Siemens D6 platform – 6.0-MW direct drive wind turbine

The new standard for offshore

Answers for energy.

Siemens, the offshore leader

Siemens has been a major driver of innovation in the wind power industry since 1980 when wind turbine technology was still in its infancy.

Technology has changed with the times, but Siemens' commitment to providing its customers with proven wind turbine solutions remains the same.

In recent times, the world has seen an intense increase in the nature and capacity of offshore wind power plants. Given the logistical challenges of offshore projects where even the smallest issue can amplify costs, having technology that works and continues to work is paramount. Exactly the right task for us.

Drawing on more than 30 years of experience in the wind power industry, a strong focus on renewables, and a global network of highly skilled and trained employees, Siemens has proven itself to be a trustworthy and reliable business partner and will continue to do so in the future.

In 1991, we installed the world's first offshore wind farm at Vindeby in Denmark. From these modest beginnings to today, Siemens benefits from a track record that makes it the world leader in offshore applications. As the choice of the world's largest offshore wind power plant – London Array – Siemens' geared wind turbines are paving the way for green energy to become the cornerstone of the global energy mix.

Over the years, Siemens has accumulated vast service experience offshore. Drawing on this substantial knowledge, the company has established a flexible range of service solutions that are designed to optimize the output of offshore wind turbines.

Prototype of the SWT-6.0-154

Intelligent ways to drive down the cost of electricity

Wind power is coming of age. It could soon be directly competitive with traditional energy sources. Driving down the levelized cost of wind energy is a key target for Siemens as we strive to make wind power independent of subsidies.

Innovation and industrialization are the main drivers of this. And our new platform strategy, founded on the knowledge and experience of more than 30 years in wind power, is a milestone along this path.

Standardization and modularization are fundamental to the new platform approach – because they allow us to streamline the entire manufacturing and installation process. The organization of our product platforms into categories allows standardized modules – such as rotors, generators, towers, and hubs – to be used with different products. The total number of different components is thus kept to a minimum.

Each of our products is now a member of one of four platforms: the Siemens G2, Siemens D3, Siemens G4, and Siemens D6. "G" denotes geared turbines, "D" signifies direct drive technology, and the associated numbers represent the predominant power rating.

Therefore, the D6 platform comprises offshore direct drive wind turbines with a power rating of 6.0-MW.

Reduced complexity, outstanding performance

The Siemens 6.0-MW wind turbines of the D6 platform embody tried and tested innovation in the field of direct drive generators, with hundreds of units already installed and operational. The Siemens D6 platform redefines the wind industry standards for leanness, robustness, and lifecycle profitability.

Based on Siemens' direct drive technology, 6.0-MW wind turbines have 50 percent fewer moving parts than comparable geared machines and a tower head mass of less than 360 tons. This unique combination of robustness and low weight significantly reduces infrastructure, installation, and servicing costs, and boosts lifetime energy output.

The 154-meter rotor, designed specifically for the Siemens 6.0-MW wind turbine, has a swept rotor area of 18,600m^2. It therefore maximizes energy yield at offshore locations, from inland waters with moderate wind resources to the most exposed offshore sites.

Lean, robust, and reliable technology

Lean

The Siemens 6.0-MW turbine of the D6 platform is based on proven Siemens direct drive technology: the simplest and most straightforward wind turbine design. Replacing the gearbox, the coupling, and the high-speed generator with a low-speed generator eliminates two-thirds of the conventional drivetrain arrangement.

As a result, the number of rotating and wear-prone parts is vastly reduced, with 50 percent fewer parts than a comparable geared machine. The associated reduction in maintenance requirements is crucial in offshore applications. Until now, the weight of large wind turbines has grown disproportionately to increases in power rating. The Siemens D6 platform has conclusively broken this trend.

With a tower head mass of less than 60 tons per megawatt, the D6 wind turbine is genuinely lean. This new low-weight standard for offshore wind turbines offers significant cost benefits in terms of substructure requirements, shipping, and installation. All of this is made possible thanks to Siemens' proven direct drive technology.

Robust

Benefiting from our unique offshore experience, the D6 platform is designed to exploit the broadest range of offshore environmental conditions. Designed to IEC I standards, the D6 platform can be deployed in any known offshore location.

The structural capacity of all components is verified by full-scale testing. Highly Accelerated Lifetime Tests on all main components and the entire nacelle demonstrate their robustness. The entire turbine design is tailored to offshore applications: all external surfaces and systems feature offshore-grade corrosion protection, and the completely enclosed nacelle is fitted with internal climate control.

Reliable

The Siemens D6 platform is designed to both maintain and enhance the legendary reliability of Siemens wind turbines. Simple and robust, the direct drive technology offers the best possible basis for this. The rotor blades combine lightness and strength through single-cast Siemens IntegralBlade® production.

The nacelle, housing every part of the power system, forms a self-contained unit delivering medium voltage power to the wind farm grid. This allows turbines to be fully precommissioned onshore, leaving only final connection to be performed after installation.

Finally, the maintenance process has been reinvented too: complete with crane and extra space, the nacelle has been repurposed as an on-site workshop.

Proven technology, advanced performance

Grid performance with the Siemens NetConverter®

Siemens sets the standard in the field of grid compliance. Power conversion is implemented by the Siemens' NetConverter® system. This system is characterized by full conversion of the power generated, efficiently decoupling generator and turbine dynamics from the grid.

The NetConverter® system offers maximum flexibility in the turbine's response to voltage and frequency control, fault ride-through, and output adjustment. As a result, Siemens wind turbines can be configured to comply with a variety of relevant grid codes in major markets and can be readily connected to the grid.

Siemens IntegralBlade® technology

The 154-meter rotor uses blades manufactured with Siemens' unique, patented IntegralBlade® technology.

The blades are made in one piece from fiberglass-reinforced epoxy resin during a single production step. As a result, all glue joints – the potential weak points that could expose the structure to cracking, water ingress, ice formation, and ightning damage – are eliminated.

Siemens WebWPS SCADA system

Via a standard Web browser, the Siemens WebWPS SCADA system provides a variety of status views of electrical, mechanical, meteorological, and grid station data as well as operation and fault status.

Wind turbine condition monitoring

Siemens' turbine condition monitoring system compares the vibration levels of the main nacelle components with a set of established reference spectra and instantly detects deviations from normal operating conditions.

This allows Siemens to proactively plan the service and maintenance of the wind turbines, as any unusual event can be categorized and prioritized based on severity.

Turbine Load Control (TLC)

The Turbine Load Control system continuously monitors the structural loading on the wind turbine. In case the loads exceed normal values, the turbine automatically regulates operation to bring loads back within the design envelope.

High Wind Ride-Through (HWRT)

Wind turbines are normally programmed to shut down if the 10-minute mean wind speed exceeds 25 m/s. This may lead to significant challenges for the grid system if the turbines in large wind farms are shut down more or less simultaneously.

The Siemens D6 platform enhances grid stability thanks to High Wind Ride-Through – an optional feature of the D6 platform. This replaces the fixed high-wind shutdown threshold with an intelligent load-based reduction in output power at some storm-level wind speeds.

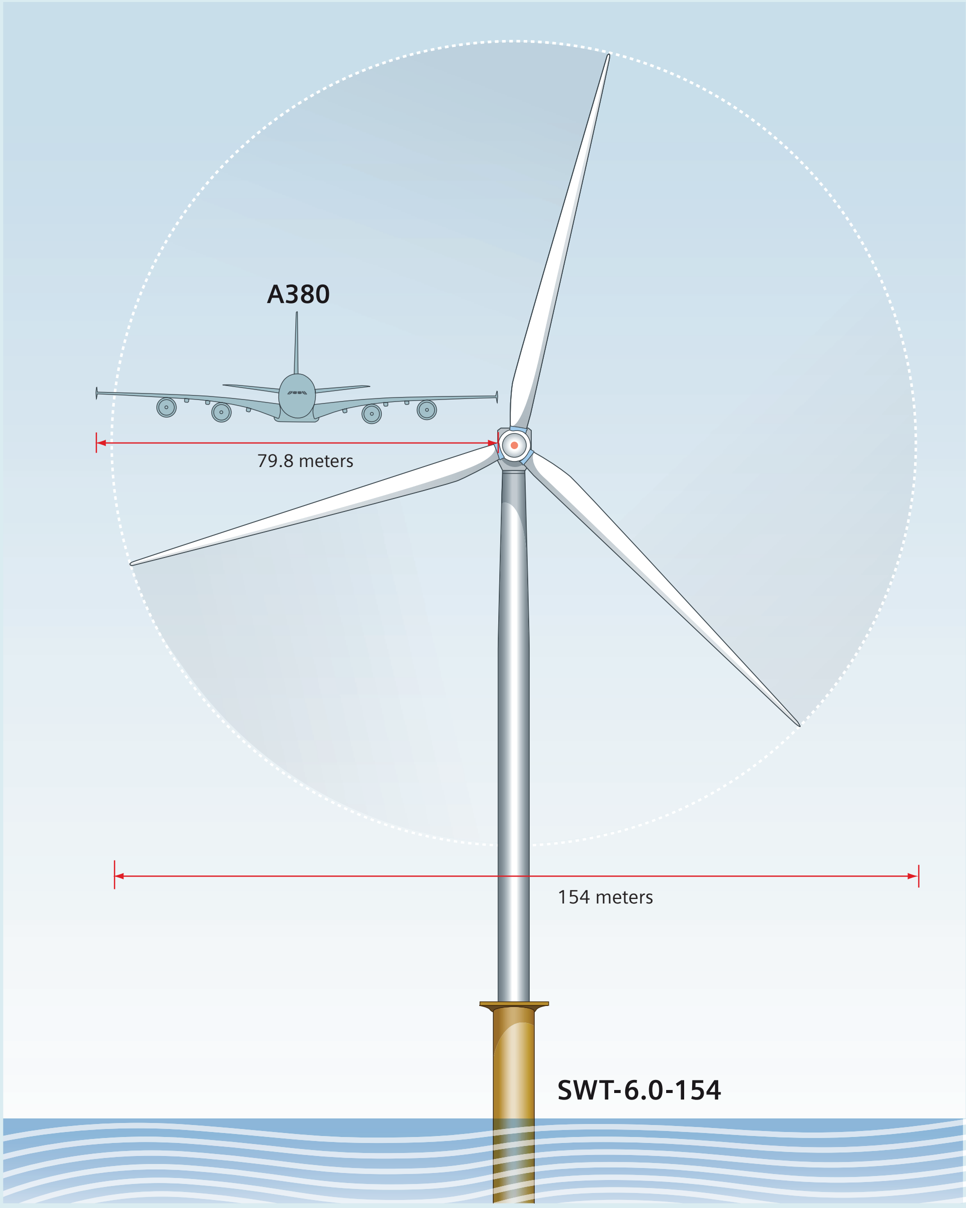
Service

From the highly qualified local technician to the senior engineer at service headquarters, it is the Siemens service team's track record and the vast amount of experience gained over time that makes the difference.

Siemens offers tailor-made service solutions for each of our turbine platforms, e.g. the SWPS-420O and the SWPS-430O service solutions for our offshore wind turbines.

Further improvements in safety

Safety is at the heart of all Siemens operations. From production to installation, operation, and service, Siemens strives to set the standard for a zero-harm culture. Onshore precommissioning and testing significantly reduce the amount of work that needs to be done in riskier offshore conditions. While the simplified direct drive concept in itself reduces service requirements, offshore maintenance has been completely rethought. Service technicians can enter the turbine via the heli-hoist platform or via conventional tower access, and here a new gangway system enables safer access in rough sea conditions. The spacious nacelle, housing far fewer parts than usual, provides technicians with optimized access to all key components.



SWT-6.0-154	
IEC Class	IA
Nominal power	6,000 kW
Rotor diameter	154 m
Blade length	75 m
Swept area	18,600 m^2
Hub height	Site specific
Power regulation	Pitch regulated, variable speed
Tower head mass	360 tons

For maximum output

The 154-meter rotor, designed specifically for the Siemens D6 platform, uses the B75 blade. This is currently the world's longest blade in operation, with a swept rotor area of 18,600 square meters. It therefore maximizes energy yield at offshore locations: from inland waters with moderate wind resources to the most exposed offshore sites.

Through optimized infrastructure, installation, and service, the D6 platform is the perfect choice for a reliable and profitable investment that helps drive down the cost of offshore wind energy.

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SIEMENS

Environmental Product Declaration

A clean energy solution – from cradle to grave

Offshore wind power plant employing SWT-6.0-154

siemens.com/wind

Assessing the performance of a wind power plant

The environmental impact of wind power

The world today faces the challenge of meeting growing demand for energy while reducing greenhouse gas emissions. One solution is to increase the contribution of renewable energy systems such as wind, sun, or biomass to the electricity mix. Siemens Wind Power is pioneering this approach by offering an extensive wind turbine portfolio that includes the SWT-6.0-154 direct drive turbine.

Siemens has performed a Life Cycle Assessment (LCA) of an offshore wind power plant employing SWT-6.0-154. The LCA evaluated the inputs, outputs, and potential environmental impacts that occur throughout the wind power plant lifecycle. It encompasses raw material extraction, materials processing, manufacturing, installation, operation and maintenance, and dismantling and end-of-life.

The results are presented in this Environmental Product Declaration (EPD) in order to communicate the impacts of our wind power plant to our stakeholders. All results are verified by internal reviews. The international ISO 14021 standard (Environmental labels and declarations – Self-declared environmental claims – Type II) is the basis for this EPD. The data presented has been derived from a full-scale LCA in accordance with ISO 14040.

Designed to deliver clean energy

Offshore wind power plant

Each wind power plant has specific site constraints that influence the choice of turbine, tower height, foundation size, and infrastructure.

This EPD is based on a full-scale LCA of an average European offshore wind power plant with 80 SWT-6.0-154 turbines installed. It includes wind turbine components such as a nacelle, rotor, and tower, as well as the foundation, cables to grid, and substation.

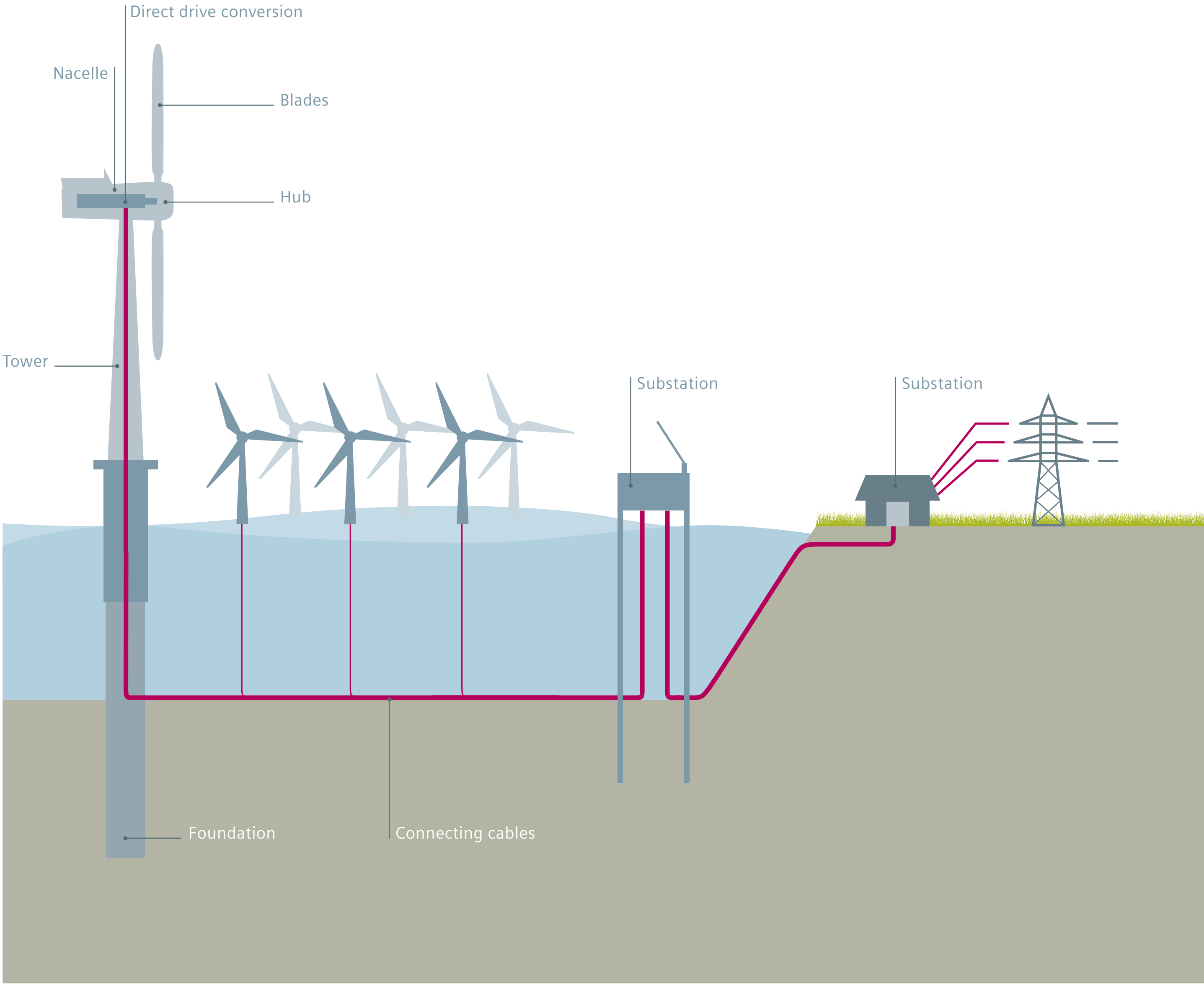
The functional unit for this LCA is defined as 1 kWh of electricity delivered to the grid.

The identified average wind speed is relative to the turbine IEC classification. Class I: 10 m/s for SWT-6.0-154.

Product and system description, including main components

Product and system description	Main characteristics
Turbine	SWT-6.0-154
Number of turbines in wind power plant	80
Expected lifetime	25 years
Expected average wind speed	10 m/s
Distance to shore/shore to grid	50 km/22 km
Annual energy production to grid per turbine (wake, availability and electrical losses of 15% substracted)	Approx. 26,500 MWh
Estimated energy production of the wind power plant in 25 years	53,000,000 MWh
Nacelle	6.0 MW DD (steel, iron, copper)
Blades	75 m (fiberglass, epoxy)
Tower	88 m (steel)
Foundation	925 t (steel)
Substations	12,700 t (steel, concrete)

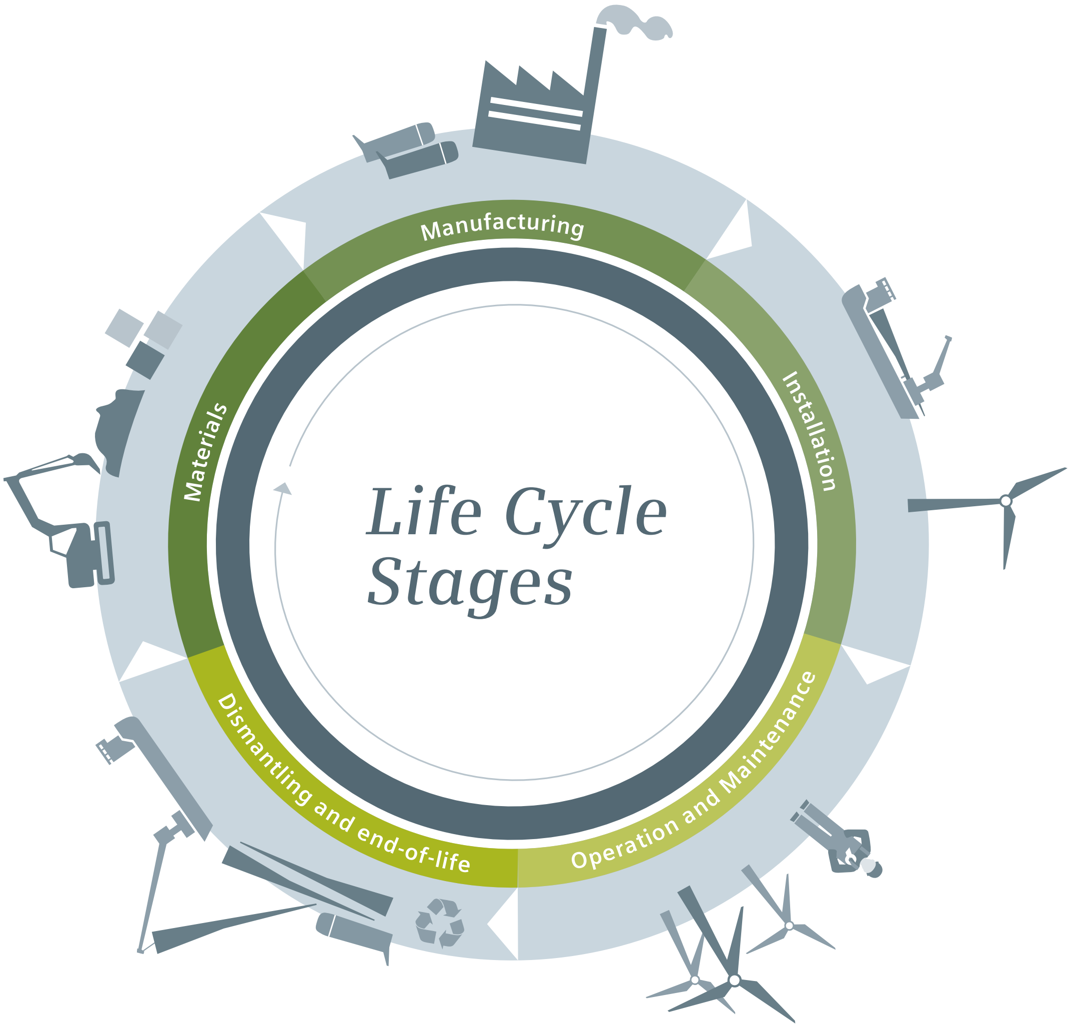
System boundaries for an offshore wind power plant



From cradle to grave

Life cycle of a wind power plant

The lifecycle has been divided into five main stages: Materials, Manufacturing of the main parts; Installation; Operation and Maintenance; Dismantling, Recycling, and Disposal at the end-of-life. Relevant transport activities and energy consumption were included in each life cycle stage.



Materials

We identified the types and quantities of materials and energy that had to be extracted and consumed to produce the turbine components and the elements needed to connect the wind power plant to the grid.

Manufacturing

We collected data from Siemens' own production sites and from main suppliers. Consumption data for manufacturing as well as waste and subsequent treatment is based primarily on annual manufacturing data from European production sites. Transport of materials to the manufacturing site is included in the data.

Installation

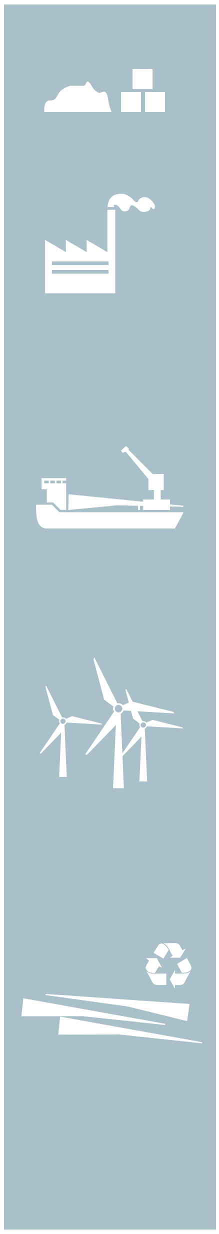
Components, auxiliary resources, and workers are transported to the site during this stage. On-site installation includes preparing the site; erecting the turbines; and connecting the turbines to the grid. These installation activities result in the consumption of resources and production of waste. Associated data has been collected from actual on-site installations.

Operation and Maintenance

The structural design lifetime of a SWT-6.0-MW turbine is designed to last 25 years. We collected actual site data, including manpower, materials, and energy required for service and maintenance over the turbine's lifetime. Wake, availability, and electrical losses have been included in our assessment to define a realistic estimate of annual energy production delivered to the grid.

Dismantling and end-of-life

At the wind power plant's end-of-life the components will be disassembled and the materials transported and treated according to different waste management systems. For the turbine components, we assumed that recycling would apply to all recyclable materials; for example, metals. Recycling leads to the recovery of materials, which subsequently reduces primary material extraction. The rest of the materials are either thermally treated or disposed of in landfills. The end-of-life stage described here represents the current status of waste management options in Northern Europe.

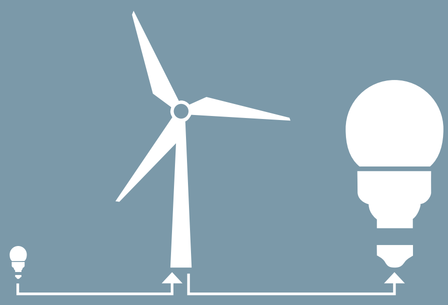


Environmental footprint

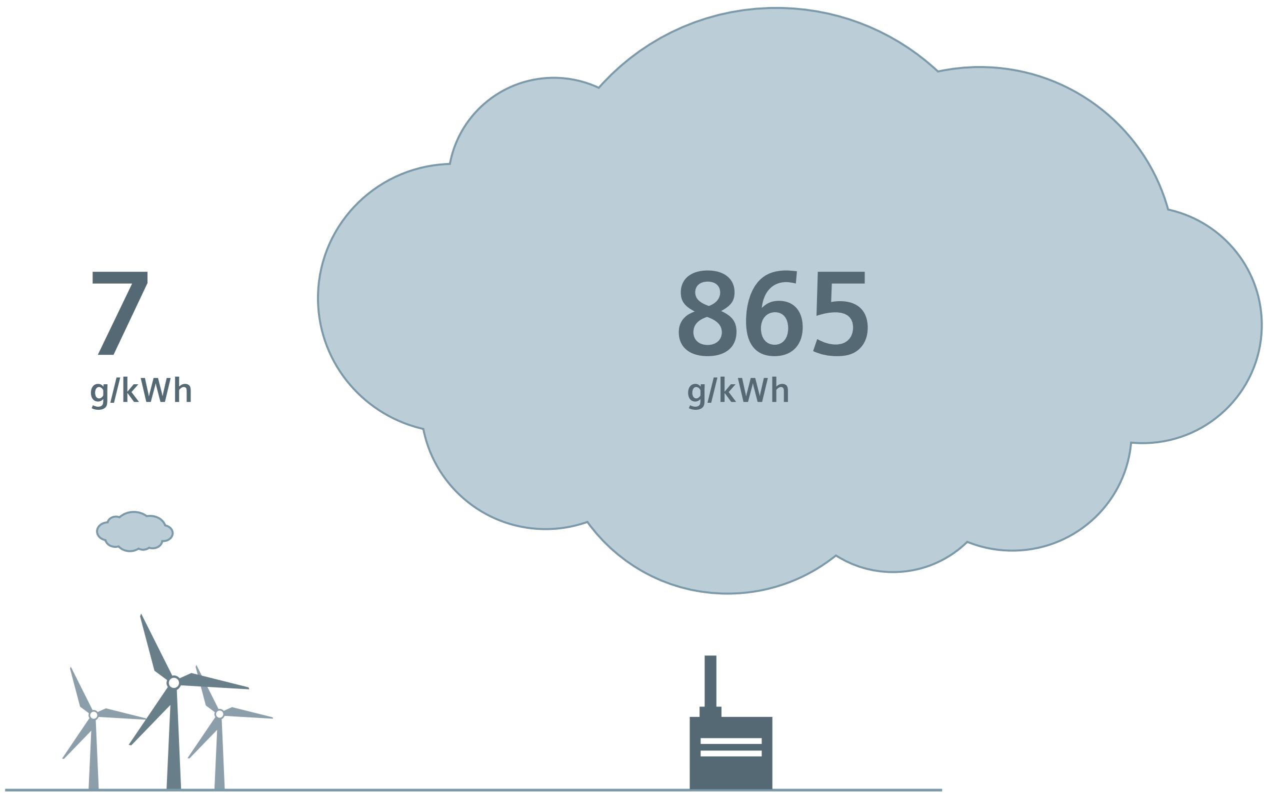
Low greenhouse gas emissions
Greenhouse gases such as CO_2 and methane contribute to global warming. Electricity produced by wind turbines contributes significantly less to global warming than electricity produced by fossil fuels. During its lifetime, the wind power plant emits less than 1% of the CO_2 emitted per kWh by an average power plant using fossil fuels.

What is "global warming"?
Global warming is an environmental impact caused by the increased concentration of greenhouse gases in the atmosphere. Each of these gases radiates different amounts of heat, which can be quantified in units of carbon called carbon dioxide-equivalent (CO_2eq). (IPCC ref)

9.5 months energy payback time
The energy payback time for the wind power plant in this assessment is less than 9.5 months. That is the length of time the wind power plant has to operate in order to produce as much energy as it will consume during its entire lifecycle.



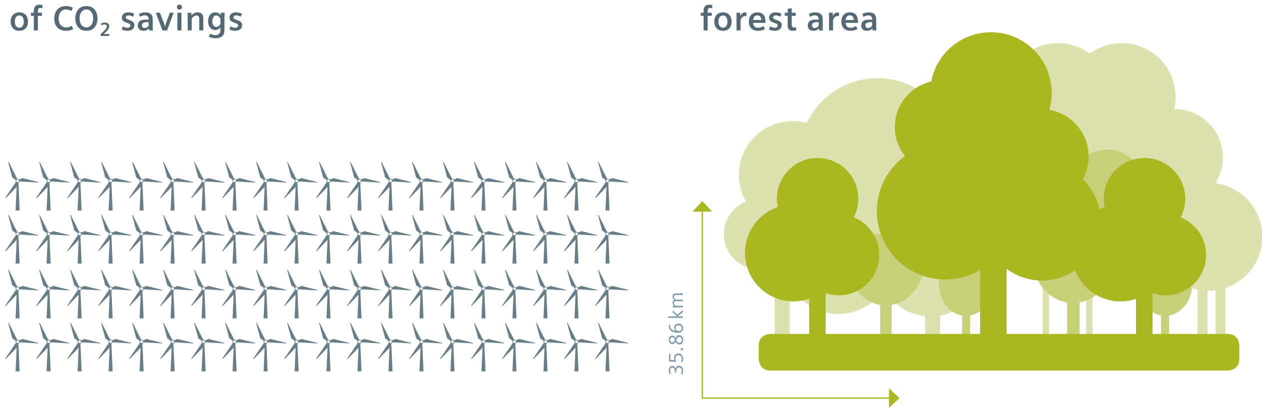
During its entire lifecycle the wind power plant produces 33 times more energy than it consumes.



CO_2 emissions from the wind power plant versus global fossil power production (IEA World Energy Outlook, 2012)

45,000,000 t
of CO_2 savings

1,286 km²
forest area



80 turbines, 25 years

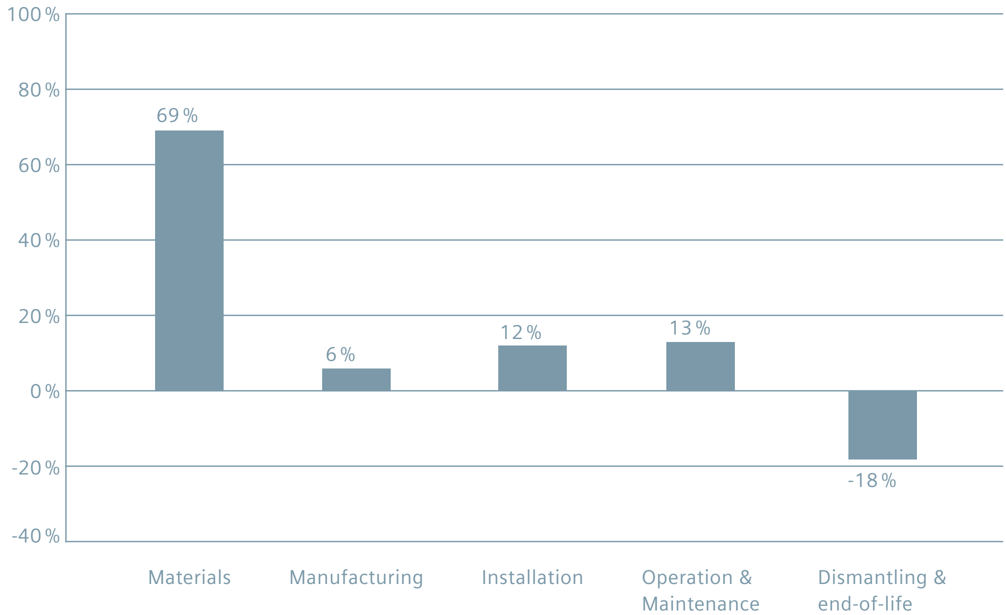
During its estimated lifetime the wind power plant produces 53,000,000 MWh and saves 45,000,000 tonnes of CO_2, which is equal to the amount of CO_2 absorbed by a forest with an area of 1,286 km² over 25 years.

Every stage counts

Contributions to global warming

To examine how much each stage of the wind power plant's life cycle contributes to global warming, we assessed their specific CO_2 emissions (figure below).

Percentage of global warming contribution from each life cycle stage ($g\ CO_2eq/kWh$)

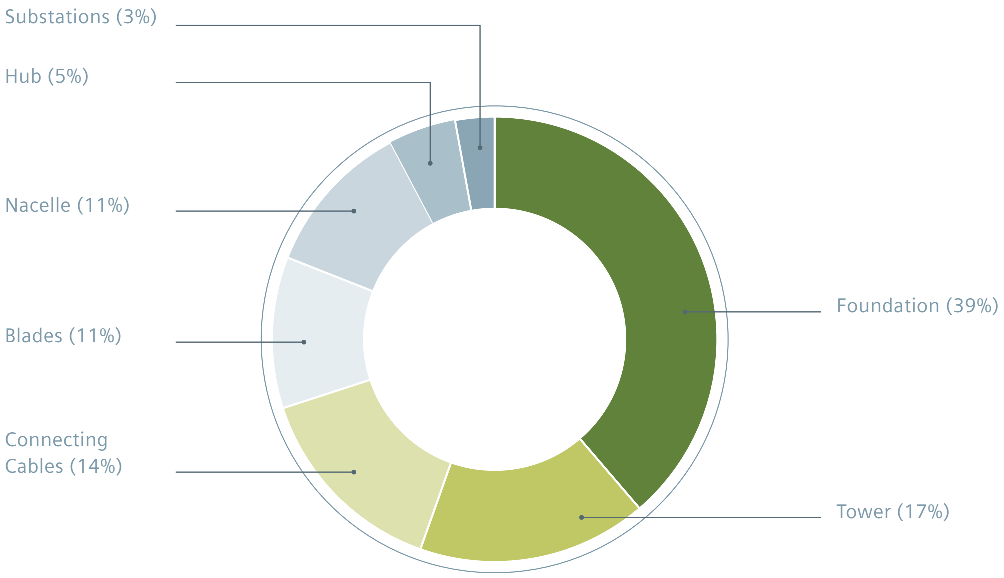


The main contributor to global warming is the Material stage (69%) because of emissions during material extraction. There are almost no emissions during wind power plant operation, and there is even an offset to emissions at end-of-life because so many of the materials are recyclable.

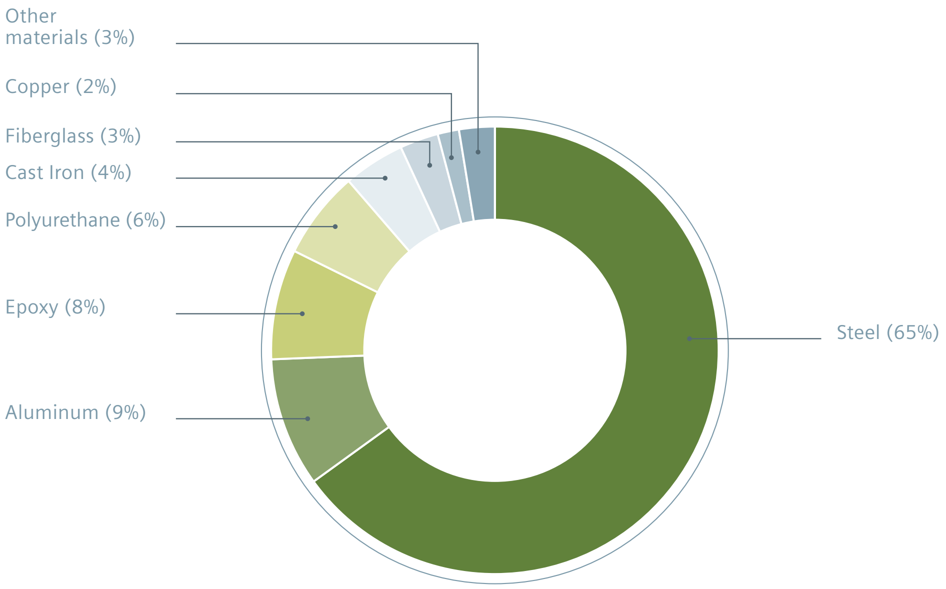
Component and material group contribution to CO_2eq emission

Each component and material group contributes to the total CO_2eq emissions of the wind power plant. Among the components, the turbine's tower and foundation contribute more than 50%, followed by connecting cables, blades and nacelle. In terms of material group contribution, steel has the highest impact on global warming, followed by aluminum and epoxy. The category with other materials consists of minerals, various plastics, chemicals, and wood.

Global warming contribution of main components in the wind power plant (CO_2eq)



Global warming contribution per material group in the wind power plant (CO_2eq)



Taking a holistic view

Assessing additional impact categories
Environmental sustainability also concerns problems other than climate change; for example, chemical pollution and resource depletion.

Electricity produced by a wind power plant can be assessed for different environmental impact categories. Such an assessment shows that focusing solely on reducing the greenhouse gas emissions raises the risk of increasing other environmental impacts. In this EPD we have chosen to present five different categories that are relevant to infrastructure projects.

The resource- and toxicity-related impacts were assessed using Impact 2002+v2.1 and USEtox v1.01.

Definitions of most relevant environmental impact categories

Global warming:
An environmental impact caused by the increased concentration of greenhouse gases in the atmosphere.

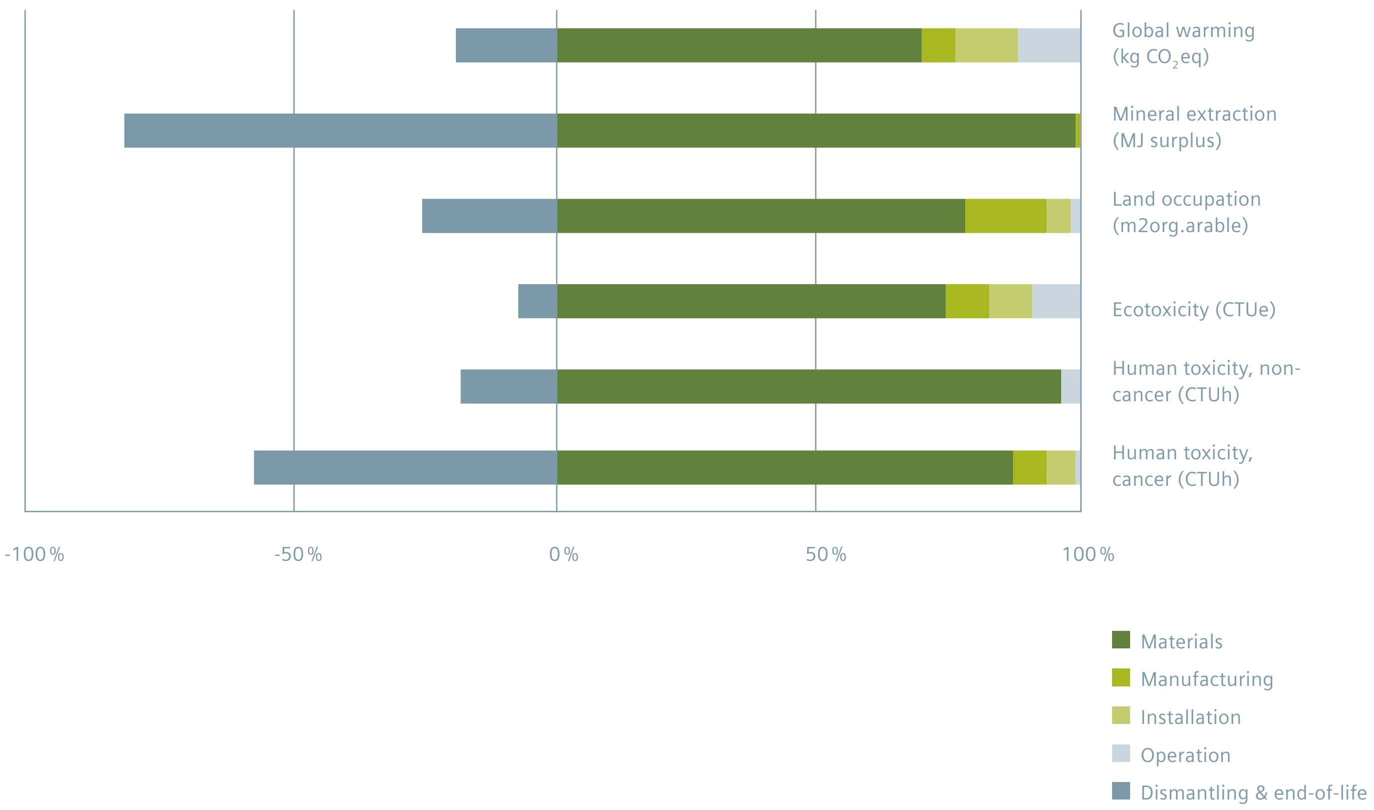
Mineral extraction:
The removal of minerals from the environment, which decreases their availability.

Land occupation:
The ecological damage to biodiversity resulting from land use. The damage is based on empirical observations of the number of plant and animal species affected per area type.

Ecotoxicity:
The toxic effects of natural or synthetic pollutants on flora and fauna.

Human toxicity:
The degree to which substances are toxic to humans.

Contribution of each Life Cycle Stage to the most relevant impact categories



Other environmental impacts

Planning a new wind power plant includes assessing the environmental impact of the installation and operation phases to minimize negative impacts. Often these assessments focus on birds, marine wildlife and visual impacts. How a wind power plant impacts its surroundings varies depending on its location and is not included in our LCA study.

End-of-life is not really the end

Recycling turbine materials
When wind turbines are dismantled, it is typically not because they have reached end-of-life but because they are replaced with larger turbines. Consequently, most dismantled turbines are refurbished and sold for installation elsewhere.

When disposing of wind turbines, recycling is the preferred solution. This not only prevents the materials from being sent to landfills, but also reduces the need for extracting of primary materials.

Options for recycling or disposal
The metals in the wind power plant components are to a great extent recycled at their end-of-life. The blades, which are made of epoxy and fiberglass, may be shredded and incinerated. The burning of epoxy generates energy, which can be recovered. The residues from fiberglass incineration can be used in other secondary applications e.g. for cement production. Magnets from the direct drive turbines can be demagnetized, remagnetized and reused or used for new magnet production. Increasing recyclability of the turbine components is high on our agenda and we continually participate in projects to support development of more recycling options.

Ready for the future

Siemens Wind Power strives to continually improve wind turbine performance by including environmental requirements in our design phase. We focus on increasing the annual energy output of the turbines and improving the material efficiency of their components.

Our improvement projects also focus on optimizing processes during manufacturing, installation, operation and maintenance, and dismantling and end-of-life. All these initiatives will contribute to even lower CO_2eq per kWh of electricity delivered to the grid.

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