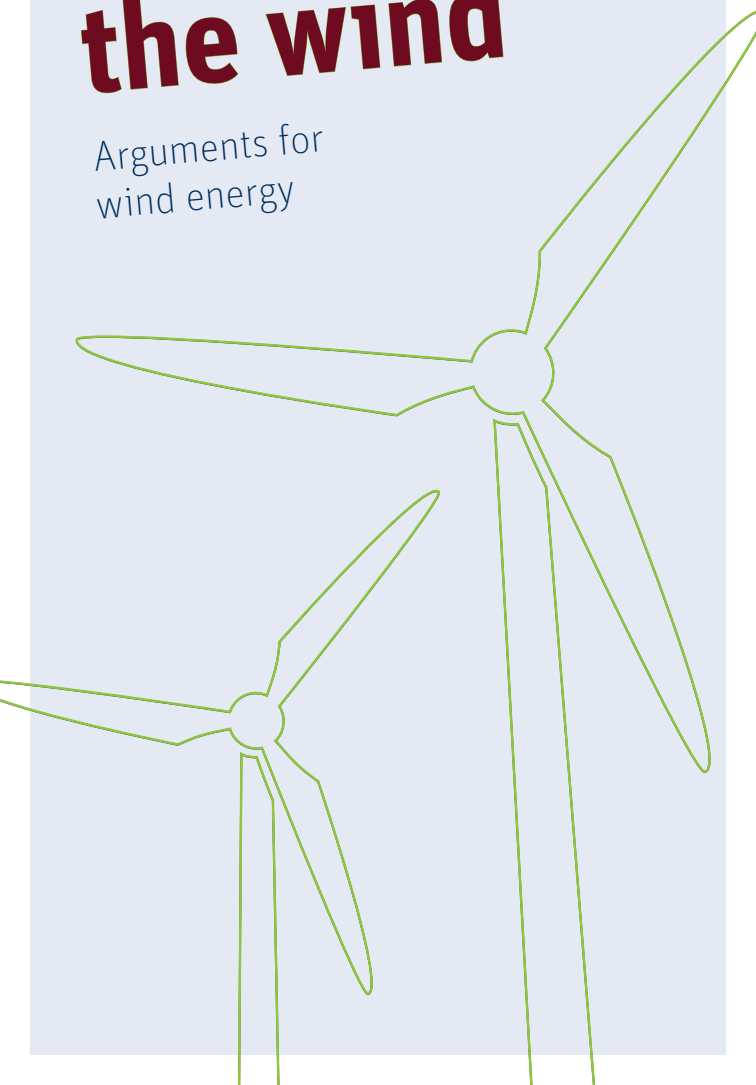
9th, fully revised Edition

Driven by the wind

Arguments for wind energy



Why wind energy is needed

Our answers to important questions surrounding wind energy

Owerview:

Sources

Wind drives
the energy transition

23.1%
wind energy =
most important source of electricity in Germany

Wind has driven people for centuries. In the past, it helped us to cross oceans, mill grain and drain land. Today it plays a key role in the transition towards environmentally and climate-friendly power supply. Almost 40 years ago, Germany's first wind farm was connected to the grid, when it supplied around 400 households with clean electricity.[1] Initially, the new technology was dismissed. As late as 1993, German electricity suppliers wrote in an advertisement: “In the long term, renewable energies such as solar, water or wind will not be able to cover more than 4 per cent of our electricity needs.” Even the former chancellor Angela Merkel adopted this claim when she became environmental minister in 1997.[2] Political changes and the vehement demand of many citizens for a sustainable and decentralised energy system made a difference. The approximately 30,000 wind turbines in Germany now generate up to 130 billion kilowatt hours (kWh) annually[3], enough for 43 million households. This corresponds to 25,5 per cent of Germany's net electricity generation. Wind energy is thus Germany's most important source of electricity and produces more electricity than nuclear power or coal.[4]

Today, Germany's largest inter-generational project, the energy transition, is facing a new stage of development: Digitisation and decentralisation as well as greater networking through blockchain technologies will be the next innovation drivers in the new energy industry. Consumers are increasingly becoming producers and are revolutionising the electricity market. Driven by the idea of a holistic energy transition, renewables will take up a greater share of transport and heating.

Germany stands behind the energy transition and climate protection targets. 87 per cent of the people in Germany welcome the expansion of renewable energies.[5] Nevertheless, heated debates are being held in many places, particularly on the expansion of wind energy. This brochure aims to accompany the discussions in the country with honest, straightforward and level arguments.

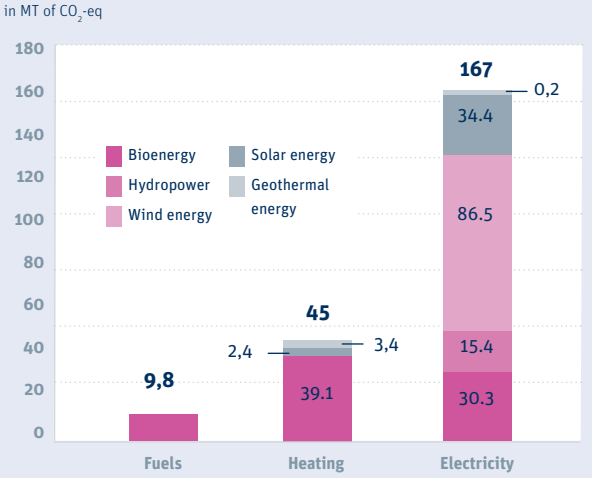
Wind energy promotes **climate protection**

The Earth's climate is constantly changing due to natural meteorological factors. But the speed at which this has happened in recent years has increased unnaturally. The drought in many regions of Europe in summer of 2022 is just another example. Humanity has contributed to accelerated global warming[6] through the depletion of the Earth's resources, ongoing deforestation and, above all, the emission of greenhouse gases – with dramatic consequences.

Alongside energy-saving measures, renewable energies are the most important means of combating climate change: in 2021 alone, 221 million tonnes of greenhouse gas emissions were saved through the use of renewable energies. Wind energy prevented around 87 million tonnes of CO2 equivalents in 2021.[7]

But there is still a long way to go before the necessary climate protection targets are achieved. Despite all the goals and declarations Germany is in danger of not achieving its commitment to the EU regarding the expansion of renewables.[8] Among other things, faster permitting and more designated land are needed to close the gap.

Prevented greenhouse gas emissions due to the use of renewable energies in Germany 2021



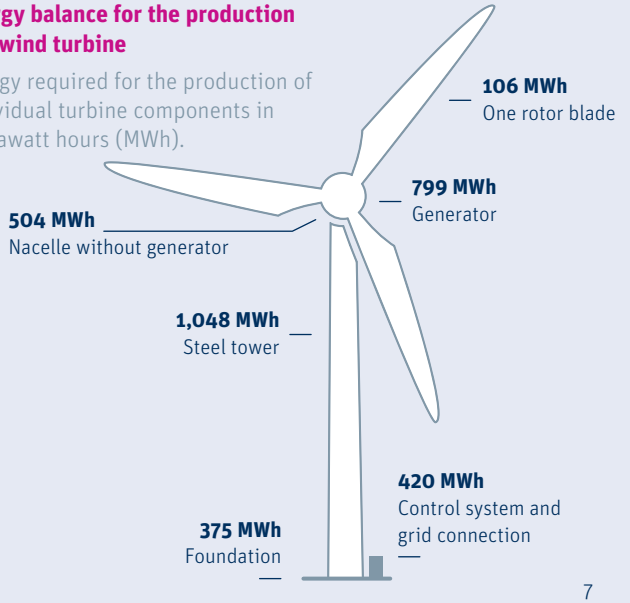
Wind turbines have excellent **life-cycle assesment results**

Wind turbines produce clean electricity, but energy also has to be produced for their production, operation and disposal. So at what point are these quantities of energy recovered? To find the answer, we need to look at the “energy amortisation”. Modern turbines can pay for themselves in terms of energy in a few months at most.[9] In other words, the energy consumed for production, operation and disposal of the turbine is easily balanced out by the electricity it produces.

Of course, energy amortisation always depends on the turbine's capacity and height, as well as its location. But even as capacities increase, the net energy and financial return times of a few months remain impressively low. What is more, a wind turbine can generate up to 70 times as much energy during its 20-year lifetime as is required for its production, operation and disposal. This increases to 90 times more energy if the recycling of materials is included in the life-cycle assessment (more on the subject of recycling on page 30). The figure[10] shows an example of the average amount of energy used to manufacture a wind turbine and how this is distributed among the individual components.

Energy balance for the production of a wind turbine

Energy required for the production of individual turbine components in megawatt hours (MWh).



The impact on nature and the environment **is low**

As with any other construction project, the planning and approval process for the construction of wind turbines ensures that the impact on nature conservation, species protection and the landscape is kept to a minimum. In addition, wind farm planners help to minimise or even fully offset any resulting damage to nature and the environment through so-called “compensation measures”, e.g. by investing in reforestation or creating feeding habitats for bird species[11] (more on the subject of species protection on page 34).

The areas in which wind turbines are installed can continue to be used for agriculture or forestry. The turbines can also be dismantled and almost completely recycled at the end of their operating life without any ensuing damage. Large parts of the turbines can be recycled in industrial processes and used in road construction or the cement industry, for example. The German Wind Energy Association (BWE) also supports the complete removal of the foundations. Modern turbines have special blast holes in the foundations to make crushing and removal much easier. In addition, transformer stations and switching systems are dismantled and the cables removed from the ground. This means that the plot can be returned to its original condition after the wind farm is no longer in use. The obligations for removal are usually stipulated before the start of construction.[12] In some federal states, the costs must be covered by a guarantee at the start of the project.

Just how environmentally friendly wind energy is, becomes particularly clear when we compare it to opencast lignite mining, where entire villages have to be relocated and the landscape undergoes permanent change and remains uninhabitable for a long time.[13] Renaturation measures are also implemented after a coal-fired power plant is dismantled, but in these exploited areas, water pollution, mining damage and the loss of biological diversity often occur.[14]

Ground penetration depth: Lignite mining and wind energy compared

Excavation: Up to 500 m

Foundation: Up to 3 m

The **costs** to society **are minimal**

The generation of electricity from fossil and nuclear sources incurs enormous costs to society,[15] which are not included in the electricity price and are therefore not immediately apparent to citizens. These forms of conventional electricity generation are associated with high costs for final disposal, environmental impact and damage to health. These are referred to as “external costs”.

Here is one example. Nuclear waste from nuclear power plants must be stored in a radiation-safe manner for one million years. The German state is responsible for the interim and final disposal in the form of a state fund of 24 billion euros established in 2016. 169 billion euros is needed in the long term to have a suitable final disposal site ready for operation by the turn of the century.[16] In the future, the companies will pay for the decommissioning and demolition of their nuclear power plants. However, for years, they have been able to invoice billions of euros from electricity customers and, in accordance with statutory provisions, record these amounts as reserves in their balance sheets, with enormous tax advantages.[17]

In the energy sector, further external costs are generated by the emission of pollutants, which in turn damage human and animal health and natural ecosystems. The mining of primary raw materials such as coal also has a lasting impact on nature. Studies estimate the follow-up costs worldwide for coal-based electricity at around 5 trillion US dollars. That's about 4,219,943,000,000 euros.[18]

When these overall societal costs are taken into account, wind energy has been the cheapest source of electricity for several years now. But even without including them, wind energy and other renewable energies that incur significantly lower societal costs are competitive from a price point of view.[19] The supply of wind is endless, and research and further development will lead to efficiency gains for new wind turbines.

The price of CO_2 emissions is far lower than the actual costs of the consequences of climate change

Price for CO_2 certificate according to ETS in euros/tonne of $CO2_2$

ETS certificate price[20] in 2021

Adequate entry price with incentive effect

Costs including the consequences of climate change

Wind energy drives the labour market

Wind energy is creating jobs in Germany as an important industrial centre. In 2016, around 130,000 people were employed directly or indirectly in the wind industry across all German federal states – including engineers, technicians, mechanics, planners and logistics specialists.[21] Wind energy has thus become an indispensable employer from Bavaria to Schleswig-Holstein. As many as 1.3 million people worldwide work in the wind energy sector.[22]

The occupational fields of employees in the wind energy industry are diverse. The areas of production and construction, as well as maintenance and operation offer numerous training opportunities for young people and those changing careers. 234 courses of study focusing on renewable energies were on offer at universities and colleges in Germany in 2018.[23]

All federal states benefit from this. Even those that clearly need to catch up in expanding their renewable capacities are in a strong position in terms of suppliers, covering fields such as mechanical and turbine engineering, electrical engineering and the IT industry. Although final production by turbine manufacturers mainly takes place in the north, the supplier industry is distributed nationwide with a focus on North Rhine-Westphalia, Baden-Wurttemberg and Bavaria. But there are also many companies in eastern Germany that are important suppliers to the wind industry.

Due to these positive trends, it is all the more important that the industry obtains politically reliable framework conditions. The legislature should therefore enable investment and planning security by removing barriers and enabling the rapid expansion of renewables.

5.

Wind energy **strengthens rural areas**

In times when large, conventional power plants were used, the revenues from energy production were centred in individual, economically strong regions. Other regions were unable to benefit from this. The use of decentralised wind energy is helping to increase the standing of these often economically underdeveloped and rural regions.[24]

Unlike conventional energy, wind power is generated in many different locations throughout Germany. This regional distribution strengthens value creation across Germany. There are various reasons for this. Firstly, jobs are created in the construction and operation of wind turbines. Secondly, in the case of public wind farms, contracts for road construction, foundations or services are often awarded to companies in the region. Finally, regional distribution provides a boost for landowners, mostly farmers, for whom the construction of wind turbines is a secure secondary means of income. They can also cultivate their fields after construction and while the turbines are in operation.

Local residents are also involved in nearly every second wind farm in Germany through citizens' energy projects. Income from leasing also usually remains in the regions and strengthens local purchasing power. Since 2009, 70 percent of trade tax has been paid to the local municipality in which the turbine is located, and 30 percent to the municipality in which the headquarters of the operating company is located.[25] The districts directly adjacent to the wind farms can also receive financial support, e.g. through the establishment of development associations or foundations. This has been mandatory in Mecklenburg-Western Pomerania since 2016 and could soon become standard nationwide. In May 2022, the Federal Constitutional Court gave the green light for mandatory participation.[26] Especially in structurally weak regions, these are important revenues that flow into, for example, the expansion of broadband networks, public road construction or investments in kindergartens.

Tourism can also be boosted; some municipalities that have completely converted their energy supply to renewable energies use the positive image of green wind energy as a tourist attraction (more about wind energy and tourism on page 39).

6.

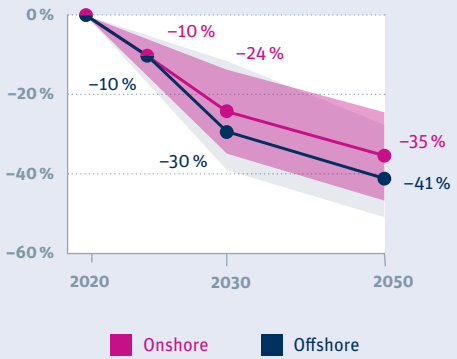
Wind power is becoming **increasingly affordable**

Electricity from wind turbines guarantees stable, low electricity prices for the long term. In 1980, one turbine was able to supply around 10 households, but today, depending on the location, it can supply up to 4000 households.[27] Wind turbines already produce less expensive electricity than newly built fossil-fuel power plants. Taking external costs into account, wind energy has been the cheapest energy source available for years.[28]

The electricity generation costs for onshore wind energy are already on a global average of only 41 US-dollar per megawatt hour and thus on a par with conventional forms of electricity generation. And it is assumed that these will continue to fall, thanks to increased competition, investments in research and development and progress in digitisation. In the area of offshore wind energy the electricity generation costs could fall by 66 percent until 2050.[29]

Conventional fuels, on the other hand, are finite and are gradually running out. This potentially increases the prices for electricity from non-renewable energy sources. Modern calculations are also able to quantify the social costs for atmosphere, environment and health for each energy source. If such calculations were used as a basis for price comparisons, the cost advantage of wind energy would increase even more significantly.

Development of the electricity generation costs of wind energy



Wind energy makes Germany **less dependent on raw material imports**

Conventional power plants require energy sources to produce electricity – raw materials such as lignite, uranium, crude oil or natural gas. For many years, Germany's energy supply depended on external suppliers of those raw materials: In 2021, 98 per cent of crude oil and about 94 per cent of the natural gas required in Germany came from imports.[30] The largest share comes from Russia, a state with which the German government no longer wants to cooperate, not only with regard to energy supplies, at the latest since the invasion of Ukraine. The list of other suppliers reads only slightly better, as among them are regions in North Africa or Central Asia with high conflict potential.[31] Military conflicts and foreign policy decisions can lead to shortages of raw materials, as Germany is experiencing at the moment. Since the invasion of Ukraine, there is a broad consensus in that it is of great importance to reduce fossil dependencies in the future.

Wind as a resource does not have to be extracted or imported. Every megawatt hour of electricity generated with wind energy makes Germany less dependent other countries. And what's more, wind turbines are manufactured, installed and maintained in Germany, meaning that the wind industry in Germany creates added value. With imported energy sources, this added value stays in the country of origin. If this potential were also used for the mobility and heating sectors the need for imports could be even further reduced. As the German finance minister, Christian Lindner, calls it: “Renewable energies are freedom energies”.[32]

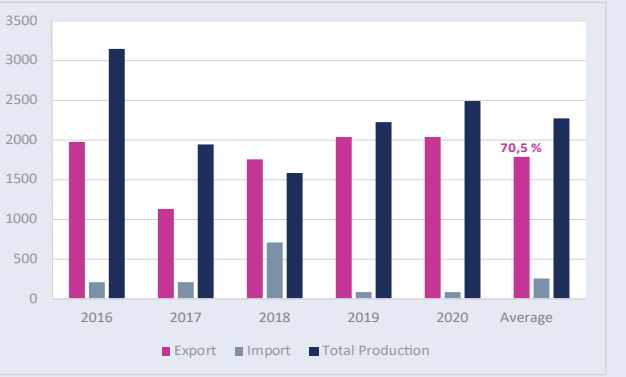
Wind turbines from Germany are a **top export**

In a global comparison, German manufacturers and suppliers occupy a leading position in the expansion of wind energy. The reasons for this are years of operational experience and targeted research and development work, which allow German companies to build more efficient and more powerful wind turbines. They are able to optimise their products during operation and thoroughly test innovations for practical suitability.

Germany was the world's second largest exporter of wind turbines in 2019, just behind Denmark.[33] By comparison, the German automotive industry only account for around 12 per cent of the global market in 2021.[34] The offshore wind industry has succeeded in exporting not only turbines but also technology for foundations and grid infrastructure. The expertise and advice of German experts – from project planners and wind consultants to maintenance contractors – are also in demand worldwide. The largest markets for wind energy in the world are China and the United States, who account for 75 per cent of the new wind turbine installations in 2020.[35]

In view of the significant sales and export figures resulting from a strong domestic market, it is all the more important that this added value is kept in the country. In particular, the market outlook for the early 2020s presents risks for companies. All market participants, whether project developers, manufacturers or suppliers, need sufficient opportunity to exist and operate adequately in the German tender system. Developments across Europe will be crucial for them.

Production and trade of wind turbines (in million euros)



Wind moves people

Almost 9 out of 10 Germans welcome the further expansion of renewable energies (86 per cent). 56 per cent of residents think that having wind turbines in the vicinity of their own home is “good” or “very good”. These are the results of a YouGov survey commissioned by the Agency for Renewable Energies.[36]

But when the energy transition comes to your own door, you want to know more about it and ask more critical questions. In this respect, there is no difference between wind turbines and new roads, new railway stations or even the establishment of national parks. In recent years, scientists have repeatedly investigated what needs to happen so that at least the majority of people in the area become supporters of a new wind farm. The answer is clear: They want to be kept fully informed from an early stage. But a “text-book approach” by politicians and planners is of little help, because the expectations of people in the communities near the planned wind farms can be very different. Often the distance to a wind farm is not the most important factor for acceptance or rejection by local residents.[37] It is the organisation of the design or planning process that is decisive. The planning authorities must make the procedure transparent and explain how these areas were selected according to a range of criteria, such as settlement structure, nature conservation and landscape. People who, for example, are co-owners of wind turbines or who receive regional electricity at reduced prices naturally no longer perceive such systems as disruptive to the same extent.

Citizens **benefit** from wind farms

There is a diverse range of operating structures for German wind farms – from private individuals, commercial enterprises and energy suppliers, to cooperatives and legal company forms like limited companies. For many years, citizens have been involved in almost every second wind energy project in Germany, with various participation formats.[38]

The energy transition has led to a decentralisation of the German energy system. Not only do citizens consume clean electricity, they now produce it themselves too. Their active participation in wind energy projects creates acceptance and support for wind farms in addition to creating regional value. These projects give local citizens a say in planning and operational management, for example as members of an energy cooperative or shareholders in a public wind farm. In addition, citizens can co-finance wind energy projects through participation models such as savings bonds, bearer bonds, subordinated loans or silent partnerships.[39] A medium to long-term goal of the energy transition is to make even greater use of local renewable energy generation structures in order to achieve self-sufficient energy units in which citizens can ultimately also trade electricity generated among themselves.

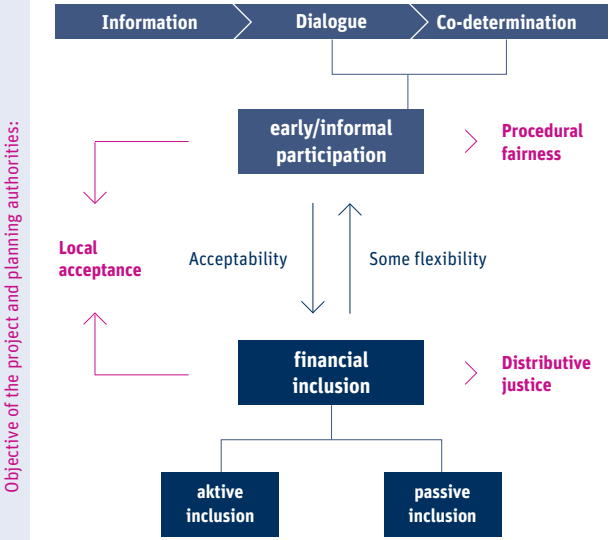
However, residents can also benefit from wind energy projects without active participation. For example, some operators offer discounts on electricity bills. Increasingly, citizens can apply for a wind energy bonus from local municipal utilities. This bonus is calculated according to how many turbines can be seen from the location and how large the town or village is. As residents of a community, citizens also benefit from trade tax and lease income, which is often invested in local infrastructure or public institutions. This allows kindergartens, schools or community centres to be financed to a large extent.

As shown by the graphic on the right, based on the idea of the Onshore Wind Energy Agency, active and passive participation is always about a balance between local acceptance and procedural justice.

Examples of financial investments (selection)

Active participation	Passive participation
Citizens produce with: · Energy cooperatives · Public wind farms as GmbH & Co. KG **Citizens finance with:** · Savings bond · Long-term bond · Silent partnership	**As resident:** · Area lease · Bonus for residents · Sale of electricity **As general public:** · Civic trust · Municipality as operator · Payments to the community

Participation and inclusion[36]



Our answers

to important questions surrounding wind energy

1. How much does **the expansion** of wind energy **cost me?**

Electricity generation costs money, no matter if it is fossil with coal and gas or renewable with wind and sun. Thanks to previous investments, especially the promotion of renewable energies through the German Renewable Energy Act (EEG), the price of wind energy in Germany has fallen below the level of fossil fuels.[40]

Unlike the cost of fossil fuels, which have far-reaching external follow-on costs for people and the environment, the cost of renewable energies is shown transparently on the electricity bill with the EEG levy. This levy, which is paid by private consumers and small and medium-sized enterprises as a surcharge on the electricity price, has stabilized in recent years at around 6,5 cents per kilowatt hour.[41] Wind turbine operators receive the EEG levy as a so-called market premium on the electricity exchange price achieved. This enables them to operate their turbines economically at all times.

New, more efficient turbines receive significantly less support from the EEG levy than older turbines. The subsidy is paid out over 20 years. Since the first old turbines with a high EEG subsidy surcharge will dropped out of the subsidy in 2020, a reduction in the EEG levy is to be expected in the long term. The price on the electricity exchange also has an influence on the amount of the EEG levy, as the market premium compensates for fluctuations in the exchange price. High electricity prices due to the Ukraine crisis and government subsidies from CO2 pricing have lead to a massive decrease in the EEG-levy in 2022 to 3,7 cents per kilowatt hour.[42] As soon as electricity prices stabilize again after the crisis, a more meaningful forecast can be made about the development of the EEG surcharge. However, a further reduction and thus falling costs for consumers in the medium term seem likely.

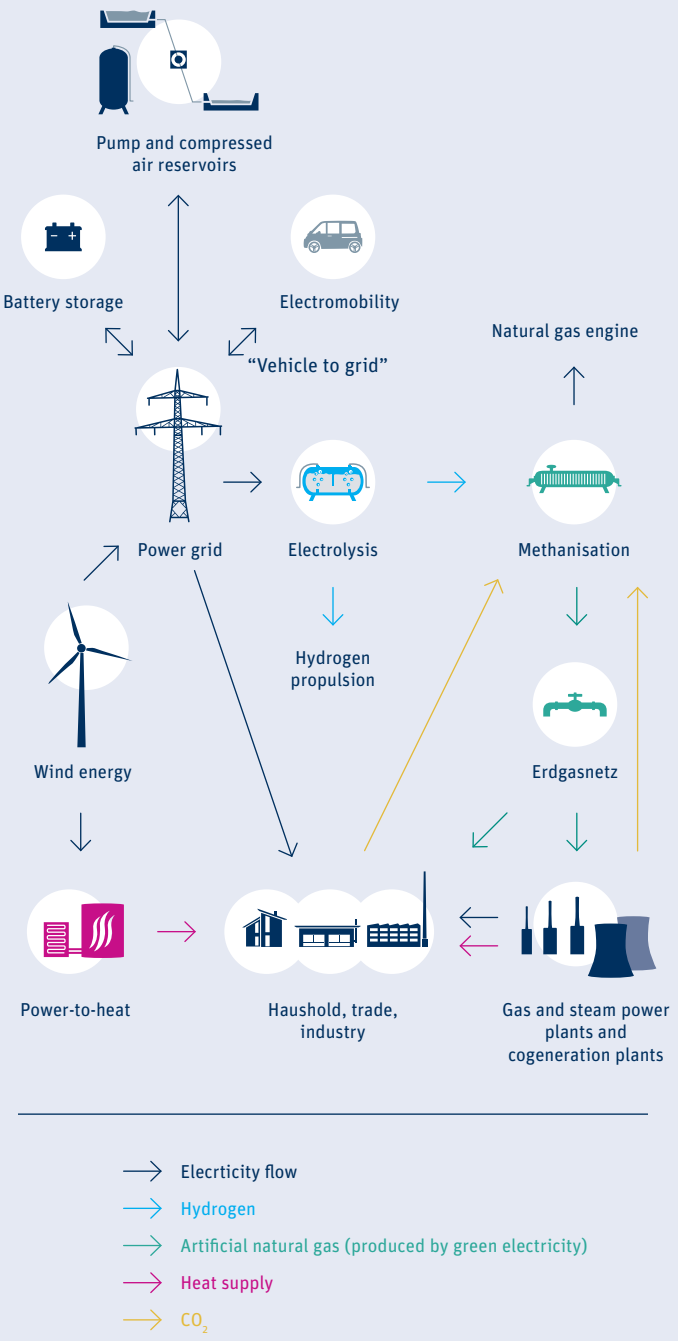
2. Can wind energy **meet demands?**

Since the beginning of the German energy transition, the number of wind turbines onshore and offshore has grown continuously. Renewables already account for 41 per cent of Germany's electricity mix.43 In future, their share will be even higher, as Germany exits not only from nuclear energy but also from coal-fired power generation in the medium term, and, as a consequence, the heating and transport energy sectors will also be increasingly tapped by renewables. The complexity of Germany's landscape of stakeholders, especially in small and medium-sized enterprises and industry, is the driving force behind technical progress and innovation. Today, technical innovations make it possible for energy production to begin at ever lower wind speeds. This leads to increasing operating hours and an overall economic use of wind energy throughout Germany.

A study by enervis energy advisors GmbH on behalf of the German Wind Energy Association (BWE) and the Natural Gas Storage Initiative (INES) comes to the conclusion that a Germany completely supplied with renewable energies is already possible with the development of 2 per cent of the country's surface area.44 In the future, efficient and reliable wind power will be generated by repowering in these areas, some of which are already developed today. In the scenario that the study draws up to 2050, the decisive factors are the interaction of onshore wind energy with other renewable energy sources such as offshore wind energy and photovoltaics, the development of a high-performance storage infrastructure, the introduction of sector coupling, and the associated increased use of renewable gases by power-to-gas. Around 930 TWh of renewable gases will be needed to achieve the decarbonisation of transport and industry and thus a greenhouse-gas-neutral energy system in Germany in 2050.

Through the creation of a storage infrastructure, wind turbines will be able to run much longer in the future without having to be disconnected from the grid despite favourable conditions and without jeopardising grid stability. In addition to battery storage, thermal storage (power-to-heat) and gas storage (power-to-gas) are important components of the future energy system.

Wind energy and sector coupling

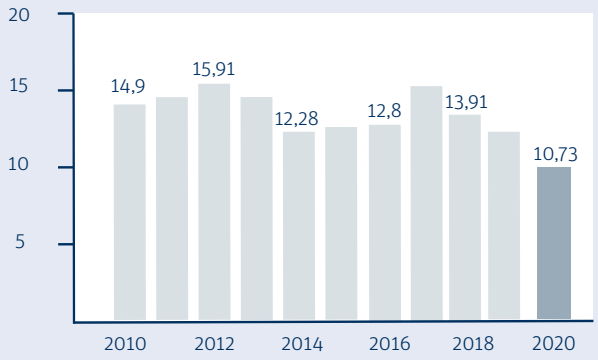


3.
Will my **power supply** stay **secure?**

Wind and solar energy are weather dependent. There are phases in which more or less electricity is produced. However, through sector coupling, this volatility can be balanced out and the power supply can be ensured at all times. In addition, biogas plants can also provide a significant amount of controllable power. In the combination and cooperation of all renewable energies, a completely fossil-free power supply can be ensured in Germany.[45]

Energy supply in Germany has been prepared for the increased feed-in from renewable energies with flexibility options for some years now. This transformation process is very complex and includes, for example, the increased use of load management, power-to-heat systems and decentralised storage systems. As a result, supply security in Germany has remained at a consistently high level since the beginning of the energy transition. In 2020, electricity customers throughout Germany were without electricity for an average of only 10 minutes and 45 seconds.[46] This also includes disturbances caused by earthworks and dredging.

Security of supply with parallel wind energy expansion: Average power outage time in minutes (2009-2020)



4.
Is wind power sufficient for **e-mobility** and **heating?**

Renewable energies nowadays account for a significant proportion of electricity generation. It is therefore high time to think ahead with regard to the energy transition and integrate it into other areas of final energy consumption. In 2020, the share of renewable energies in final energy consumption was 19 per cent, and by 2030 it could rise to 30 per cent, in accordance with the goals of the German government.[47]

After the energy sector, transport is the main cause of CO2 emissions in Germany.[48] In addition to other renewable energy sources, wind energy can play a central role in the CO2-free supply of electric cars. Especially in the case of further electrification of the transport sector, it is important that energy is provided from renewable sources. If this succeeds, the Federal Republic of Germany will come significantly closer to its climate protection goals.

In periods of high winds, high volumes of electricity from wind energy are available, especially in northern Germany. In some cases, this cannot all be fed into the grid, as grid expansion has not progressed far enough or there is no flexibility to reduce the power from conventional power plants. Instead of the wind turbines being shut down, the electricity could be used by nearby consumers, such as electric cars. The expansion of the charging infrastructure for electromobility is of central importance for this. The German government has therefore set itself the goal of having one million charging points in Germany by 2030.[49]

Other interfaces include the use of wind power to provide heat (power-to-heat) or to generate wind gas (power-to-gas). Energy converted into gas is easy to transport and can be stored like conventional gas. These technologies are already in use today, but the necessary business models require additional incentive mechanisms for successful implementation.

Electricity from wind energy is therefore already available in large parts of Germany in sufficient quantities. Sector coupling must now continue so that clean electricity from wind turbines can be transferred to the transport and heating sectors through smart energy supply concepts.

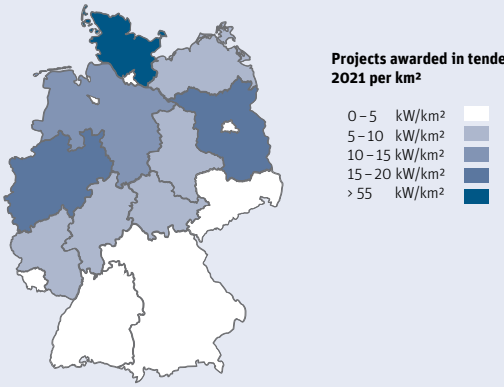
5.
Do wind farms **in the south of Germany** make sense?

Throughout Germany there are locations with wind conditions that are suitable for wind power generation and these should be used as part of a socially supported energy transition. Today, technical innovations make it possible for energy production to begin at ever lower wind speeds. In wind farms with older and newer turbines, it can be observed that the technically more sophisticated new types start up even at low wind speeds. This leads to increasing operating hours and even more economical use of wind energy throughout Germany.

If wind power is generated inland, this has additional advantages. The electricity does not have to be transported from the coast, across the entire country to the large industrial customers and conurbations in southern Germany. This avoids transmission losses during electricity transport and relieves the grid bottlenecks that are currently still occurring in the north. Finally, weather-related fluctuations are also compensated for: the nationwide expansion will increase the security of supply, as lulls at one location can be compensated for by wind turbines running at another location.

However, the prerequisite for the nationwide expansion of wind energy in Germany is that all federal states award contracts to projects under tender. Unfortunately there's a widening gap between northern and southern states when it comes to permitting and deploying wind energy projects. In Bavaria, Baden-Wurttemberg, Saxony and Thuringia the numbers have been stagnating at low level for years, despite the state's enormous potential.[50]

Contracts awarded for projects under tender 2021



6.
Why are wind turbines sometimes **standing still**, even though the **wind is blowing?**

There are a number of reasons why turbines actually stop temporarily. As the name of the technology implies, wind turbines are naturally dependent on wind. Measurements of local wind conditions on site guarantee that they are built in areas with sufficient wind. There are often other reasons for turbines to be temporarily shut down.

One reason is the delayed expansion of the grid and an oversupply of conventional electricity that stands in the way of an even more efficient use of wind energy. Occasionally, wind turbines have to be shut down when they are actually working most efficiently, namely when a lot of wind power is being fed into the grid in strong winds. In the future, these cases will decrease. There are two reasons for this: an optimised and efficient power grid will be able to absorb more wind power in the future and better balance supply and demand. The expansion of the grids will ensure the largest possible share of electricity from renewable energies in the long term and throughout Europe. Germany decided to phase out all nuclear power plants until 2023 and coal until 2035, if not 2030. Due to their inflexibility, they are currently still clogging the power grids with climate-damaging electricity and thus causing the shutdown of flexible wind turbines. Coal-fired power plants will no longer be needed in the electricity system of the future, which will be characterised by wind energy, other renewables and flexible gas-fired power plants.

In addition, there are a number of reasons why the rotors of wind turbines do not rotate in some cases despite good wind conditions. Maintenance and repairs are often the reason for a temporary shutdown. Another reason for the stoppage may be the protection of birds and bats during breeding and flying out times. To protect residents, turbines are also switched off if they cast shadows on adjacent residential buildings for more than 30 minutes a day when the sun is low in the sky.[51]

7. Why are **old** wind turbines being **replaced** by new ones?

In order for Germany to meet its climate protection targets, the share of renewable energies in energy consumption must increase. For onshore wind energy, this does not necessarily mean a proportionately greater number of wind turbines, but the use of more efficient technology with a higher yield.[52] Repowering is the replacement of old turbines with more powerful ones, which have also been optimised with regard to other requirements in recent years. A newly constructed turbine in 2022 had an average output of 4,103 kW, whereas the average output of the turbines dismantled in the same year was 1,207 kW. These increases in efficiency are primarily achieved by raising the hub heights and thus increasing full-load hours.

What are the advantages of repowering? Firstly, the process can reduce the total number of turbines. A rule of thumb is that repowering can double the output and triple the electricity yield with half the number of turbines. Dismantling existing turbines that are often scattered close to built-up areas and replacing them with fewer but more powerful wind turbines relieves the landscape and, depending on the spatial planning situation, offers the opportunity to rearrange the turbines. The second advantage is that modern turbines can be integrated much better into the electricity grid because they feed in electricity more constantly and in larger quantities. Thirdly, there are the advantages of resident protection, since the new turbines are visually more acceptable due to a lower number of revolutions and are quieter than the existing turbines due to new technologies.

Although local acceptance and existing infrastructure speak in favour of repowering in existing areas, administrative obstacles such as new area designations, height limitations and changed distance regulations pose spatial planning challenges. In order to exploit the full repowering potential, ways should be found in land use and regional planning to preserve the existing areas for repowering.

And the potential is huge: Several Gigawatts of installed wind energy capacity will reach the end of their 20-year funding period until 2025. Due to the currently high electricity prices, most of them will remain on the grid for a few more months if not years. But BWE estimates that through facilitated repowering regulations, an additional capacity of 45 GW could be installed within 2 years.[53]

The potential of repowering should be made possible and exploited due to the many advantages that repowering brings.

Triple the electricity yield with half the number of turbines

Classic repowering project:
4 modern ind turbines (4 MW) replace 8 old turbines (1.3 MW)

- ➔ reduction of the total number of turbines
- ➔ better integration into the power grid
- ➔ lower rotation speed
- ➔ lower noise emissions

8.
Can wind turbines be **recycled?**

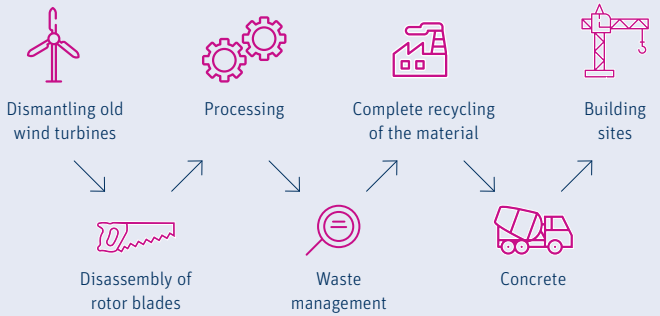
Wind turbines are highly advanced technologies. Nevertheless, the dismantling and recycling of their components is not a problem, as waste management companies have confirmed. In the meantime, companies have found safe solutions for recycling wind turbines and reusing them profitably.

Modern wind turbines can be almost completely recycled: 80 to 90 percent of the components of a wind turbine, based on their total mass, can be recycled.[54] They consist of more than 80 percent steel and concrete. After processing, the concrete parts of the foundation are used as recycled concrete, for example in road construction. The steel segments mainly return to the steelworks as secondary material. Some components, such as rotor blades, cannot find a secondary market and must be recycled. The recycling of rotor blades is particularly challenging due to the composition of glass fibre plastics, carbon fibres and other plastics. This means that the thermal utilisation of old rotor blades can only be carried out by specialised companies.

It has recently become possible for the rotor blades to be incinerated in an industrial recycling process. The ash, which still accounts for about 30 per cent of the raw material by volume, can then be used as a substitute for other raw materials in the cement industry. This technology is also used for complex plastics from other industries, such as the automotive, aviation and shipping industries.

Several wind turbine manufacturers are actively pursuing zero-waste targets and publish annual sustainability reports in which they document their progress in improving their production process, as well as the lifespan and recyclability of their products.[55]

Recycling old wind turbines



9.
Do more turbines mean **more grids?**

We are already successfully responding to the fluctuating demand for electricity with constant control of power grid management. For the new generation landscape around renewable energies, however, an increasingly "intelligent" power grid is needed to coordinate generation and consumption accordingly. The basic principle is still to optimise existing grids and only expand them after optimisation (the so-called "NOVA" principle). What is new, however, are so-called "smart grids", which ensure communication between all energy producers, all energy stores and all energy consumers.

The transmission grid operators are confidently accepting the challenge posed by increased feed-in from wind and sun. In order to reduce the costs for feed-in management and redispatch, the grid expansion projects defined in 2009 by the Power Grid Expansion Act (EnLAG) and the grid development plan must be further implemented. In 2016, for example, the transmission grid operator 50 Hertz initiated the commissioning of the first system of the southwest coupling line („Thüringer Strombrücke"), thus making a clear contribution to a significant reduction in redispatch costs the following year. At the end of 2020, however, only 55 per cent of the EnLAG projects were realised. More should follow. In addition, innovative grid systems and technologies help the user to shift the load in the grid and optimise consumption. Whether the use of high-temperature conductor cables, the interaction of smart market and smart grid, the modern measurement of current weather data, the utilisation of available storage capacities or the flexibilisation of consumers – modern grid operation offers many possibilities.[56]

The wind energy industry, on the other hand, is working on balancing the production of wind power in order to minimise the challenges for grid operation. Technological development is also helping to increase the stability of wind power utilisation and reduce grid requirements. In the future, more and more electrical appliances and electricity producers will be networked in smart grids.

In the industry, the production of green hydrogen will help to transform and decarbonize production processes. It relieves the grids, since it can be stored and transported along the already existing gas-infrastructure. On the other hand, the production of hydrogen needs a lot of electricity which makes the expansion of wind energy and other renewables even more urgent. It is not yet sure whether Germany will be able to satisfy the increasing demand for green hydrogen in the future through its own national production capacities or the import of hydrogen from abroad. As of today, the German government aims to increase the installed production-capacities for hydrogen and the infrastructure around it through their national Hydrogen strategy up until 2030.[57]

10.
Why do we need **offshore** wind energy?

Technologies in the energy mix that have a stabilising and balancing effect are also decisive for the overall efficiency of the energy system. Offshore wind energy plays a key role as a supplement to onshore wind energy and photovoltaics. Wind energy on the open sea is available on average 363 days a year and is an indispensable pillar of the energy transition due to the uniform supply of clean electricity.[58]

Germany is the world market leader for offshore technology and has the entire value chain at its disposal for the construction of these high-performance turbines. The advantage of being able to cover supply, production, project planning and operation with German companies must be maintained and expanded with regards to job security and export opportunities. There is enormous growth potential in the offshore industry. While coastal access in Germany is limited, other countries have a much greater demand for the leading offshore technologies from Germany. Due to their high capacity generator and their constant production of wind power, offshore wind turbines make a decisive contribution to supply security. If the ambitious German climate protection targets are to be achieved, offshore wind power needs to be expanded as well as onshore.

Did you know? The most stringent requirements throughout Europe apply for the use of offshore technologies in the North Sea and the Baltic Sea. Since the wind farms are closed to shipping and fishing, plants and animals in this region can regenerate particularly well.[59] This even creates new biotopes. In addition, the offshore industry is doing a considerable amount of research and development work to ensure that the construction of these large-scale facilities has as little impact as possible on the natural marine environment. Noise-reducing technologies such as the so-called “bubble curtain” are also used to protect special marine animals such as the harbour porpoise.[60] Another example is the use of environmentally friendly “suction bucket foundations”, which can be put in place without noisy pile driving. In addition, components that are permanently exposed to a certain depth are effectively protected against corrosion by cathodic protection. This prevents harmful substances from being washed into the sea.

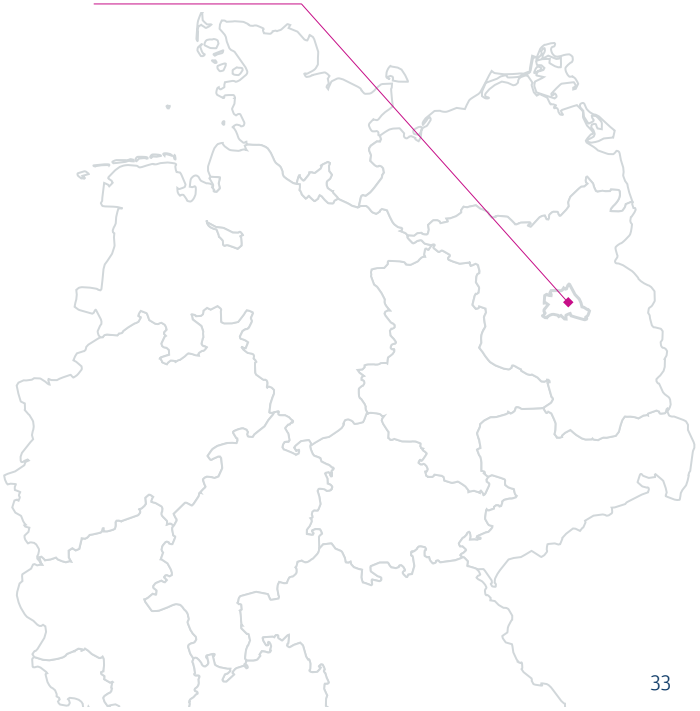
11.
Will wind farms be built **everywhere?**

In the public debate, the question is repeatedly raised as to whether turbines are to be erected all over Germany and at any location. However, there is no need to be afraid of uncontrolled expansion, because with only 2 per cent of national territory reserved for wind farms, Germany will be able to produce enough electricity to cover its demand.

Furthermore, only areas that are identified as priority areas for wind energy in state regional plans and that withstand detailed examination will be considered. In addition to the distances to residential areas and transport routes, bodies of water, nature and landscape conservation areas, military bases, airports or listed buildings, the local wind conditions must be right. And even in optimistic forecasts based on a completely renewable energy system, Germany will not be covered with wind turbines.[61,62]

High performance in a small area

In 2021, the land usage of all wind turbines in Germany corresponded to about one tenth of the area of Berlin.

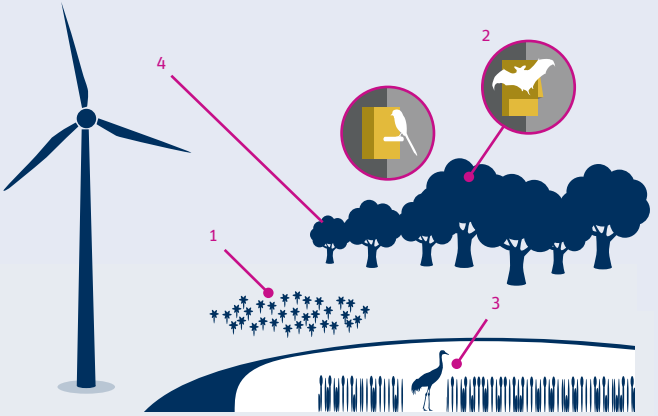


12. Are **birds and bats** protected?

Wind turbines interfere with nature, just like the construction of road links and the use of land for modern agriculture. Therefore, the consequences for local wildlife must be carefully assessed. However, the alternatives to wind energy such as coal mining and unabated climate change continue to pose the greatest threat to Germany's biodiversity.

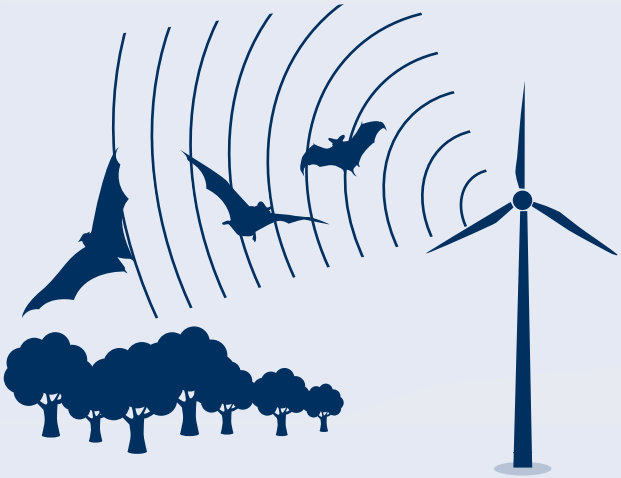
One thing is clear: Wind energy and nature conservation are not mutually exclusive. This is guaranteed by nature conservation audits in the regional assessment and approval procedures for wind farms. The Federal Nature Conservation Act defines legal standards for interventions in nature and the protection of wild animals. Almost every project nowadays is accompanied by species protection studies and environmental impact assessments.[63] This involves a thorough examination of whether the planned site is home to protected species of birds and bats. Unoccupied bird nests must also be taken into account, as it is considered probable that temporarily unoccupied breeding grounds and hunting grounds will be reused by the animals at a later time. In any case, important species protection areas are not included in the choice of wind power locations.

Furthermore, project planners of wind turbines often commit themselves to compensatory measures for the protection of birds and bats, such as the creation of biotopes protected areas. In some cases, such measures have even led to an improvement in the living conditions of the animals and their populations have grown in parallel with the expansion of wind energy. All 25 species of bats native to Germany are strictly protected under the Federal Nature Conservation Act. They are subject to the rules on special species protection. If there is still an acute danger during high frequency flying times, the wind turbines are temporarily switched off. The development and testing of such algorithms are mostly based on federal research projects and innovations by wind turbine manufacturers. Practice also shows that the risk of collision is overestimated. The swept area of a modern rotor is above the flight altitude of most animals. Birds flying in high altitudes however, are aware of rotor blades and swerve them according to longterm monitoring studies.[64]



Compensation for interventions in nature

To compensate for interventions in nature and the landscape, many ecological projects are implemented, such as planting flowering meadows and orchards (1), placing nestboxes (2), creating biotopes (3) or supporting ecological forest conversion and afforestation (4). Wind farms in conservation areas remain taboo.



Shutting down for bats

On warm, windless summer nights, some species of bats hunt so high in the air that they can come into the area swept by the rotors. On such nights, many wind turbines are therefore temporarily shut down.

13.
What must be considered for **wind farming in forest?**

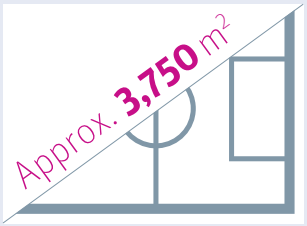
First things first: Germany does not make available particularly valuable forest areas for wind farming. Deciduous forests and protected areas of particularly high ecological value for humans and animals are excluded from wind farming. In most federal states, coniferous forests used intensively for forestry purposes are available instead. They offer large areas of ecologically less critical sites (mono-silviculture) and are generally outside protected areas. In these types of forest, species diversity is usually lower than in natural forests. Possible bare areas as a result of storm and climate change damage, as well as existing impacts from motorways or technical infrastructure such as transmission masts can also reinforce their suitability for wind farming.

Yes, some clearings might be required for the construction of turbines in the forest. However, the total forest utilised can be reduced by a space-saving installation concept and favourable site characteristics, for example with low terrain inclination or with existing access routes, which were often established in commercial forests for forestry vehicles before the construction of wind turbines. Furthermore, all clearings must be compensated and afforested at another place.

Just as for open land, the planning and construction of wind turbines in commercial forests are subject to strict rules. In addition to the Federal Nature Conservation Act, the forest regulations of the Federal Forests Act and the State Forests Act apply in Germany. The early involvement of the forestry authority in the planning and approval procedures ensures that the decision is carefully considered. Once the site has been selected in accordance with the intervention regulations, the forestry authority determines the necessary compensation measures. As a rule, this includes the obligation to carry out reforestation or to increase the quality of existing forests[65].

Wind energy has comparatively low land consumption.

For a modern onshore turbine with on output of **4-5 MW**, the area of half a football field, including the access roads, is required.



14.
Are we **citizens** even **asked** about the expansion of wind energy?

The formal participation of citizens in the planning and approval processes is guaranteed and regulated by law. The planning authorities protect the interests of all parties involved and ensure that wind turbines are erected where as few conflicts as possible occur. The local population is therefore involved in regional planning by the authorities long before the specific planning of a wind farm.

In addition, residents should also inform themselves about the planned wind energy project in good time and in detail. Wind farm planners and authorities offer various formats for this purpose: Energy discussion forums, on-site visits, workshops, information events, planning workshops, etc. can be used as communication formats for the exchange between citizens and project developers. All sides benefit from such a dialogue: residents can express their concerns and suggestions for changes and thus have more influence on project design and implementation. The project promoters benefit from the knowledge of local stakeholders, can respond to criticism constructively and identify possible risks at an early stage.

Open communication on an equal level alone does not guarantee success, but can help to reduce reservations. The acceptance of wind energy projects on site is effectively increased by clarifying misunderstandings. Experience shows that reservations about wind energy are declining significantly, especially in the vicinity of wind farms. Concerned residents are often not informed about the current state of turbine technology. Information about the greatly reduced noise emissions thanks to aerodynamically optimised and adjustable rotor blades, no more reflective coatings or sensor-supported shutdown as soon as the shadow cast exceeds the legal maximum of 30 minutes per day or 30 hours per year can significantly increase acceptance. In conflicts with people and nature, there is a rule that applies to planners and also to residents: A workable compromise is always better than enforcing one's own rights in court.

15.
Will **my house** go down in **value?**

For the valuation of property prices, wind turbines must be assessed in the same way as other buildings that characterise the local infrastructure (industrial plants, pig farms, supermarkets, railway stations, motorways and airports).[66] However, changes in the market value of a property cannot be attributed to a single factor alone. Instead, the value of a property depends on a whole range of different factors. Supply is guided by the location of a property, real estate stocks, vacancy and new construction activities, while demand is influenced by the location, the regional social and economic structure as well as the general development of assets and demographic change.[67] Personal motives also play a role in the decision to buy a property or a home.

The following aspect is interesting from a psychological point of view: although it is clear from previous scientific studies that wind turbines do not have a negative impact on property values, the mere assumption that wind turbines pose a value-reducing risk can have a short-term effect on the pricing of land and property.[68] Without this psychological component, the price trend often behaves differently.

If one considers the influx of workers into rural areas and the regional value added through the expansion of wind energy, it can instead be assumed that this has a rather positive effect on the development of property prices, especially in structurally weak regions. This assumption is supported by the results of a study in the East Frisia region at locations with a very high density of wind turbines compared to the German average.[69] A positive development of property prices was recorded there. A long-term analysis by the city of Aachen on property price development regarding the "Vetschauer Berg" wind farm comes to the same conclusion.[70] It was found there that the properties in the immediate vicinity of the wind farm showed a positive price trend.

16.
Do wind parks scare off **tourists?**

Various studies and a range of creative holiday resorts prove that tourism and wind energy not only go hand in hand, but that wind farming can also have positive effects on visitor numbers and overnight stays.

According to a study by the Institute for Tourism and Spa Research in Northern Europe (NIT), only one in 100 guests would avoid a holiday resort because of a nearby wind farm.[71] According to the survey, other factors are much more important in choosing a travel destination. For example, the friendliness of holiday providers, quality of accommodation, prices and variety of offers on site play a key role in holidaymakers' decision-making. The satisfaction of holiday guests is reduced if there is a lack of cycle paths, horseback riding trails, hiking trails, interlinked public transport or culinary and cultural recreation offers. Innovative hotel concepts and offers for sustainable and social travel are also in demand. Some holiday resorts have even enhanced their image through local wind energy. Wind turbines symbolise innovative power, future orientation and sustainability.[72] Information about renewable energies, visits to wind turbines and integrated hiking or cycling trails now provide additional tourist attractions.

The bioenergy village Jühnde[73] in Lower Saxony, the energy landscape-Morbach[74], Feldheim[75] in Brandenburg and the "WindErlebnis Ostfriesland" (East Frisia Wind Experience) are some prime examples of how wind energy can boost tourism and increase the number of overnight stays in rural areas. German travel groups as well as those from abroad who are interested in the energy transition create value locally and have positive effects for local hotels, restaurants and businesses. Due to the high interest in renewables, there are now also travel guides[76] focusing on climate-friendly energy production.

17.
Can wind energy cause **health** problems?

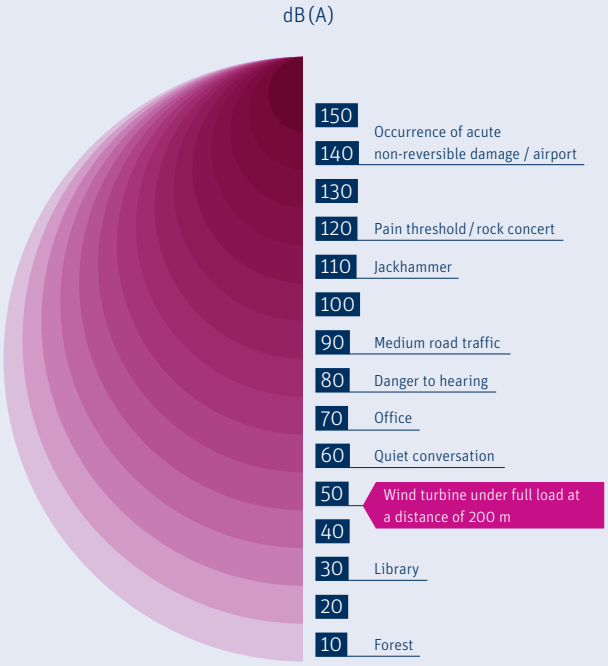
People are surrounded by modern technology every day, not only in cities and communities, but also directly in their private homes and work environment. However, wind energy is one of the most visible technologies in the landscape. Understandably, residents are wondering whether wind turbines near residential areas can have an impact on health.

Various studies and expert opinions dispel these fears. According to studies by the German Society for Nature Conservation and various state environmental agencies, sound levels in the immediate vicinity of wind turbines are not in the slightest harmful to health.[77] Far higher infrasonic values than those of a wind turbine at a distance of 150 metres can be measured, for example, in the interior of a medium-sized car travelling at 130 km/h or in other everyday situations. According to current international knowledge, no effects on human health are therefore to be expected [78]. These studies are supported by a ruling by the Würzburg Administrative Court on the harmlessness of noise emissions from wind turbines.[79] These assessments also correspond to regular on-site measurements.

Like gusty wind, sea surf or moving cars, wind turbines also generate sound at very low frequencies, so-called infrasound. These are very low tones with a frequency of less than 20 Hertz (Hz). These frequencies are normally not perceptible to humans. Nevertheless, some local residents fear that infrasonic exposure might affect their health.[80]

Although researchers cannot replicate the supposed cause-and-effect relationship between wind power and the occurrence of illnesses, there are people who suffer from complaints such as headaches or nausea. These complaints are real and must be taken seriously. Experts attribute the so-called “wind turbine symptom” to the nocebo effect. According to this, residents do not suffer from acoustic or optical signals from the wind turbine, but from fears that these could be harmful to health. Further educational work and research are urgently needed here.

At a distance of 200 metres, quieter than quiet conversationg



- A study commissioned by the Australian government shows that there is no link between optical and acoustic emissions from wind turbines and health problems.
- A long-term study conducted by the Bavarian Environment Agency in 2012 confirms that at a distance of 250 metres, the sound emissions of the wind turbines examined are far below the human perception threshold. The infrasound caused by the wind is significantly stronger than that generated by the wind turbine itself.
- A study by the German Federal Ministry for the Environment shows that overall, there is “no significant inconvenience” due to the obstruction markers of wind turbines.

18. What is the industry doing about the **flashing lights at night?**

Wind turbines are not only built on land and at sea, but also in the vicinity of towns and settlements. Wind turbines in the vicinity of towns and settlements can occasionally be perceived as a nuisance due to optical stimuli. The question therefore arises as to how residents are protected from possible disturbances caused by wind turbines. A prime example of improved legal framework conditions and new technological solutions to ensure the acceptance of wind turbines is needs-based night warning lighting.[81]

The red flashing lights (obstruction lights) on the rotor blades are mandatory to warn aircraft and helicopters of obstacles of this type. At present, they are permanently on. In many wind farms, however, the lights only come on when they are actually needed. Radar sensors monitor the surroundings of the wind turbines. With such a system, the lights will only light up as needed, i.e. when aircrafts approach. As it is rare for aircraft to fly over a wind farm at critical altitude at night, the lights can remain off for over 90 per cent of the night. The current deadline up until all onshore turbines need to have needs-based night warning lighting is the 31st of December 2022.[82]

For a successful continuation of the German energy transition, the wind energy industry and politicians are interested in securing the acceptance of turbines among the population. A variety of legal regulations have already been adopted for this purpose. There are clearly defined noise protection guidelines for wind turbines in the vicinity of residential areas. Corresponding distance regulations are observed during planning and construction. There are also defined immission control regulations for the shadow cast by the rotor blades. This means that a wind turbine must be temporarily shut down if its shadow falls on a house for more than 30 hours per year and 30 minutes per day. But also with technical solutions such as non-reflective paints, reduced speed and encapsulated nacelles, the industry optimises resident protection even beyond these legal requirements.

Overview

Facts and figures on wind energy

Energy supply 2021

Total energy supply from renewable energies:
467.3 terawatt hours (TWh)[83]
(of which electricity 234 TWh, heating 199 TWh, transport 34 TWh)

Avoided greenhouse gas emissions through renewable energy use:
221.4 million tonnes (MT) CO_2 equivalent[84]
(of which electricity 167 MT, heating 45 MT, ransport 10 MT)
Proportion of wind energy: **86.5 MT** CO_2 equivalent (39.1 %)

Gross electricity generation from renewables in 2021: **224.6 TWh**[85]
Share of renewables in the electricity mix (net): **45.8 %**

Power from wind energy

Net electricity generation from wind energy 2021: **113.5 TWh**[85]

Share of wind energy

...in the German electricity mix (net electricity generation) in 2021: **23.1 %**[85]

➘ This makes wind energy Germany's second most important source of electricity

...in electricity from renewable energies in 2021: **50.55 %**

Germany's share of wind energy worldwide in 2021: **7.71 %**[86]

Industry figures

New construction (installed capacity on land) 2021: **1.9 GW**[87]

Existing capacity (installed capacity on land) 31.12.2021: **56.1 GW**

Number of employees in the wind energy industry in 2020: **100,000**[88]
of which onshore: **85,000 people**
of which offshore: **15,000 people**

Number of employees in the wind energy industry worldwide: **1.25 million**[89]
Export share of German wind turbine production: **70,5 %**[90]

Expansion goals

Renewable energy expansion targets of the German government

80% of the electricity mix by 2030[91]
115 GW installed onshore capacity by 2030
2 % of national territory for wind energy until 2032

Potential at 2 percent area use[92]

Installed wind capacity: **200 GW**
Wind energy yield per year: **390 TWh**
➘ Corresponds to: **65 %** of German gross electricity consumption

Acceptance

51 % of citizens with previous experience think that wind turbines in their residential environment are “good” or “very good”[93]

83 % support the expansion of renewable energies

Technology

Average capacity of a wind turbine

1993: 260 kW
2022: 4,103 kW[94]

➘ More than tenfold increase in past years

Largest wind turbine 2022 for offshore and onshore wind farms

Technical data	Offshore	Onshore
Type of turbine:	**SG 14-222 DD / 14,000 kW**[95]	**V-172 / 7,200 kW**[96]
Manufacturer:	Siemens Gamesa	Vestas
Rotor diameter:	**222 m**	**172 m**
Swept area:	**39,000 m²**	**23,240 m²**
Capacity:	**14 - 15 MW**	**7.2 MW**
Supply of households:	**Approx. 18,000 households**	**Approx. 6.000-8.000 households**

Have you ever been ...

... on a wind turbine? If not, visit a virtual one. Experience rare insights and views with the 360 degree video from the BWE at www.youtube.de/BWEeV.

Sources

1 **Northern German Broadcasting Corporation** (2017)
Vor 30 Jahren: Erster deutscher Windpark startet.
http://www.ndr.de/nachrichten/schleswig-holstein/Vor-30-Jahren-Erster-deutscher-Windpark-startet,windkraft880.html

2 **Solar Energy Promotion Association** (2008)
The las argument of the nuclear lobby. https://www.sfv.de/briefe/brief97_1/sob97135

3 **Statista** (2022)
Windkraft - Stromerzeugung in Deutschland 2021. https://de.statista.com/statistik/daten/studie/156379/umfrage/stromerzeugung-durch-windkraft-in-deutschland-seit-1998/

4 **DeStatis** (2022)
Stromerzeugung 2021.
https://www.destatis.de/DE/Presse/Pressemitteilungen/2022/03/PD22_116_43312.html

5 **ARD Deutschlandtrend** (2022)
Breite Zustimmung für den Ausbau der erneuerbaren Energien.
https://presse.wdr.de/plounge/tv/das_erste/2022/04/20220407_ard_deutschlandtrend_energien.html

6 **Federal Environmental Agency** (2021)
Häufige Fragen zum Klimawandel.
https://www.umweltbundesamt.de/themen/klima-energie/klimawandel/haeufige-fragen-klimawandel#menschlicher-beitrag

7 **Federal Environment Agency** (2022)
Erneuerbare Energien in Zahlen.
https://www.umweltbundesamt.de/themen/klima-energie/erneuerbare-energien/erneuerbare-energien-in-zahlen#emissionsbilanz

8 **Tagesschau** (2022)
Wie stark der Windkraft-Ausbau stockt.
https://www.tagesschau.de/wirtschaft/technologie/windkraft-ausbau-deutschland-101.html

9 **Competence Center Nature Conservation and Energy Transition** (2018)
Wie stark der Windkraft-Ausbau stockt.
https://www.naturschutz-energiewende.de/fragenundantworten/148-energetische-amortisation-windenergieanlagen/

10 **Harokopio University Athen** (2014)
Assessment of the Environmental Impacts of a Wind Farm in Central Greece during its Life Cycle.
http://dergipark.gov.tr/download/article-file/148161

11 **Onshore Wind Energy Agency** (2018)
Kompensation von Eingriffen in das Landschaftsbild durch Windenergieanlagen.
https://www.fachagentur-windenergie.de/fileadmin/files/Veroeffentlichungen/FA_Wind_Hintergrundpapier_Kompensation_Eingriffe_Landschaftsbild_durch_WEA_06-2016.pdf

12 **German Wind Energy Association** (2019)
Es liegt in unserer Natur. Klima- und Umweltschutz mit Windenergie
https://www.wind-energie.de/fileadmin/redaktion/dokumente/publikationen-oeffentlich/themen/01-mensch-und-umwelt/03-naturschutz/FINAL_-_BWE-Broschuere_-_Windenergie_und_Naturschutz_-_20190823_aktualisiert_Online_01.pdf

13 **Federal Environmental Agency** (2022)
Flächenverbrauch für Rohstoffabbau.
https://www.umweltbundesamt.de/daten/flaeche-boden-land-oekosysteme/flaeche/flaechenverbrauch-fuer-rohstoffabbau#inlandische-rohstoffentnahme

14 **Federal Environmental Agency** (2021)
Daten und Fakten zu Braun- und Steinkohle.
https://www.umweltbundesamt.de/sites/default/files/medien/5750/publikationen/2021-03-18_texte_28-2021_daten_fakten_braun-_und_steinkohle.pdf

15 **Eco-Social Market Economy Forum** (2017)
Was Strom wirklich kostet. Vergleich der staatlichen Förderungen und gesamtgesellschaftlichen Kosten konventioneller und erneuerbarer Energien. Überarbeitete und aktualisierte Auflage.
https://www.greenpeace-energy.de/fileadmin/docs/publikationen/Studien/GPE_Studie_StromKosten_WEBV02_DS.pdf

16 **Deutschlandfunk** (2019)
Atommüll-Entsorgung. Staatsfonds macht Verluste.
https://www.deutschlandfunk.de/atommuell-entsorgung-staatsfonds-macht-verluste-100.html

17 **Eco-Social Market Economy Forum** (2017)
Was Strom wirklich kostet. Vergleich der staatlichen Förderungen und gesamtgesellschaftlichen Kosten konventioneller und erneuerbarer Energien. Überarbeitete und aktualisierte Auflage.
https://www.greenpeace-energy.de/fileadmin/docs/publikationen/Studien/GPE_Studie_StromKosten_WEBV02_DS.pdf

18 **Coady, D., Parry, I., Sears, L., Shang, B.** (2017)
How Large Are Global Fossil Fuel Subsidies?,
https://www.sciencedirect.com/science/article/pii/S0305750X16304867

19 **Eco-Social Market Economy Forum** (2021)
Kostenvergleich Kohle, Erneuerbare Energien.
https://foes.de/publikationen/2021/2021-09_FOES_Factsheet_Kostenvergleich_Kohle_EE.pdf

20 **Statista** (2022)
Preisentwicklung von CO2-Emissionsrechten im europäischen Emissionshandel (EU-ETS) von 2005 bis 2021. https://de.statista.com/statistik/daten/studie/1304069/umfrage/preisentwicklung-von-co2-emissionsrechten-in-eu/

21 **Statista** (2021)
Windindustrie - Anzahl der Beschäftigten in Deutschland.
https://de.statista.com/statistik/daten/studie/162646/umfrage/anzahl-der-beschaeftigten-der-windindustrie-von-2004-bis-2009/

22 **Deutsche Welle** (2021)
Windkraft-Ausbau: Millionen neue Jobs weltweit.
https://www.dw.com/de/windkraft-ausbau-millionen-neue-jobs-weltweit-wartung-fernwartung-anlagenbau-planung-installation/a-60154523 etzel/Regionale_Wertsch%C3%B6pfung_in_der_Windindustrie.pdf

23 **Federal Ministry for Economics and Climate Action (BMWK)** (2022)
Ich mach was mit Erneuerbaren.

https://www.bmwi-energiewende.de/EWD/Redaktion/Newsletter/2019/11/Meldung/direkt-erfasst_infografik.html

24 **University of Kassel** (2016)
Regionale Wertschöpfung in der Windindustrie am Beispiel Nordhessen.

25 **Section 29 German Trade Tax Act** (2022)
https://www.gesetze-im-internet.de/gewstg/BJNR009790936.html

26 **Handelsblatt** (2022)
Verfassungsgericht – Pflicht zur finanziellen Beteiligung der Gemeinden an Windanlagen zulässig.
https://www.handelsblatt.com/politik/deutschland/energieversorgung-verfassungsgericht-pflicht-zur-finanziellen-beteiligung-der-gemeinden-an-windanlagen-zulaessig/28308514.html

27 **Windfacts.at** (2020)
10 Gründe für die Windkraft.
https://windfakten.at/?xmlval_ID_KEY%5B0%5D=1230

28 **PV-Magazine** (2020)
IRENA: Erneuerbare meist kostengünstiger als neue Kraftwerke.
https://www.pv-magazine.de/2020/06/03/irena-erneuerbare-energien-meist-kostenguenstiger-als-neue-kohlekraftwerke/

29 **German Parliament - Scientific Services** (2022)
Gestehungskosten von Strom im Vergleich.
https://www.bundestag.de/resource/blob/887090/1867659c1d4edcc0e32cb093ab073767/WD-5-005-22-pdf-data.pdf

30 **Federal Environmental Agency** (2022)
Primärenergiegewinnung und -importe.
https://www.umweltbundesamt.de/daten/energie/primaerenergiegewinnung-importe

31 **Institute of Energy Economics at the University of Cologne** (2022)
Erdgas, Steinkohle, Erdöl: Analyse der europäischen Energieimporte.
https://www.ewi.uni-koeln.de/de/aktuelles/energieimporte/

32 **Editorial Network Germany** (2022)
Lindner: Erneuerbare Energien sind „Freiheitsenergien".
https://www.rnd.de/politik/lindner-zu-krieg-in-der-ukraine-erneuerbare-energien-sind-freiheitsenergien-lauterbach-stimmt-zu-ZQGHVBLMTJFJHBB3F3HLNE63NA.html

33 **Institute of the German Economy** (2021)
xportperformance von Gütern zur Herstellung erneuerbarer Energie.
https://www.iwkoeln.de/presse/pressemitteilungen/juergen-matthes-thilo-schaefer-deutsche-exporte-fallen-zurueck.html

34 **Statista** (2022)
Global automotive market share in 2021, by brand.
https://www.statista.com/statistics/316786/global-market-share-of-the-leading-automakers/

35 **Global Wind Energy Council** (2021)
Global Wind Report 2021.
https://gwec.net/global-wind-report-2021/

36 **Agency for Renewable Energies** (2017)
Repräsentative Umfrage von Kantar Emnid zur Akzeptanz Erneuerbarer Energien.
https://www.unendlich-viel-energie.de/themen/akzeptanz-erneuerbarer/akzeptanz-umfrage/akzeptanzumfrage2017

37 **Onshore Wind Energy Agency** (2015)
Mehr Abstand – mehr Akzeptanz? Ein umweltpsychologischer Studienvergleich.
https://www.fachagentur-windenergie.de/fileadmin/files/Akzeptanz/FA-Wind_Abstand-Akzeptanz_Broschuere_2015.pdf

38 **trend:research / Leuphana University of Lüneburg** (2013)
Definition und Marktanalyse von Bürgerenergie in Deutschland, S. 45.
https://www.buendnis-buergerenergie.de/fileadmin/user_upload/downloads/Studien/Studie_Definition_und_Marktanalyse_von_Buergerenergie_in_Deutschland_BBEn.pdf

39 **Onshore Wind Energy Agency** (2017)
Beteiligung bei Windenergie an Land.
https://www.fachagentur-windenergie.de/themen/beteiligung.html

40 **German Parliament - Scientific Services** (2022)
Gestehungskosten von Strom im Vergleich.
https://www.bundestag.de/resource/blob/887090/1867659c1d4edcc0e32cb093ab073767/WD-5-005-22-pdf-data.pdf

41 **Statista** (2022)
Höhe der EEG-Umlage für Haushaltsstromkunden in Deutschland.
https://de.statista.com/statistik/daten/studie/152973/umfrage/eeg-umlage-entwicklung-der-strompreise-in-deutschland-seit-2000/

42 **Next-Kraftwerke** (2022)
Was ist die EEG-Umlage?
https://www.next-kraftwerke.de/wissen/eeg-umlage

43 **Federal Environment Agency** (2022)
Erneuerbare Energien in Zahlen.
https://www.umweltbundesamt.de/themen/klima-energie/erneuerbare-energien/erneuerbare-energien-in-zahlen#emissionsbilanz

44 **enervis energy advisors GmbH** (2017)
Erneuerbare Gase – ein Systemupdate der Energiewende. Studie im Auftrag des BWE e. V und INES e. V.
http://erdgasspeicher.de/files/20171212_studie_erneuerbare_gase.pdf

45 **German Institute for Economic Research** (2021)
100 Prozent erneuerbare Energien für Deutschland: Koordinierte Ausbauplanung notwendig.
https://www.diw.de/de/diw_01.c.821878.de/publikationen/wochenberichte/2021_29_1/100_prozent_erneuerbare_energien_fuer_deutschland_koordinierte_ausbauplanung_notwendig.html

46 **Statista** (2022)
Länge der Versorgungsunterbrechung je Stromverbraucher in Deutschland in den Jahren 2006 bis 2020.
https://de.statista.com/statistik/daten/studie/241414/umfrage/stromversorgungsunterbrechungen-in-deutschland/

47 **Federal Environment Agency** (2022)
Energieverbrauch nach Energieträgern und Sektoren.
https://www.umweltbundesamt.de/daten/energie/energieverbrauch-nach-energietraegern-sektoren#allgemeine-entwicklung-und-einflussfaktoren

48 **Federal Environment Agency** (2021)
Emissionsquellen.

https://www.umweltbundesamt.de/themen/klima-energie/treibhausgas-emissionen/emissionsquellen#energie-verkehr

49 **Federal Ministry for Digital Affairs and Transport** (2022)
Masterplan Ladeinfrastruktur II der Bundesregierung auf der Zielgeraden.
https://www.bmvi.de/SharedDocs/DE/Pressemitteilungen/2022/048-master-plan-ladeinfrastruktur-2.html

50 **German Wind Energy Association** (2022)
Genehmigungen erstmals wieder rückläufig.
https://www.wind-energie.de/presse/pressemitteilungen/detail/genehmigungen-erstmals-wieder-ruecklaeufig-turbo-fuer-beschleunigte-verfahren-fehlt/

51 **State Committee for Imission Control** (2002)
Hinweise zur Ermittlung und Beurteilung der optischen Immissionen von Windenergieanlagen (WEA-Schattenwurf Hinweise) – Arbeitsgruppe Schattenwurf.
www.lung.mv-regierung.de/dateien/wea_schattenwurf_hinweise.pdf

52 **German Wind Energy Association** (2017)
Repowering: Leistungsstärker, ruhiger, verträglicher.
https://www.wind-energie.de/fileadmin/redaktion/dokumente/publikationen-oeffentlich/themen/04-politische-arbeit/04-weiterbetrieb-repowering/20170508_informationspapier_repowering.pdf

53 **German Wind Energy Association** (2022)
BWE-Präsident Albers: Aus Vorsätzen echte Taten machen – Beschleunigungsgesetz jetzt!.
https://www.wind-energie.de/presse/pressemitteilungen/detail/bwe-praesident-albers-aus-vorsaetzen-echte-taten-machen-beschleunigungsgesetz-jetzt/

54 **VDI Zentrum Ressourceneffizienz GmbH** (2014)
Ressourceneffizienz von Windenergieanlagen.
https://www.ressource-deutschland.de/fileadmin/user_upload/downloads/kurzanalysen/2014-Kurzanalyse-VDI-ZRE-09-Ressourceneffizienz-Windenergieanlagen.pdf

55 **Vestas** (no date)
Zero Waste.
https://www.vestas.com/en/sustainability/environment/zero-waste

56 **Agora Wind Energy** (2018)
Toolbox für die Stromnetze.
https://www.agora-energiewende.de/de/themen/-agothem-/Produkt/produkt/471/Toolbox+f%C3%BCr+die+Stromnetze/

57 **Federal Government** (2020)
Die Nationale Wasserstoffstrategie.
https://www.bmwk.de/Navigation/DE/Wasserstoff/wasserstoffstrategie.html

58 **Fraunhofer Institute for Wind Energy and Energy System Technology** (2017)
Energiewirtschaftliche Bedeutung der Offshore-Windenergie für die Energiewende – Update 2017.
https://www.offshore-stiftung.de/sites/offshorelink.de/files/documents/Studie_Energiewirtschaftliche%20Bedeutung%20Offshore%20Wind.pdf

59 **Russel, D.J.F. et al.** (2014)
Marine mammals trace anthropogenic structures at sea.
Current Biology 24(14), 638 ff.

60 **Federal Ministry for the Environment, Nature Conservation and Nuclear Safety** (2013)
Konzept für den Schutz der Schweinswale vor Schallbelastungen bei der Errichtung von Offshore-Windparks in der deutschen Nordsee.
https://www.bfn.de/fileadmin/BfN/awz/Dokumente/schallschutzkonzept_BMU.pdf

61 **Ram, M., Bogdanow, D., Aghahosseini, A., Oyewo, S., Gulagi, A., Child, M., Breyer, C., Fell, H.-J.** (2017)
Global Energy System based on 100% Renewable Energy Power Sector. Study by Lappeenranta University of Technology and Energy Watch Group: Lappeenranta, Berlin.

62 **Ram, M., Bogdanow, D., Aghahosseini, A., Oyewo, S., Gulagi, A., Child, M., Breyer, C., Fell, H.-J.** (2017)
Global 100% RE System: Europe – Germany – Country Profile.

63 **Onshore Wind Energy Agency** (2022)
Umweltverträglichkeitsprüfung.
https://www.fachagentur-windenergie.de/themen/genehmigung/umweltvertraeglichkeitspruefung/

64 **Onshore Wind Energy Agency** (2022)
Zwei neue Studien zum Flugverhalten von Vögeln.
https://www.fachagentur-windenergie.de/aktuelles/detail/zwei-neue-studien-zu-flugverhalten-von-voegeln/

65 **German Wind Energy Association** (2021)
Windenergie im Forst.
https://www.wind-energie.de/fileadmin/redaktion/dokumente/publikationen-oeffentlich/themen/01-mensch-und-umwelt/03-naturschutz/20210831_BWE-Broschuere_Wind_im_Forst.pdf

66 **EnergieAgentur NRW** (2017)
Faktencheck Windenergie und Immobilienpreise. Dokumentation der Veranstaltung.
www.energiedialog.nrw.de/wp-content/uploads/2017/07/Eigenpublikation_Windenergie-Immobilienpreise_final.pdf

67 **Federal Institute for Research on Building, Urban Affairs and Spatial Development (ed.)** (2016)
Wohnungs- und Immobilienmärkte in Deutschland 2016. Analysen Bau.Stadt.Raum. Band 12. Bonn.

68 **Research Medien AG** (2014)
Der Immobilienbrief Nr. 321. Windkraft und Immobilienpreise.
Dr. Günter Vornholz (EBZ Business School)
www.rohmert-medien.de/wp-content/uploads/2014/05/Der-Immobilienbrief-Nr-321.pdf

69 **Expert Committee for Property Values, Aurich** (2016)
Grundstückmarktbericht 2016: Einfluss von Windkraftanlagen auf die Kaufpreise von Wohnimmobilien, Page 48.

70 **City of Aachen** (2011)
Hat der Windpark ‚Vetschauer Berg' Auswirkungen auf den Grundstücksmarkt von Wohnimmobilien in den Ortslagen Vetschau und Horbach? www.aachener-zeitung.de/lokales/aachen/windkraft-in-aachen-kein-einfluss-auf-die-immobilienpreise-1.389335

71 **NIT – Institute for Tourism and Spa Research in Northern Europe** (2014)
Einflussanalyse Erneuerbare Energien und Tourismus in Schleswig-Holstein.
http://www.nit-kiel.de/fileadmin/user_upload/NIT-ee-und-tourismus-sh-kurzfassung.pdf

72 **new energy** (09/2014)
Das Ziel heißt: Erneuerbar. Tourismus und Windkraft sind kein Gegensatz. J.-R. Zimmermann, Berlin 2014, S. 29ff.

73 http://www.bioenergiedorf.de/home.html

74 http://www.energielandschaft.de/

75 http://nef-feldheim.info/

76 **Frey, Martin** (2014)
Deutschland. Erneuerbare erleben. Zweite Auflage, Karl Baedecker Verlag.

77 **Bavarian Environment Agency** (2014)
UmweltWissen. Windkraftanlagen – beeinträchtigt Infraschall die Gesundheit?, S. 6.
https://www.lfu.bayern.de/buerger/doc/uw_117_windkraftanlagen_infraschall_gesundheit.pdf

78 **VTT Finnland** (2020)
Infrasound Does Not Explain Symptoms Related to Wind Turbines.
https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/162329/VNTEAS_2020_34.pdf?sequence=1&isAllowed=y

79 **Baden-Württemberg State Institute for the Environment, Survey and Nature Conservation** (2016)
Tieffrequente Geräusche und Infraschall von Windkraftanlagen und anderen Quellen. S. 17ff.
www4.lubw.baden-wuerttemberg.de/servlet/is/223628/

80 **Federal Environment Agency** (2014)
Machbarkeitsstudie zu Wirkungen von Infraschall. Entwicklung von Untersuchungsdesigns für die Ermittlung der Auswirkungen von Infraschall auf den Menschen durch unterschiedliche Quellen. S. 114f
www.umweltbundesamt.de/sites/default/files/medien/378/publikationen/texte_40_2014_machbarkeitsstudie_zu_wirkungen_von_infraschall.pdf

81 **Onshore Wind Energy Agency** (2016)
Bedarfsgerechte Nachtkennzeichnung von Windenergieanlagen.
https://www.fachagentur-windenergie.de/fileadmin/files/Befeuerung/FA-Wind_Hintergrundpapier_BNK_2016-07-27.pdf

82 **German Wind Energy Association** (2020)
Bedarfsgesteuerte Nachtkennzeichnung von Windenergieanlagen. https://www.wind-energie.de/index.php?eID=dumpFile&t=f&f=5230&token=ad29d1be6ac877bc2cfd84c2ca4c3f99c7c36116

83 **Federal Agency of the Environment** (2022)
Erneuerbare Energien in Zahlen. https://www.umweltbundesamt.de/themen/klima-energie/erneuerbare-energien/erneuerbare-energien-in-zahlen#ueberblick

84 **Federal Agency of the Environment** (2022)
Erneuerbare Energien – Vermiedene Treibhausgase.
https://www.umweltbundesamt.de/daten/energie/erneuerbare-energien-vermiedene-treibhausgase#undefined

85 **Fraunhofer ISE Institute** (2022)
Öffentliche Nettostromerzeugung in Deutschland im Jahr 2021.
https://www.energy-charts.info/downloads/Stromerzeugung_2021.pdf

86 **Global Wind Energy Council** (2022)
Global Wind report 2022.
https://gwec.net/global-wind-report-2022/

87 **German Wind Energy Association** (2022)
Status des Windenergieausbaus an Land 2021.
https://www.wind-energie.de/fileadmin/redaktion/dokumente/publikationen-oeffentlich/themen/06-zahlen-und-fakten/Factsheet_Status_Windenergieausbau_an_Land_2021.pdf

88 **German Wind Energy Association** (2022)
Beschäftigte in der Windindustrie.
https://www.wind-energie.de/themen/zahlen-und-fakten/deutschland/

89 **International Renewable Energy Association** (2022)
Renewable Energy and Jobs - Annual Review 2021.
https://www.irena.org/publications/2021/Oct/Renewable-Energy-and-Jobs-Annual-Review-2021

90 **Own calculation according to the German Agency for statistics** (2021)
Genesis Online Datenbank.
https://www-genesis.destatis.de/genesis/online?sequenz=statistikTabellen&selectionname=51000#abreadcrumb

91 **Deutscher Bundestag** (2022)
Entwurf eines Gesetzes zu Sofortmaßnahmen für einen beschleunigten Ausbau. https://dserver.bundestag.de/btd/20/016/2001630.pdf

92 **Deutscher Bundestag** (2022)
Entwurf eines Gesetzes zur Erhöhung und Beschleunigung des Ausbaus von Windenergieanlagen an Land. https://dserver.bundestag.de/btd/20/023/2002355.pdf

93 **German Renewable Energies Agency** (2021)
Akzeptanzumfrage 2021: Klimapolitik - Bürger*innen wollen mehr Erneuerbare Energien.
https://www.unendlich-viel-energie.de/themen/akzeptanz-erneuerbarer/akzeptanz-umfrage/akzeptanzumfrage-2021-klimapolitik-%e2%80%93-buergerinnen-wollen-mehr-erneuerbare-energien

94 **German Wind Energy Association** (2022)
Status des Windenergieausbaus an Land 2021.
https://www.wind-energie.de/fileadmin/redaktion/dokumente/publikationen-oeffentlich/themen/06-zahlen-und-fakten/Factsheet_Status_Windenergieausbau_an_Land_2021.pdf

95 **Siemens Gamesa** (2022)
SG 14-222 DD Offshore Windturbine.
https://www.siemensgamesa.com/products-and-services/offshore/wind-turbine-sg-14-222-dd

96 **Vestas** (2022)
V172-7.2 MW™ at a glance
https://www.vestas.com/en/products/enventus-platform/V172-7-2-MW

German Wind Energy Association (BWE)
represented by the President

Euref Campus 16
10829 Berlin

info@wind-energie.de
Tel. +49 (0)30 212341-210
Fax +49 (0)30 212341-410

9th updated and revised edition, September 2022

BWE

German Wind Energy Association

This brochure can be downloaded free of charge from www.wind-energie.de or ordered from the BWE shop at www.wind-energie.de/shop.