 % compared to the previous year. Of the new installed capacity, 30 % was installed as part of repowering projects.

This increase was offset by the decommissioning of 423 wind turbines with a capacity of 534 MW. The net addition resulting from the difference between additions and decommissioning thus amounts to 3,033 MW.

This results to a cumulative total of 28,677 wind turbines with a combined capacity of 61,010 MW at the end of 2023. The total installed capacity has therefore increased by 5 % over the course of the year, while the total number of turbines has only risen by 1 %.

Status of onshore wind energy development

		Capacity	Turbines
Development Year 2023	Gross installations	3,567 MW	745 WT
	Repowering share	1,076 MW	225 WT
	Decommissioning	534 MW	423 WT
	Net installations	3,033 MW	322 WT
Cumulative 2023-12-31	Cumulative	61,010 MW	28,677 WT



Annual development onshore wind energy capacity in Germany

Decommissioning, Continued Operation and Repowering

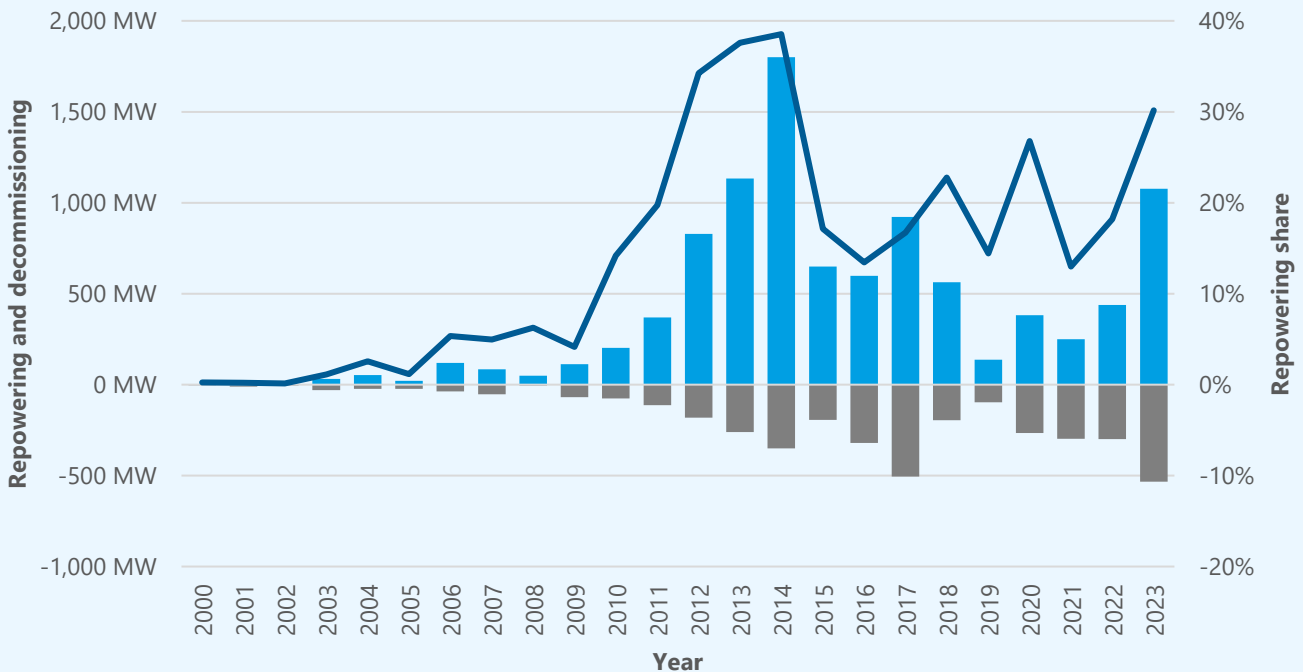
In the course of 2023, 423 wind turbines with a capacity of 534 MW were decommissioned. The majority of the decommissioned turbines were dismantled as part of repowering projects and were or will be replaced by new turbines in the coming year. In 2023, repowering plants accounted for 30 % of new installations.

The average age of these decommissioned turbines was 22 years. Most of these turbines were therefore no longer entitled to subsidies under the EEG at the time of decommissioning. 7,624 wind turbines with a total capacity of 7,807 MW that were no longer entitled to subsidies under the EEG in 2023 are still in operation. At the end of 2023, the entitlement to support under the EEG also ended for all wind turbines that were commissioned in 2003. Accordingly, the phase of unsubsidized continued operation will begin at

the start of 2024 for 1,615 wind turbines with a total capacity of 2,497 MW.

Age of dismantled and operating wind turbines

Age	Decommissioning Year 2023		Cumulative 2023-12-31	
	Capacity	Turbines	Capacity	Turbines
>20 years, no funding claim (COD ≤ 2002)	335 MW	299 WT	7,807 MW	7,624 WT
15 - 20 years (COD 2003 - 2007)	153 MW	102 WT	9,951 MW	5,787 WT
10 - 15 years (COD 2008 - 2012)	33 MW	17 WT	9,081 MW	4,322 WT
5 - 10 years (COD 2013 - 2017)	9 MW	4 WT	21,426 MW	7,699 WT
0 - 5 years (COD 2018 - 2023)	5 MW	1 WT	12,746 MW	3,245 WT
Total	534 MW	423 WT	61,010 MW	28,677 WT



■ Annual installed repowering capacity ■ Annual decommissioning — Repowering share of annual capacity installation

Development of annual decommissioning, annual installed repowering capacity and repowering share

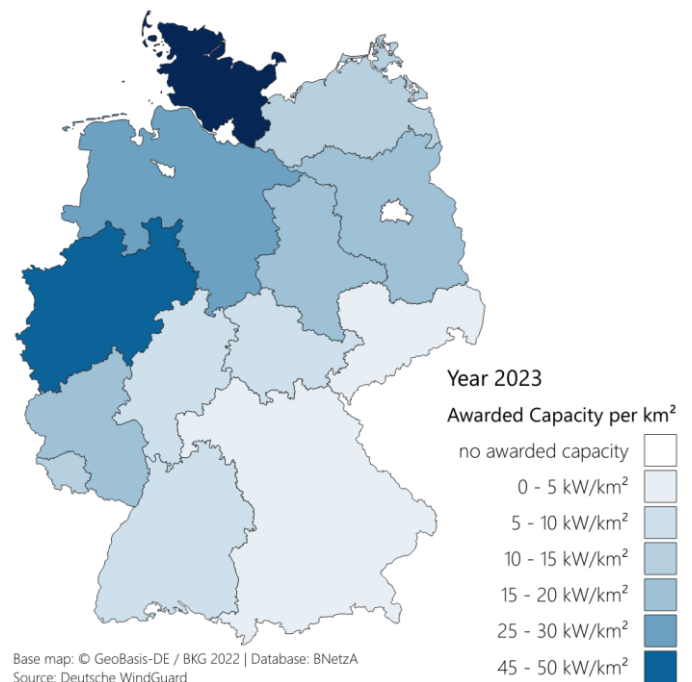
Regional Distribution of Wind Energy Installation

In 2023, Schleswig-Holstein continues to lead the comparison of new installations among the federal states. 249 wind turbines with a capacity of 1,210 MW were erected in the northernmost federal state. This corresponds to a 34 % share of total new installations in Germany.

Schleswig-Holstein's lead over the other federal states becomes particularly clear when looking at the power density per km²: in relation to the area of the state, around five times as many turbines were erected as in Lower Saxony, North Rhine-Westphalia and Brandenburg. With shares of 12 % to 18 % of total new installations in 2023, these three federal states nevertheless made a significant contribution. All other federal states installed a maximum of 5 % of the total expansion in Germany.

The installed capacity was particularly low in Bavaria, Baden-Württemberg, Thuringia and

Saxony. Berlin remains the only federal state without a new installed wind turbine in 2023.



Regional distribution of gross capacity installation

Gross installation, dismantling, net installation and repowering in German federal states

Year 2023		Gross installations			Dismantling and net installation			Repowering		
Position	Federal state	Capacity Installation	Number of new turbines	Share*	Capacity Dismantling	Number of dismantled Turbines	Net Installation	Capacity Repowering	Number of repowering turbines	Repowering-share**
1	Schleswig-Holstein	1,210 MW	249 WT	34 %	100 MW	98 WT	1,109 MW	431 MW	87 WT	36 %
2	North Rhine-Westphalia	527 MW	114 WT	15 %	118 MW	98 WT	409 MW	233 MW	52 WT	44 %
3	Brandenburg	425 MW	77 WT	12 %	28 MW	26 WT	397 MW	134 MW	23 WT	32 %
4	Lower Saxony	638 MW	131 WT	18 %	155 MW	99 WT	483 MW	120 MW	28 WT	19 %
5	Saarland	24 MW	6 WT	1 %	0 MW	0 WT	24 MW	0 MW	0 WT	0 %
6	Bremen	4 MW	1 WT	0 %	2 MW	1 WT	2 MW	0 MW	0 WT	0 %
7	Mecklenburg-Western Pomerania	184 MW	41 WT	5 %	27 MW	22 WT	157 MW	55 MW	14 WT	30 %
8	Hesse	163 MW	37 WT	5 %	0 MW	0 WT	163 MW	11 MW	2 WT	7 %
9	Rhineland-Palatinate	139 MW	33 WT	4 %	11 MW	6 WT	128 MW	17 MW	3 WT	12 %
10	Hamburg	4 MW	1 WT	0 %	0 MW	0 WT	4 MW	0 MW	0 WT	0 %
11	Saxony-Anhalt	87 MW	17 WT	2 %	75 MW	49 WT	12 MW	39 MW	7 WT	45 %
12	Saxony	47 MW	10 WT	1 %	9 MW	15 WT	37 MW	20 MW	5 WT	44 %
13	Thuringia	32 MW	6 WT	1 %	0 MW	0 WT	32 MW	12 MW	3 WT	37 %
14	Baden-Württemberg	59 MW	15 WT	2 %	6 MW	7 WT	52 MW	0 MW	0 WT	0 %
14	Bavaria	26 MW	7 WT	1 %	2 MW	2 WT	23 MW	4 MW	1 WT	16 %
	Berlin	0 MW	0 WT	0 %	0 MW	0 WT	0 MW	0 MW	0 WT	-
	Germany	3,567 MW	745 WT		534 MW	423 WT	3,033 MW	1,076 MW	225 WT	30 %

Average Turbine Configuration and Regional Differences

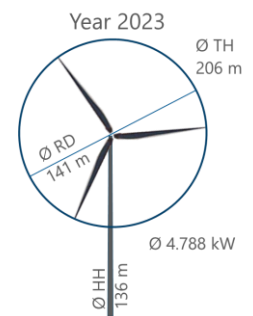
With a capacity of 4,788 kW, the average onshore wind turbine installed in Germany in 2023 is 10 % more powerful than the average turbine of the previous year. The average total height, on the other hand, has hardly changed compared to the previous year and is 206 m. On average, slightly smaller hub heights (Ø 136 m) and slightly larger rotor diameters (Ø 141 m) were installed than in the previous year.

Particularly powerful and high turbines with an average capacity of over 5 MW and a total average height of 230 m were erected in Brandenburg, Thuringia and Saxony-Anhalt in 2023. In Hamburg, Bremen, Bavaria and Baden-Württemberg, smaller generators with an average of less than 4 MW

were used. In Bremen and Hamburg, the turbines are comparatively low (178 m), in Schleswig-Holstein, too, very low turbines with an average total height of only 179 m were erected despite the higher average mean capacity (Ø 4.7 MW).

Average wind turbine configuration

Installations Year 2023	Change compared to prior year
Turbine Capacity	+10 %
Rotor Diameter	+3 %
Hub Height	-1 %
Tip Height	+0 %



Average turbine configuration of newly installed wind turbines in German federal states

Installations Year 2023	State	Number of turbines	Average configuration of newly installed turbines			
			Turbine capacity	Rotor diameter	Hub height	Tip height
	Schleswig-Holstein	249 WT	4,858 kW	138 m	110 m	179 m
	Lower Saxony	131 WT	4,871 kW	146 m	151 m	224 m
	North Rhine-Westphalia	114 WT	4,619 kW	140 m	140 m	210 m
	Brandenburg	77 WT	5,520 kW	151 m	156 m	232 m
	Mecklenburg-Western Pomerania	41 WT	4,488 kW	135 m	135 m	202 m
	Hesse	37 WT	4,403 kW	138 m	155 m	225 m
	Rhineland-Palatinate	33 WT	4,210 kW	138 m	150 m	219 m
	Saxony-Anhalt	17 WT	5,135 kW	148 m	160 m	234 m
	Baden-Württemberg	15 WT	3,900 kW	138 m	156 m	226 m
	Saxony	10 WT	4,680 kW	132 m	154 m	220 m
	Thuringia	6 WT	5,400 kW	154 m	165 m	243 m
	Bavaria	7 WT	3,643 kW	134 m	152 m	219 m
	Saarland	6 WT	4,027 kW	137 m	144 m	212 m
	Bremen	1 WT	3,600 kW	117 m	120 m	178 m
	Hamburg	1 WT	3,600 kW	117 m	120 m	178 m
	Berlin	0 WT	-	-	-	-
Germany		745 WT	4,788 kW	141 m	136 m	206 m

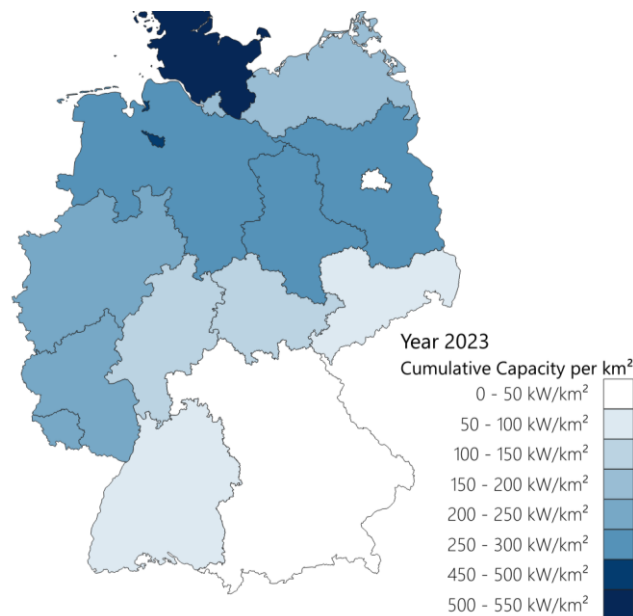
Regional Distribution of the Cumulative Portfolio

At the end of 2023, the cumulative total stock amounted to 28,677 wind turbines with 61 GW capacity. The historically existing north-south divide is further exacerbated by the continued low expansion in the south and the high expansion in Schleswig-Holstein.

Lower Saxony has the highest capacity portfolio with 12.5 GW, accounting for 21 % of total installed capacity in Germany. Brandenburg and Schleswig-Holstein each account for 14 % of total capacity, followed by North Rhine-Westphalia with 12 % and Saxony-Anhalt with 9 %.

Due to the different state sizes, Schleswig-Holstein makes the largest contribution with 541 kW/km². The small federal state of Bremen follows close behind with 483 kW/km². Brandenburg, Lower Saxony and Saxony-Anhalt have a capacity density of 250 to 300 kW/km² in relation to the state area. At less than 50 kW/km², the capacity density is

particularly low in Bavaria and Berlin as well as in Baden-Württemberg and Saxony, with values between 50 and 100 kW/km².



Base map: © GeoBasis-DE / BKG 2022 | Database: MaStR with own modifications

Regional distribution of the cumulative capacity

Cumulative capacity and number of wind turbines in the German federal states

Cumulative portfolio* (2023-12-31)				
Federal state	Cumulative capacity	Cumulative number	Share	Capacity per area
Lower Saxony	12,542 MW	6,169 WT	21 %	263 kW/km ²
Brandenburg	8,662 MW	4,039 WT	14 %	292 kW/km ²
Schleswig-Holstein	8,549 MW	3,241 WT	14 %	541 kW/km ²
North Rhine-Westphalia	7,153 MW	3,610 WT	12 %	210 kW/km ²
Saxony-Anhalt	5,331 MW	2,752 WT	9 %	261 kW/km ²
Rhineland-Palatinate	4,005 MW	1,780 WT	7 %	202 kW/km ²
Mecklenburg-Western Pomerania	3,722 MW	1,852 WT	6 %	160 kW/km ²
Bavaria	2,636 MW	1,150 WT	4 %	37 kW/km ²
Hesse	2,536 MW	1,181 WT	4 %	120 kW/km ²
Thuringia	1,830 MW	869 WT	3 %	113 kW/km ²
Baden-Württemberg	1,795 MW	782 WT	3 %	50 kW/km ²
Saxony	1,361 MW	873 WT	2 %	74 kW/km ²
Saarland	544 MW	218 WT	1 %	212 kW/km ²
Bremen	203 MW	87 WT	0 %	483 kW/km ²
Hamburg	125 MW	68 WT	0 %	166 kW/km ²
Berlin	17 MW	6 WT	0 %	19 kW/km ²
Germany	61,010 MW	28,677 WT		171 kW/km²

* with a minimum turbine capacity of > 100 kW

Results of Tender Rounds

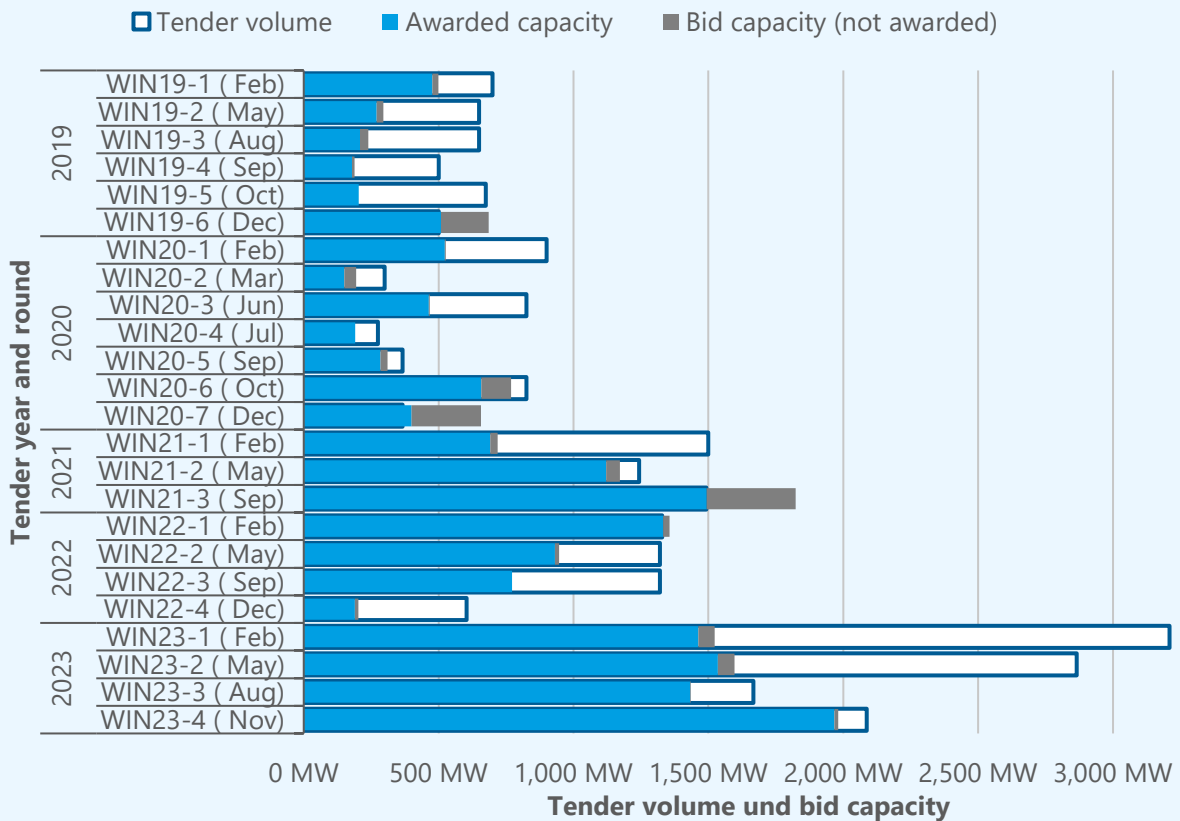
Four tender rounds for onshore wind energy were held in 2023. All four rounds were under-subscribed, meaning that the total tender volume of 9,829 MW was offset by awards with a volume of only 6,399 MW. Originally, a tender volume of 12,840 MW was planned, which was reduced in advance by the BNetzA due to an expected lack of competition. Although the desired volumes have not yet been awarded, the volume awarded in 2023 represents a doubling compared to the previous year.

The average award value across all tendering rounds in 2023 amounts to 7.33 ct/kWh and is therefore only just below the maximum value. At the end of 2023, the BNetzA announced that the maximum value of 7.35 ct/kWh will also apply for

2024. This value has applied since the increase at the end of 2022 due to significant cost increases.

Development of awarded bids of tender rounds for onshore wind energy in Germany (Database: BNetzA)

	Year	Maximum permissible value	Average capacity-weighted award value
Tender Year	2019	6.20 ct/kWh	6.14 ct/kWh
	2020	6.20 ct/kWh	6.11 ct/kWh
	2021	6.00 ct/kWh	5.88 ct/kWh
	2022	5.88 ct/kWh	5.81 ct/kWh
	2023	7.35 ct/kWh	7.33 ct/kWh

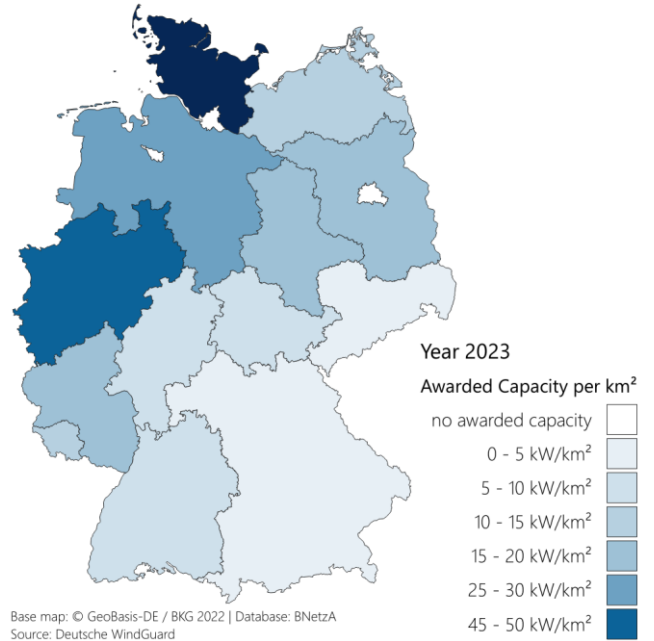


Competitive situation in tender system for onshore wind energy (Database: BNetzA)

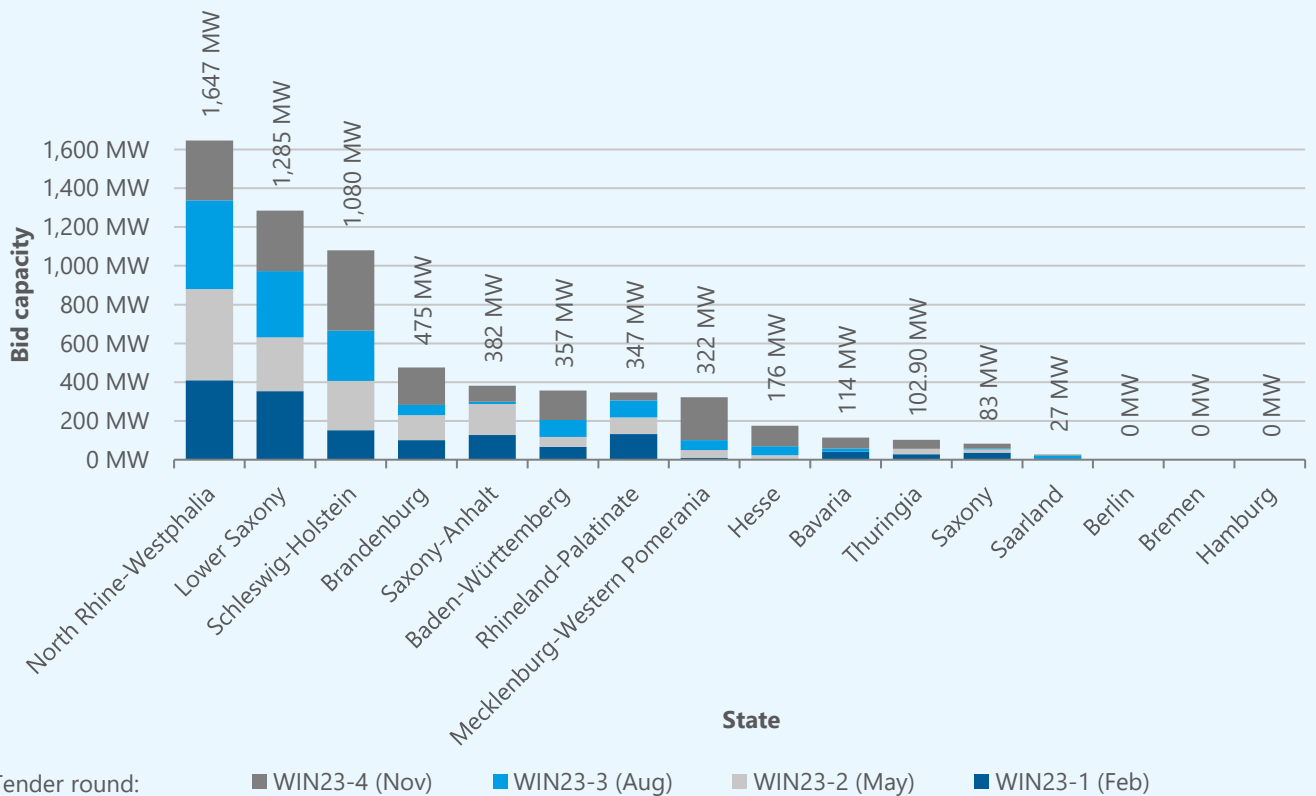
Regional Distribution of Awarded Bids

North Rhine-Westphalia (26 %), Lower Saxony (20 %) and Schleswig-Holstein (17 %) accounted for the largest shares of the award volume in 2023. The volume awarded by the other federal states is significantly lower than these frontrunners. Brandenburg, Saxony-Anhalt, Baden-Württemberg, Rhineland-Palatinate and Mecklenburg-Western Pomerania achieved award volumes of 300 to just under 500 MW. All other federal states achieved new awards of less than 200 MW. Despite their small shares of the total volume, all federal states, with the exception of Hesse, Saarland and the city states, were able to increase the volume awarded compared to the previous year.

In a comparison of the federal states, the volume in relation to the state area is particularly low in Bavaria, Saxony, Thuringia, Hesse and Baden-Württemberg. As in previous years, Schleswig-Holstein achieved the highest volume of surcharges in relation to land area.



Regional distribution of awarded capacity across the federal states (Database: BNetzA)



Regional distribution of awarded capacity across the German federal states (Database: BNetzA)

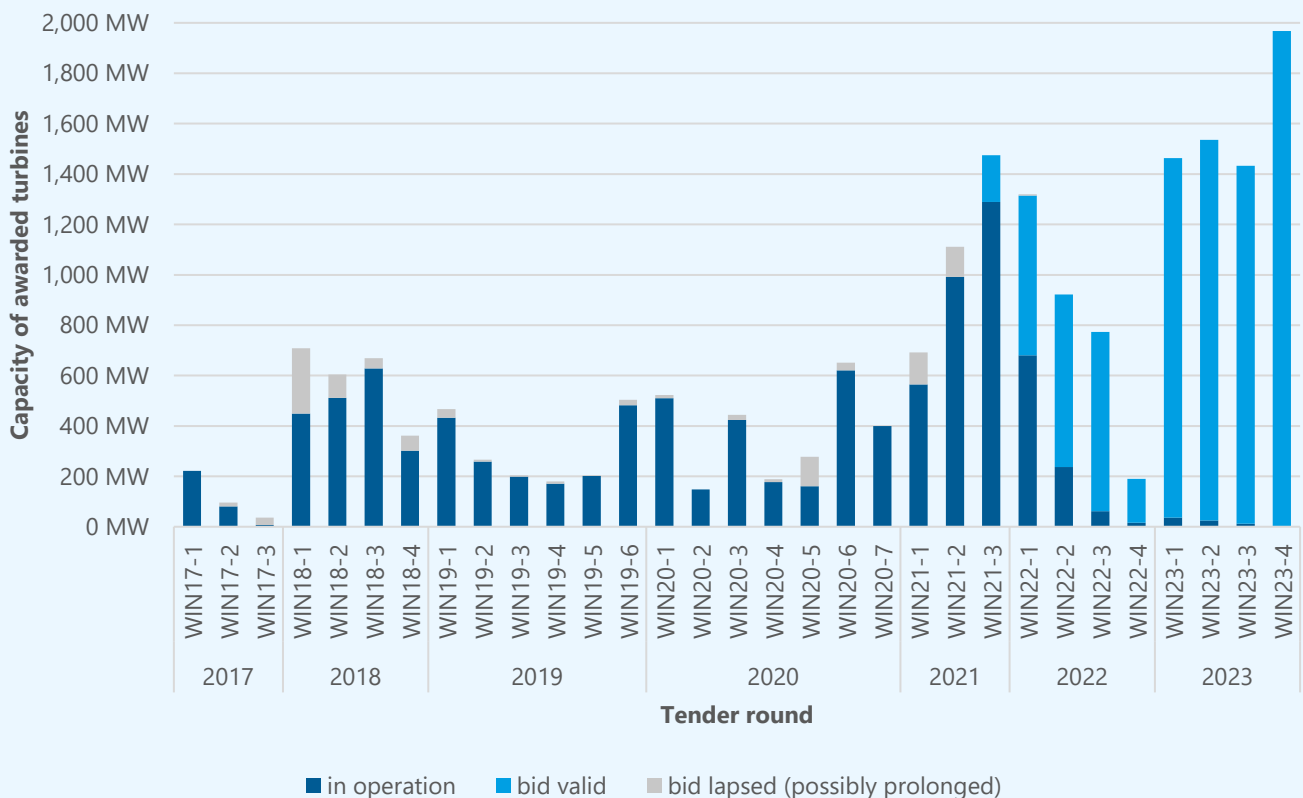
Development Status of Awarded Turbines

Of the 22.6 GW of wind energy capacity awarded since the introduction of tenders, 8.8 GW have been realized to date. The regular realization period for awards of 3.6 GW from the tendering rounds, which were carried out until mid-2021, has expired. These awards have either expired or have applied for an extension of the realization period. In 2017, a year dominated by awards for unapproved wind turbines, the realization rate was only 11 %. It has risen significantly since then. For the 2018 award year, it was 81 %, and in 2019 and 2020, realization rates reached over 90 %. The implementation period for many awards from 2021 is still running, with an implementation rate of 86 % achieved by the end of 2023. At 29 %, the realization of the 2022 awards is within the usual range for awards from the previous year. The first turbines from the 2023 awards have also already gone into operation.

Realized capacity* of tenders for onshore wind energy in Germany

	Year	Realized capacity	Realization rate
Year of tender	2017	310 MW	11 %
	2018	1,890 MW	81 %
	2019	1,744 MW	94 %
	2020	2,440 MW	91 %
	2021	2,846 MW	86 %
	2022	996 MW	31 %
	2023	75 MW	1 %

* The evaluations represent an assessment of the development status based on an analysis of the MaStR and the awards issued by BNetzA. Deviations from actually allocated awards are possible. It was assumed that the award volume corresponds to the permitted/installed capacity.



Development status* of awarded capacity (Database: BNetzA, MaStR, own research and assumptions)

Permitted Capacity and Future Tender Rounds

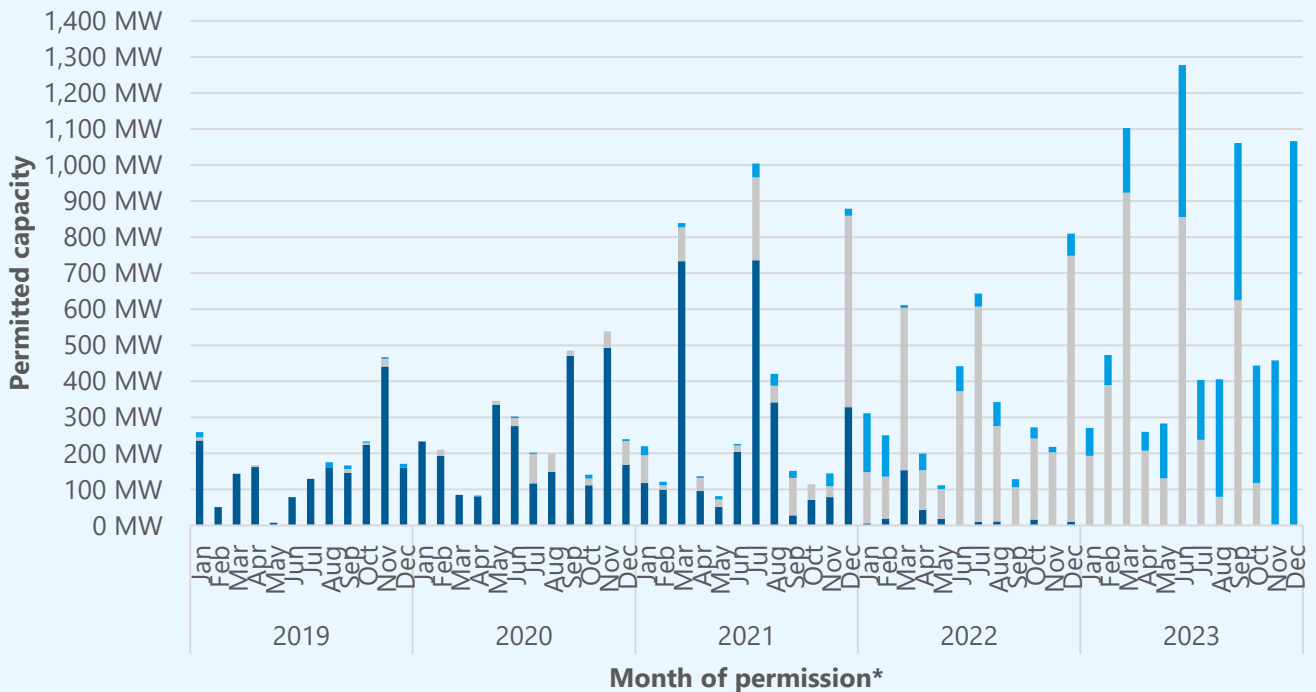
In 2023, 1,382 new wind turbines were approved, with a combined capacity of 7,504 MW. Compared to the previous year, this represents an increase of 73 % in approved capacity.

Half of the newly approved turbines have already been awarded a subsidy under the EEG in the course of the year. Permits issued in November and December 2023 have not yet had the opportunity to participate in a tender. Some installations with older permits will not participate in a tender for the time being, for reasons such as long implementation times (e.g. due to supply chain problems or re-approval procedures) or otherwise justified funding claims (pilot or

community wind installations). Around 10 % of the permits issued in 2021 and 2022 have not yet been awarded.

Annual permitted capacity

	Year	Permitted capacity	Permitted wind turbines
Year of permission	2019	2,053 MW	513 WT
	2020	3,067 MW	691 WT
	2021	4,337 MW	897 WT
	2022	4,341 MW	855 WT
	2023	7,504 MW	1,382 WT



■ in operation ■ awarded in tender ■ not awarded yet

* Permits with an updated permit date have been dated back to the date of the first registration in MaStR.

Monthly permitted capacity including status

Expected Development and Political Target

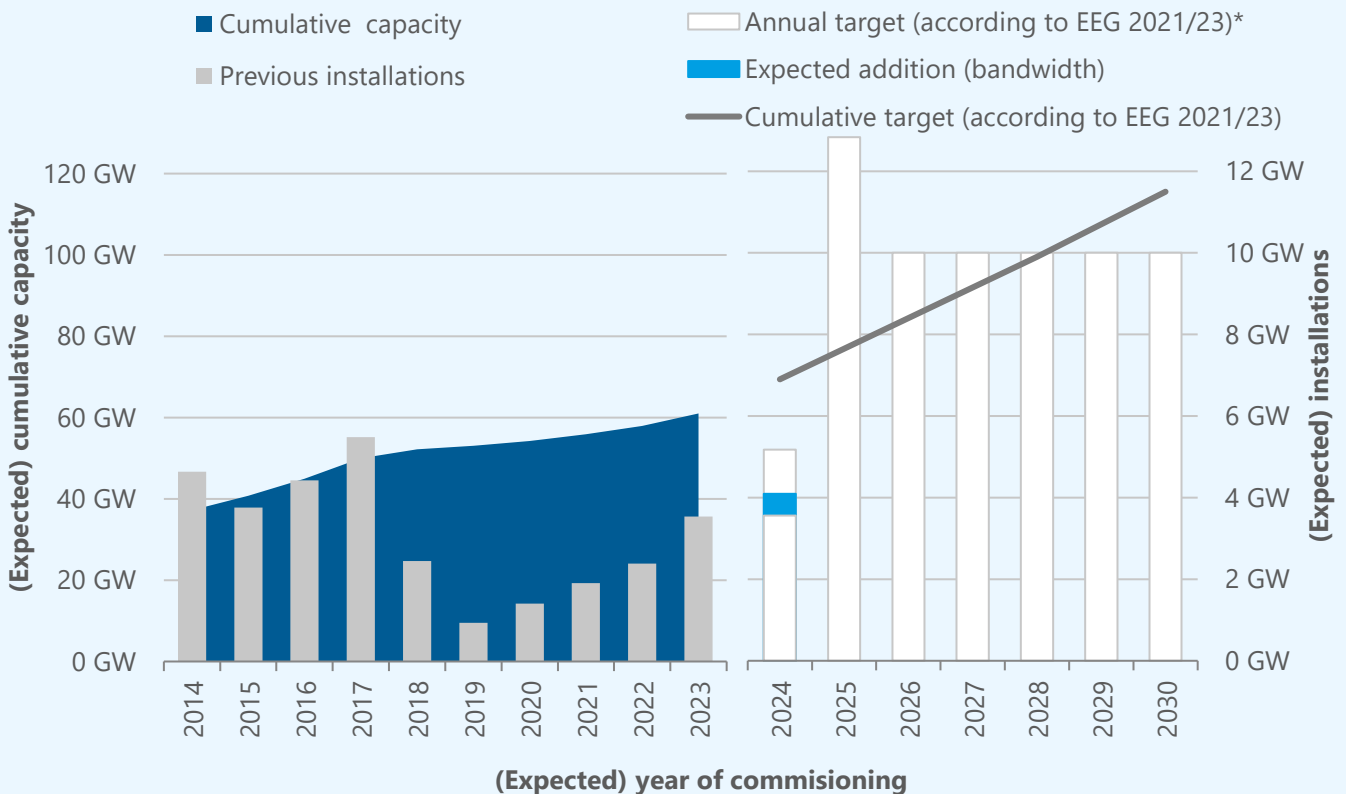
The EEG 2023 sets out the targeted expansion path for onshore wind energy. In 2024, for example, 69 GW of installed capacity is to be achieved. At the end of 2023, the cumulative stock is around 61 GW, meaning that a net addition of 8 GW will be required in 2024 to achieve the target. A total stock of 115 GW is to be reached as early as 2030.

The tendering volumes defined in the EEG specify the annual gross additions required to achieve the target in order to compensate for the expected decommissioning. If the tendering rounds continue to be significantly undersubscribed, the targets will not be achieved.

Due to the awards for wind turbines in previous years, an expansion of 3.6 to 4.1 GW is expected

in 2024 - assuming the same speed of realization and comparable realization rates as in previous years. As a result of the significant reduction in tendering volumes and the undersubscription of the tendering rounds in 2023, it can be assumed that expansion in 2025 will fall well short of the target.

The EEG contains provisions that allow quantities not awarded in the previous year to be carried over to subsequent rounds. However, these can only take effect from spring 2024 if corresponding approval volumes are available and increased competition is expected.



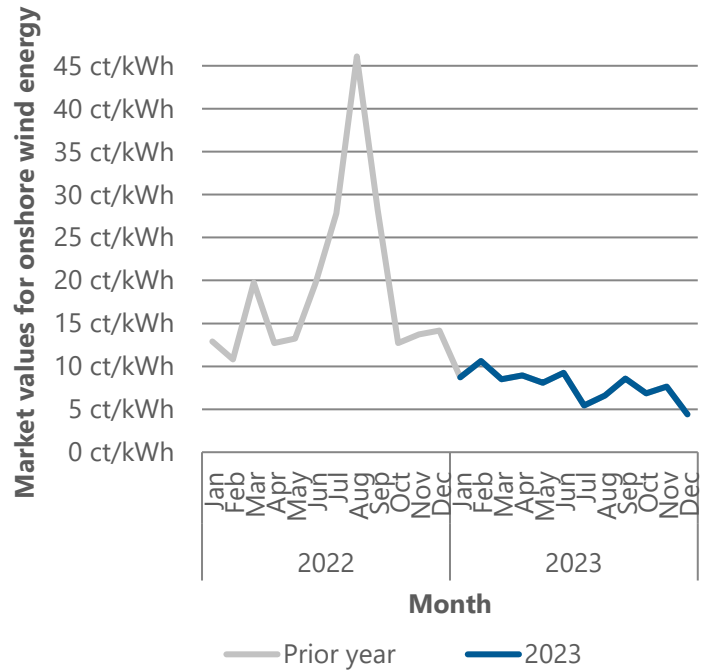
Expected installations in 2024 and political targets according to EEG 2021/23

*The expansion target of the EEG was derived from the planned tender volumes in the year before the previous year.

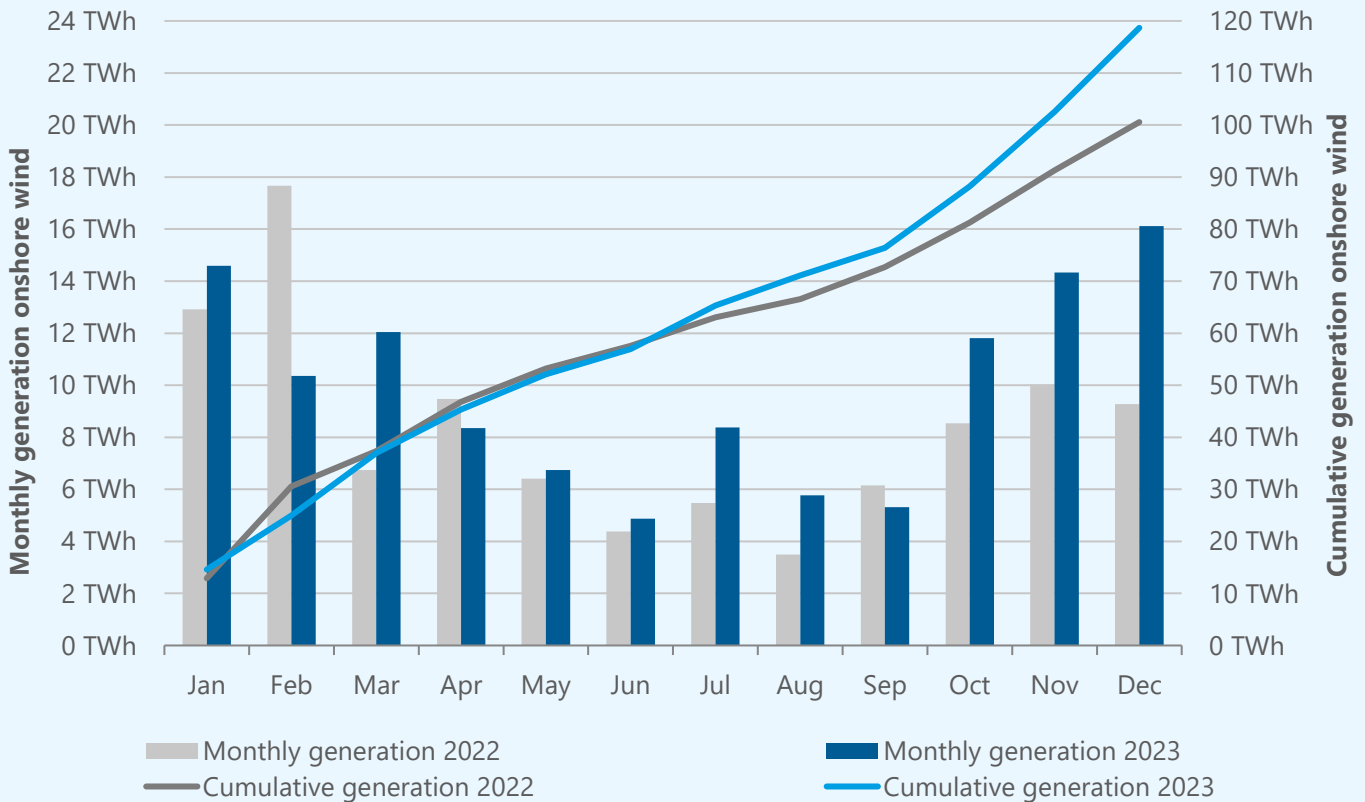
Power Generation and Market Values

The onshore wind energy turbines installed in Germany generated almost 119 TWh in 2023. This corresponds to an increase of 18 % compared to the previous year. In the fourth quarter in particular, electricity generation from wind turbines was significantly higher than in 2022. With a share of 26.5 % of total generation, onshore wind energy is the most important energy source in Germany.

The market value of onshore wind energy fell significantly following the record values recorded in 2022. A continuing downward trend was observed over the course of 2023, with the volume-weighted annual average at 7.62 ct/kWh. In December 2023, the price fell below 5 ct/kWh for the first time since spring 2021.



Monthly market values for onshore wind energy (Database: Netztransparenz)



Power generation onshore wind (Database: Bundesnetzagentur | SMARD.de)

About Deutsche WindGuard

In the complex energy market, Deutsche WindGuard is committed to providing unbiased, manufacturer-independent consulting and comprehensive scientific, technical and operational services. The broad portfolio creates extensive synergy effects: Whether due diligence, market analysis, contract consulting or feasibility studies – each of them contains expertise and know-how of the entire WindGuard group. Deutsche WindGuard has been publishing the semi-annual statistics on wind energy development since 2012.

About Bundesverband Windenergie e.V. [German Wind Energy Association (BWE)]

BWE, a member of Bundesverband Erneuerbare Energie [German Renewable Energy Federation (BEE)] with more than 20,000 members, represents the entire wind industry in Germany. Members of BWE range from industry suppliers in the fields of mechanical engineering and manufacturing over project developers to legal experts, the financial sector, electricity traders, network operators, energy suppliers, and companies specialized in logistics, construction, service/maintenance, and storage technologies. Its broad membership makes of BWE the primary point of contact for politics, business, science, and the media in all matters linked to wind energy.

About VDMA Power Systems

VDMA Power Systems is the association of the energy plant manufacturers. It represents the interests of manufacturers of wind energy and hydropower plants, fuel cells, thermal plants and storage systems in Germany and abroad. For them, VDMA Power Systems serves as an information and communication platform for all industry topics such as energy policy, legislation, market analyses, trade fairs, standardisation as well as press and public relations. VDMA Power Systems is a trade association within the German Engineering Federation VDMA e.V.