A photograph of a white offshore wind turbine standing in the ocean. The turbine is partially obscured by large, white-capped waves crashing against its base. The sky is blue with scattered white clouds. The text 'Electricity from a European offshore wind farm using SG 14-222 wind turbines' is overlaid in white on the left side of the image.

Electricity from a European offshore wind farm using SG 14-222 wind turbines

Environmental Product Declaration according to ISO 14025
PCR 2007:08 - Electricity, steam, and hot water generation & distribution - Version 4.2
The International EPD® System, www.environdec.com
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Acronyms and abbreviations

AEP	Annual Energy Production
BoM	Bill of Materials
B2B	Business to Business
B2C	Business to consumer
EPD	Environmental Product Declaration
GPI	General Programme Instructions
HSE	Health, Safety & Environment
IUCN	International Union for Conservation of Nature
PCR	Product Category Rules
CPC	Central Product Classification
IEC	International Electro technical Commission
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LCoE	Levelized cost of energy
MW	Megawatt
WTG	Wind Turbine Generator

1. Introduction

1.1. Functional unit

This document represents the certified Environmental Product Declaration (EPD), of the electricity generated through an offshore wind farm of SG 14-222 wind turbine generators, located in an European scenario and operating under high wind conditions (IEC I wind class).

Siemens Gamesa is dedicated to both the design and the manufacturing of its wind turbines as well as to the installation commissioning and maintenance of the final product at the wind farm. Therefore, the company is fully aware of the entire life cycle of their products.

The functional unit, to which all outcomes are referred to is:

Functional unit

1 kWh net of electricity generated through an offshore wind farm of Siemens Gamesa SG 14-222 wind turbine generators, located in an European scenario and operating under high wind conditions (IEC I), and thereafter distributed to a 66 kV European electrical grid.

A total reference flow of 119,061,250 MWh has been used to refer all the inputs and outputs of the system to 1 single kWh. This reference flow represents the whole net electricity generation expected for 80 SG 14-222 WTG under high wind conditions during its service life, which has been set to 25 years.

Siemens Gamesa is able to supply different tower length, seeking a right placement of the rotor at the height which optimizes the energy harvested. The baseline scenario includes 116 meters high towers.

Wind energy is the most reliable and effective renewable energy to meet the growing electricity demand¹, with the foreseeable depletion of the non-renewable traditional energy resources. Furthermore, it is a guarantee of competitiveness, because in most countries is responsible for the lowering price of the energy pool.

Although having common features with other renewable energy sources -avoids CO₂ emissions, it is an inexhaustible resource and reduces the energy vulnerability of countries– its industrial character and maturity, with a developed technological learning curve, allows achieving very competitive market prices.

Wind energy will be the leading technology in transforming the global electricity supply structure towards a truly sustainable energy future based on indigenous, non-polluting and competitive renewable technologies.

¹ https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Renewable_energy_statistics

1.2. Environmental Declaration and the EPD system

An environmental product declaration is defined in ISO 14025 as the quantification of environmental data for a product with categories and parameters specified in the ISO 14040 standard series, but not excluding additional environmental information.

The international EPD® system (Environdec) has as main goal, the ambition to help and support organizations to communicate the environmental performance of their products (goods and services) in a credible and understandable manner.

Therefore, it offers a complete program for any organization interested in developing and communicating EPDs according to ISO 14025, also supporting other EPD programmes (i.e., national, sectoral, etc.) in seeking cooperation and harmonization and helping organizations to broaden the use of environmental claims on the international market.

Environmental Product Declarations add a new dimension to the market, offering information on the environmental performance of products and services. The use of EPDs, leads to a number of benefits for organizations that develop declarations of their own products as well as for those who make use of the information contained in these Environmental Product Declarations.

This EPD has been made in accordance with the standards of the International EPD Consortium. Environdec, is a system for international use of type III Environmental Declarations, according to ISO 14025. The international EPD® system and its applications are described in the General Program Instructions (GPI).

The documents on which this EPD is based are, in order of relevance:

- Product Category Rules 2007:08. Electricity, steam, and hot water generation & distribution. Version 4.2
- General Programme Instructions for Environmental Product Declarations, Ver. 3.01;
- ISO 14025:2010 - Type III environmental declarations;
- ISO 14040:2006 and ISO 14044:2006 on Life Cycle Assessment (LCA).

This EPD contains an LCA-based environmental behavior statement. It also contains additional environmental information, in accordance with the corresponding PCR 2007:08 - Electricity, steam, and hot water generation & distribution - Version 4.2:

- Information on the biodiversity protection;
- Information on land use and land cover classification in Europe;
- Information on environmental risks;
- Information on electromagnetic field generation;
- Information on the product noise;
- Information about the visual impact of the wind farm.

2. The company and the product

2.1. Siemens Gamesa Renewable Energy

Siemens Gamesa is a leading supplier of wind power solutions to customers all over the globe. A key player and innovative pioneer in the renewable energy sector, we have installed products and technology in more than 90 countries, with a total capacity base of over 84 GW installed globally and 25,000 employees.

Siemens Gamesa's end-to-end value chain expertise encompasses onshore and offshore wind turbine design, manufacturing, installation as well as cutting-edge service solutions.

Onshore

Siemens Gamesa Onshore offers an extensive range of wind turbine technologies to cover all wind classes and site conditions around the world. Continuous innovation, a dedication to technological excellence and solutions adapted to customer needs are the pillars of our portfolio, setting the foundation for Siemens Gamesa as a benchmark technologist. This is backed by validated and recognized products, as well as by more than 35 years of experience and over 75 GW installed across the globe.

Offshore

Siemens Gamesa Offshore is the most experienced player in offshore wind; pioneering the industry when installing the world's first offshore wind power plant, Vindeby in Denmark, in 1991. Since then, we have successfully installed approximately 3,000 offshore wind turbines with a combined capacity of more than 11.5 GW. These turbines have been installed in Denmark, UK, Germany, Norway, Sweden, Finland, The Netherlands, China, and Taiwan.

Services

Siemens Gamesa has a proven track record of excellence in operation and maintenance. Leveraging scale and global reach, we offer a flexible service portfolio that can be tailored to our customers' diverse operating models. We also provide advanced diagnostics and digitalization capabilities, as well as customized offshore services.

Siemens Gamesa business management system, is certified according to the following international standards:

- ISO 14001:2015 - Environmental management systems;
- ISO 14064-1:2018 - Greenhouse gases; According to Fiscal Year 2022
- ISO 9001:2015 - Quality management systems;
- ISO 45001:2018 - Occupational health and safety management systems

2.2. Product system description

The baseline system under study is an offshore SG 14 - 222 DD European wind farm, using 116 meters high towers. Since Siemens Gamesa started the LCA study, it was found interesting to extrapolate the results, as far as possible, to a test case of a European wind farm and not only to a specific site. The reason pursued, is to make the information extracted from this report useful to a wider audience. To achieve this goal, it has become necessary to create a generic wind farm model, representing a Siemens Gamesa European average client

2.2.1. The European SG 14-222 DD wind site

The differences between the environmental impacts caused by the commissioning of various wind farms rely primarily on two variables, the location and the size of the site. The location of the wind plant is directly related to the environmental impact caused during the distribution stage. The farther the wind farm is from the production centers, the more logistics needed.

The determination of the geographical location of the average offshore wind farm, is based on Siemens Gamesa's construction experience, leading to a default distance of 50 km between the final wind farm location and the shore of the preassembly site, which in this case has been considered to be at Esbjerg (Denmark).

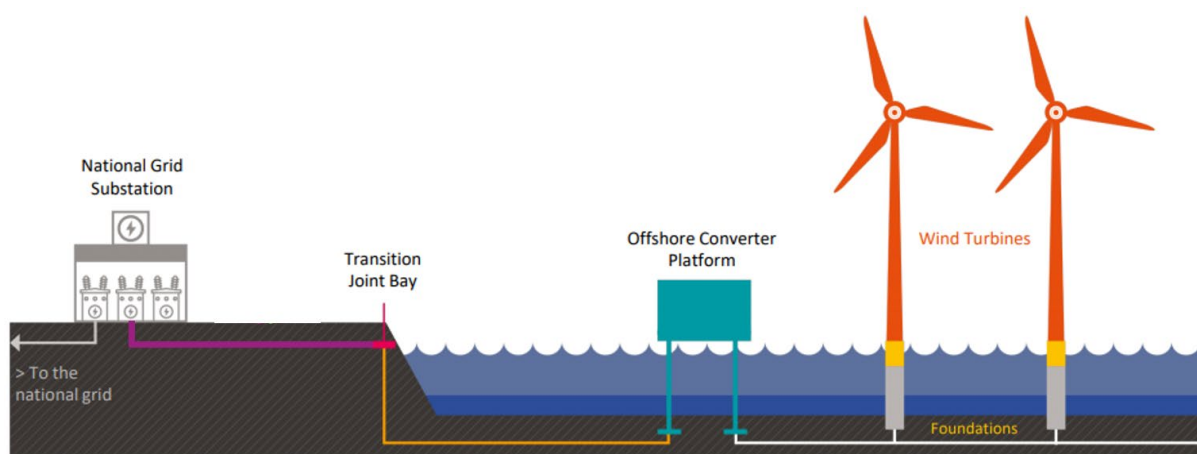


Figure 1.- Considered connections for the European average windfarm case

Once the energy is generated in the wind farm, it needs to be delivered to the customers through different electrical networks. This stage is known as the downstream module in the LCA. In this case, the downstream module covers the electricity losses from the windfarm until an average European customer connected to a 66 kV network. Moreover, the downstream module also includes the construction of the underground electrical lines from the wind farm shore until 22 Km away. This point constitutes the boundary of the analyzed system.

Regarding the size of the wind farm, the average size of an offshore wind site in Europe has been considered to be 80 turbines. Therefore, the installed power considered for the European average wind farm is set to 1,120 MW. When modelling the infrastructures shared by many wind turbines (i.e., transformer substation, internal wiring, connection infrastructure to the electrical network...) this average wind farm size of 1,120 MW installed has been used to reference all the values.

2.2.2. SG 14-222 Wind turbine

The new SG 14-222 DD is the next step towards producing clean and safe energy. With an unprecedented 14 megawatts capacity, and up to 15 megawatts with Power Boost, we offer proven technology to deliver sustainable energy.

We have enhanced and upgraded our proven Direct Drive technology. Raising the rating of our newest turbine to 14 megawatts has been made possible by increasing the rotor diameter to 222 meters – using the 108-meter-long B108 blades. This enables the SG 14-222 DD to offer an increase in Annual Energy Production (AEP) of more than 25 % compared to its predecessor in similar conditions.

SG 14-222 DD	
IEC class	I, S
Nominal power	14 MW
Rotor diameter	222 m
Blade length	108 m
Swept area	39,000 m ²
Hub height	Site-specific
Power regulation	Pitch-regulated, variable speed

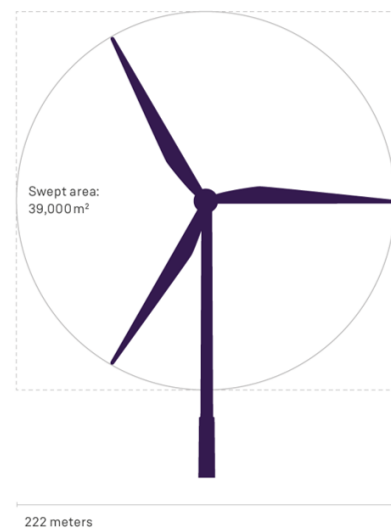


Figure 2.- SG 14-222 WTG Technical specifications

We strive to make a difference, and we are committed to safely maximizing operational performance while minimizing technological risks. Our focus on development and extensive testing leads us to the goal of reducing the Levelized Cost of Energy (LCoE). From both an environmental and a financial point of view, we are committed to driving the offshore wind industry to levels where clean energy becomes the indisputable global choice for power generation.

Direct Drive technology, IntegralBlade® technology, tower concepts, as well as maintenance and safety systems, have evolved over generations of Siemens Gamesa offshore wind turbines. Features such as High Wind Ride Through and the Power Boost function enable our turbines to produce even more energy while maintaining an industry-leading availability.

We ensure unmatched reliability through extensive testing in one of the world's largest dedicated wind turbine test centers. With every new generation of our offshore Direct Drive technology, component improvements allow for greater performance while maintaining the proven dependability of the technology.

The expected service life of the product is stated in 25 years, not considering Siemens Gamesa's life extension program which can significantly enhance this period of time. For the present LCA, a life cycle model has been created, using 116 m high towers.

2.2.3. Electricity transmission and distribution infrastructure

Once the wind is converted into electricity by the SG 14-222 wind turbine, the energy is delivered to each consumer through the electrical transmission and distribution network. This electrical transport stage also entails some environmental impacts that cannot be left out.

On one hand, the environmental impacts associated with the construction and dismantling of the infrastructure needed to transport all the electricity generated by the WTGs, must be considered. The materials used to build these electrical lines, depend on the voltage level of the electricity being transported in each step, from the power generation until later consumption.

Furthermore, the electrical losses which occur as a result of the inevitable heating of electric wires during transport and in the successive voltage transformations that occur until the consumption point, cannot be avoided. All these impacts have also been considered in the system under study.

The WTG generates low voltage electricity. This voltage is increased in the transformer located inside the backend reaching medium voltage level to minimize electricity losses. At the exit of the wind farm there is another transformer station allowing the delivery of high voltage electricity (66 kV) to the general network.

The distance between the wind farm transformer station and the connection point to the electrical grid is a variable value dependent on the specific location. According to previous Siemens Gamesa experiences in an European context, this value was assumed to be 22 km average, which is the length of the line modeled for the LCA. The environmental impacts of building and dismantling this electricity transmission line have been taken from the Ecoinvent 3.8 (cut-off) LCI database. Ecoinvent estimates a technical service life for this kind of line of 30-40 years, over the windfarm technical life cycle.

It should also be noted, that Siemens Gamesa is not a company dedicated to the energy distribution business. Instead, it is dedicated to the manufacture of wind turbine generators, so that the environmental impacts of this stage are inside the wind energy life cycle, but outside of the direct range of the Siemens Gamesa activities.

3. Environmental performance based on LCA

3.1. Life cycle assessment methodology

As stated in ISO 14025:2010 (Environmental labels and declarations - Type III environmental declarations - Principles and procedures), the environmental impact data outlined in an Environmental Impact Declaration EPD, are part of the results obtained from an analysis following the Life Cycle Assessment methodology.

The LCA methodology, which has been followed when conducting this study is a procedure based on the international standards ISO 14040, ISO 14044 and the Product Category Rules 2007:08 - Electricity, steam, and hot water generation & distribution - Version 4.2. The evaluated product category code is CPC 171 standing for electrical energy generation.

With the use of the LCA method we are able to obtain a complete breakdown of the elementary inputs and outputs which compose our product system along its whole life cycle. These inputs and outputs are given in as raw material consumption or as different kind of emissions, and are the indicators showing

the real interaction of the analyzed product with nature. Besides, the LCA methodology also allows us to obtain global results associated to different environmental impact categories such as global warming potential, acidification potential, eutrophication potential or photochemical ozone creation potential, if we apply different characterization methods.

The LCA only quantifies information on environmental impacts, leaving apart social and economic indicators. In the same way, some environmental impacts associated with the product life cycle as land use, biodiversity protection, electromagnetic fields, noise, visual impact or accidental risks cannot be identified from the LCA perspective. For this reason, these environmental impacts will be individually analyzed in section 4 of this EPD (“Additional environmental impact”).

3.2. System boundaries and data sources

This Environmental Product Declaration reflects the cradle-to-grave life cycle impact of the electricity generated through an offshore wind farm using SG 14-222 wind turbines, located on an European scenario, operating under high wind conditions (IEC I) and thereafter distributed to an European 66 kV power transmission grid.

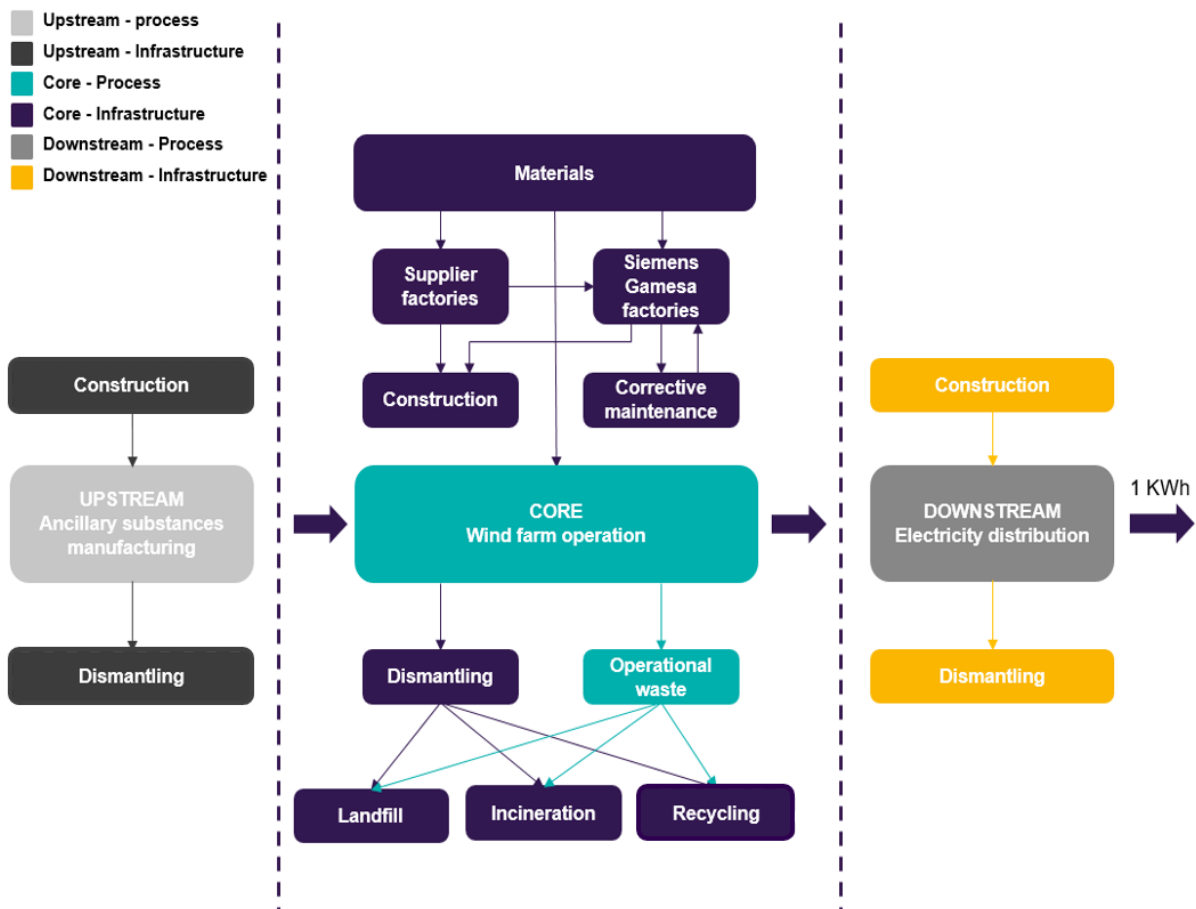


Figure 3.- System boundaries

Obviously, the energy life cycle is a complex system in which it is necessary to clearly establish the boundaries between the different phases to avoid mistakes. Following the recommendations of the PCR, the whole life cycle has been divided into three main modules. These are the core module, the up-stream module and the down-stream module. The concepts included in each of these modules are summarized in the following paragraphs.

The previous figure provides a simplified representation of the boundaries of the studied system, decomposing the life cycle on different modules, as required by the PCR. The arrows represent the different transport of materials, parts or bigger components.

The data used to create the model of the life cycle phases described in the above diagram, have been obtained directly from Siemens Gamesa Renewable Energy or from its suppliers. These data are fully traceable and are the basis for ensuring that the results of the LCA correspond to the reality of the product.

As baseline, all the data for which Siemens Gamesa has direct access to, have been included in the analysis seeking the best data completeness. However, given the complexity of the system and the multitude of information needed, in order to ease the assessment, the following cut-off criteria have been followed when making the life cycle inventory:

- The sum of all material flows that have not been included in the analysis should be less than 1% of the total weight of all material flows;
- The sum of all energy flows that have not been included in the analysis should be less than 1% of the total energy flows.

By the time the study ended, 99.81% of the total material flows of the system had been successfully included. The inflows that have been not included in the model, are related to small parts and pieces that are difficult to be inventoried (e.g., nuts, bolts, washers, small parts...). From previous Siemens Gamesa experiences, it is known that these parts do not have relevant environmental contribution in the results. In addition, all the energy flows incurred in Siemens Gamesa manufacturing plants have also been included in the analysis. Regarding data quality, the environmental impact of the processes where other generic data were used, is below 10% of the overall environmental impact from the whole product system.

From these primary data, when creating the life cycle model of the analyzed system Ecoinvent 3.8 (cut-off) life cycle inventories database has been used. Ecoinvent is the most well-known LCA database worldwide used by around 4,500 users in more than 40 countries. This database contains international industrial life cycle inventory data on energy supply, resource extraction, material supply, chemicals, metals, agriculture, waste management services, and transport services. Ecoinvent is the world's leading supplier of consistent and transparent life cycle inventory (LCI) data of known quality.

All the data used to create the life cycle model of the electricity generated by an offshore wind farm using SG 14-222 wind turbines, reflect the technology currently used by the manufacturer and are considered representative for the period of validity of this EPD.

In the points of the study where impact allocation was required, physical allocation criteria was used to resolve multifunctionality issues, as recommended by the relevant PCR of the International EPD® System concerning this product category. In the manufacturing stage of the wind turbine, the annual environmental aspects of every production center were divided between the total units of components manufactured during that year in every specific location, in order to obtain the allocated impacts per wind turbine.

In the next sections, the scope of the study and the data sources used are further detailed for every of the different stages that compose the life cycle of the generated and distributed energy.

3.2.1. Upstream

The upstream module considered in the study, includes the environmental impacts related to the production of all necessary ancillary substances for the proper operation of the wind farm during the 25 years of service life.

Since wind power requires no fuel for equipment operation, this module mainly includes the required quantities of hydraulic oil, lubricating oil and greases, as well as the emissions arising from the transport of these substances from the suppliers to the wind farm. The replacements of lubricating oil, hydraulic oil and grease due to preventive maintenance, were obtained from Siemens Gamesa's statistics on the requirement for these supplies.

3.2.2. Core – Infrastructure

The core infrastructure phase encompasses all the steps related to the construction, and decommissioning of the wind farm from cradle to grave. This comprehends all the stages from the extraction of the raw materials needed to build the WTGs and the wind farm, until the dismantling of the wind farm, including the proper management of the generated waste and the recycled components as well as their corresponding end of life treatments.

This module also refers to the manufacturing processes of the WTG performed by Siemens Gamesa and its suppliers. Besides, the expected corrective maintenance actions for the machinery during its service life (estimated component replacements and repairs) are included. All the environmental impacts arising from the logistics related to the previously mentioned concepts, are part of the core module too.

3.2.2.1. Wind farm Construction

The main environmental aspects of the construction of a wind farm are commonly related to the machinery use during the groundwork and WTG assembly, as well as to the material consumption for the foundations.

For this EPD, Siemens Gamesa has calculated the environmental impacts arisen from the construction of a virtual 80 WTG wind farm, as explained in section 2.2.1.



Figure 4.- Westermost Rough offshore wind farm

Different items have been considered in the LCA model of the wind farm construction stage, such as the energy consumed by the vessels when building the foundations or for the WTG assembly, as well as the consumption of construction materials for the foundations and all the inter array wiring network. All the assets and materials needed for the construction of the offshore electrical substation, including the topside and its foundation, have also been included in the analysis.

3.2.2.2. Wind turbine generator manufacturing

On the other hand, Siemens Gamesa is responsible for the manufacturing and assembly of most of the major components of the wind turbine. The company, as manufacturer of the WTGs has provided primary data on the raw materials, energy flows and generated waste streams during the wind turbines manufacturing and assembly stage, according to their real manufacturing processes. These data are based on the technology currently used by Siemens Gamesa, and are considered representative as long as the same manufacturing technologies are used.

Data on the environmental aspects of Siemens Gamesa production processes have been collected during 1 full financial year period (from October 2019 to September 2020, both included). In addition, the material breakdown of the WTGs has been extracted from the BoM of the turbine models actually designed during the year 2020.

In the case of an offshore SG 14-222 wind turbine delivered to an European location, the factories involved in the manufacturing of the machine are the ones collected in the following table. Primary data have been gathered for all of these manufacturing plants, which have been individually assessed for the purpose of the study.

Activity	Location	Owner
Backend & hub & generator manufacturing	Cuxhaven - GERMANY	SIEMENS GAMESA
Blades manufacturing	Aalborg - DENMARK	SIEMENS GAMESA
Tower manufacturing	Give - DENMARK	WELCON
Foundation manufacturing	Ferrol - SPAIN	NAVANTIA

Table 1.- Manufacturing plants included in the core infrastructure module

These facilities are responsible for the manufacturing and assembly of the main components of the SG 14-222 wind turbine, given an European client. All the electricity consumed in the manufacturing centers and offices owned by Siemens Gamesa during 2020 has 100% renewable Guarantee of Origin certified by the supplier of the electricity. In the LCA model, this 100% renewable guaranteed electricity has been modeled using only the share of renewable sources in the 2020 electricity mix for the countries in which the manufacturing centers are established.

This is the case for the SGRE blades manufacturing center at Aalborg (Denmark) and for the SGRE backend-hub-generator manufacturing center at Cuxhaven (Germany). The electricity consumed in the other two manufacturing centers included in the scope that are not directly owned by Siemens Gamesa (NAVANTIA and WELCON), has been modeled using the Spanish and Danish national electricity mixes respectively, for 2020, from the Ecoinvent 3.8 database.

Data on components directly purchased from suppliers and the distances traveled by these components to Siemens Gamesa manufacturing plants are real primary data, so that these distances closely match the reality of an European scenario. In addition, data on the distance traveled by the main components of the WTG to the wind farm, have been included considering the European average wind farm location explained in section 2.2.1.

3.2.2.3. Reinvestments

All the SG 14-222 wind turbine components are designed to have a service life equal to or greater than the turbine itself. However, sometimes the WTG is exposed to situations that differ from the normal design operation, that can reduce the expected lifetime of a component or even disable it.

Seeking to have a good overview of the environmental impact caused by these unexpected failures and the need for reinvestment of components, the impact of performing corrective maintenance actions on SG 14-222 turbines has been modeled in the LCA which supports this EPD. Data on failure rate statistics have been taken directly from internal studies made by Siemens Gamesa.

3.2.2.4. End of life

Finally, the materials that appear after the decommissioning of the wind farm and their end-of-life management have been estimated according to previous Siemens Gamesa LCA experiences. For the LCA, the following hypotheses have been assumed.

Sub-system	End of life hypothesis
Foundation materials	Fully recyclable
Tower	Fully recyclable
Blades	95 % Landfilled 5 % Repaired
Transformer	85 % Landfilled 15 % Repaired
Canopy	Landfilled
Cooler	Landfilled
Rest of backend materials	Fully recyclable
Generator	90 % Landfilled 10 % Repaired
Hub	Fully recyclable
Spinner	Landfilled
Rotor lock	Landfilled
Inter array cables	95 % Recycled 5 % Landfilled
Export cables	95 % Recycled 5 % Landfilled
Onshore cables	95 % Recycled 5 % Landfilled
Electrical substation foundation	Left in situ
Electrical substation topside	Plastics and fiber materials - Landfilled Other materials - Recycled

Table 2.- End of life hypotheses

3.2.3. Core – Process

All the environmental impacts associated with the operation of the wind farm, given its 25 years of life, have been considered in this module. One of the main advantages of the wind energy over other non-renewable sources of energy is its independence on fossil fuels. This environmental benefit is reflected at this stage when we look at the results.

In the core-process module the following concepts have been considered:

- Preventive maintenance required during the lifespan of the wind farm, including the maintenance travel vessels fuel consumption;
- The proper waste management of the consumables needed during operation and maintenance of the wind farm, including transportation stage to the authorized entity for later treatment.



Figure 5.- Blade manufacturing in Siemens Gamesa

Finally, the core also contains a vital part of the wind turbine life cycle, which is the technical performance. Factors such as the annual energy production, the availability of the machine, the electrical losses during operation or the energy self-consumption of the turbine for its auxiliary systems, have a decisive influence on the environmental impact of the functional unit. These are also primary data directly provided by the manufacturer.

3.2.4. Downstream

Lastly, the downstream stage comprises all the impacts that happen from the moment when the energy is delivered to the electricity network (leaving this way the wind farm), until the moment when it reaches the final consumer.

The downstream module represents mainly two different environmental impacts. The first one is the impact related to the construction and decommissioning of the electrical grid, which is considered within the sub-module “downstream infrastructure”. The second impact is related to the electrical losses inherent to the voltage transformations and to the Joule effect when transporting the generated electricity, which are considered in the sub-module “downstream process”. Note that these losses depend on the connection voltage of the final consumer.

Siemens Gamesa has experienced difficulties trying to separate the distributed energy losses to every kind of European customer. Accordingly, an average value of 2.2% until a 66 KV network has been used to simulate these electrical losses, according to European Regulators Group for electricity and gas (ERGEG). This means that 2.2% of every generated kWh, is lost in the distribution network between the wind farm and the declared customer.

On the other hand, the distance between the wind farm transformer station and the connection point to the electrical grid is a variable value dependent on the specific location. According to previous Siemens Gamesa experiences, this value has been assumed to be 22 km from shore for this study. These underground export cables were modelled for the LCA using primary information gathered by the company.

3.3. Eco-profile

In the following tables, the environmental performance of the SG 14-222 wind turbine from a life cycle perspective is shown, in the separated phases that were described above. The characterization factors for each of these impact categories have been used in accordance with the mandatory core environmental impact categories in EN 15804:2012+A2:2019/AC:2021 standard, based on the characterization factors from the Environmental Footprint method 3.0.

The EPD verifier had access to more comprehensive information on the LCA, which supports this declaration. The functional unit, to which all outcomes are referred to is:

Functional unit

1 kWh net of electricity generated through an offshore wind farm of Siemens Gamesa SG 14-222 wind turbine generators, located in an European windfarm and operating under high wind conditions (IEC I), and thereafter distributed to a 66 kV European electrical grid.



3.3.1. Potential environmental impacts

Potential environmental impacts		Unit	Upstream	Core process	Core Infrastructure	Total generated	Downstream process	Downstream infrastructure	Total distributed
Global warming potential	Fossil	g CO ₂ eq	9.76E-03	5.57E-01	9.05E+00	9.62E+00	2.12E-01	4.68E-02	9.87E+00
	Biogenic		4.80E-06	2.04E-04	4.47E-02	4.49E-02	9.88E-04	1.49E-04	4.60E-02
	Land use and transformation		1.19E-05	5.41E-05	7.54E-02	7.55E-02	1.66E-03	2.61E-04	7.74E-02
	TOTAL		9.78E-03	5.57E-01	7.91E-04	5.68E-01	1.25E-02	1.53E-06	5.80E-01
Photochemical oxidant formation potential		g NMVOC eq	1.05E-04	7.48E-03	4.47E-02	5.23E-02	1.15E-03	1.49E-04	5.36E-02
Acidification potential		mol H ⁺ eq	7.66E-08	5.60E-06	7.54E-05	8.11E-05	1.78E-06	2.61E-07	8.31E-05
Eutrophication potential (freshwater)		g P eq	5.26E-07	1.87E-06	7.91E-04	7.93E-04	1.74E-05	1.53E-06	8.12E-04
Eutrophication potential (marine)		g N eq	9.72E-06	2.48E-03	1.70E-02	1.95E-02	4.30E-04	4.12E-05	2.00E-02
Eutrophication potential (terrestrial)		mol N eq	1.05E-07	2.72E-05	1.27E-04	1.54E-04	3.39E-06	4.61E-07	1.58E-04
Ozone layer depletion		g CFC-11eq	7.56E-09	1.15E-07	6.52E-07	7.75E-07	1.71E-08	1.78E-09	7.94E-07
Abiotic depletion potential - Elements		g Sb eq	6.92E-08	2.81E-07	1.43E-03	1.43E-03	3.15E-05	4.78E-07	1.46E-03
Abiotic depletion potential – Fossil fuels		MJ, net calorific value	5.05E-04	7.40E-03	1.09E-01	1.17E-01	2.57E-03	8.05E-04	1.20E-01
Water scarcity potential		m ³ eq	4.23E-06	1.23E-05	3.29E-03	3.31E-03	7.27E-05	2.10E-05	3.40E-03

Table 3.- Potential environmental impacts

3.3.2. Use of resources

Primary energy resources Renewable	Unit	Upstream	Core process	Core Infrastructure	Total generated	Downstream process	Downstream infrastructure	Total distributed
Used as energy carrier	MJ, net calorific value	8.19E-06	4.18E-05	1.18E-02	1.19E-02	2.61E-04	5.85E-05	1.22E-02
Used as raw materials	MJ, net calorific value	0.00E+00	0.00E+00	1.75E-04	1.75E-04	3.86E-06	0.00E+00	1.79E-04
TOTAL	MJ, net calorific value	8.19E-06	4.18E-05	1.20E-02	1.20E-02	2.65E-04	5.85E-05	1.24E-02

Table 4.- Primary energy resources – Renewable

Primary energy resources Non-renewable	Unit	Upstream	Core process	Core Infrastructure	Total generated	Downstream process	Downstream infrastructure	Total distributed
Used as energy carrier	MJ, net calorific value	2.59E-04	7.40E-03	1.05E-01	1.13E-01	2.49E-03	5.44E-04	1.16E-01
Used as raw materials	MJ, net calorific value	2.47E-04	0.00E+00	3.80E-03	4.05E-03	8.91E-05	2.61E-04	4.40E-03
TOTAL	MJ, net calorific value	5.05E-04	7.40E-03	1.09E-01	1.17E-01	2.57E-03	8.05E-04	1.20E-01

Table 5.- Primary energy resources - Non-Renewable

3.4. Hot spot analysis and conclusions

In order to find the aspects that are mainly causing these environmental impacts, it is required to look into every phase of the whole life cycle from an integral perspective.

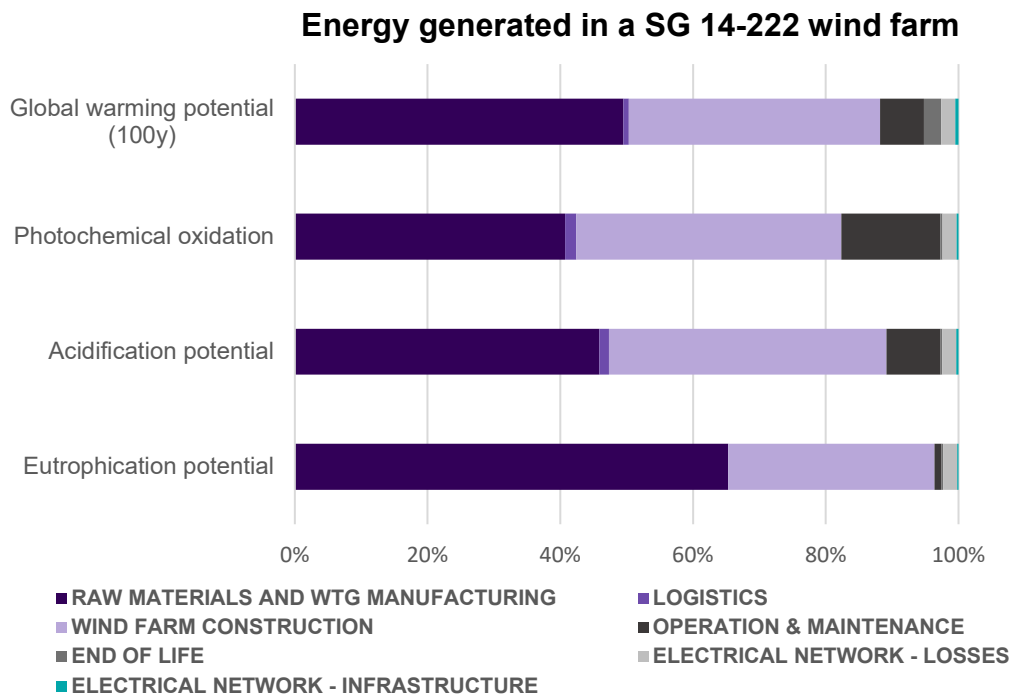


Figure 6.- Environmental hot-spots

As shown in the figure above, there are two life cycle stages dominating the life cycle environmental impacts of the distributed energy. The wind farm construction stage together with the raw material and WTG manufacturing stage, are responsible for approximately 88% of the total environmental impacts for these 4 impact categories.

From a life cycle point of view, these two stages are the main hot-spots of the energy generated in the SG 14-222 windfarm, and should be carefully designed in future projects.

Nearly 50.3% (in average for the 4 impact categories) of the environmental impacts of the energy generated and distributed by a SG 14-222 WTG are caused in the raw material acquisition and WTG manufacturing phase. This is a logical consequence, since a wind turbine does not consume any fossil fuel during its operation as the conventional energy sources do, so the main environmental aspect of this technology is related to the manufacturing of its infrastructure. This is mostly caused by the raw materials needed to manufacture all the steel parts of the WTG and the subsequent machining phases. The most critical components in this phase are the tower and the electronic components.

Concerning the wind farm construction, this stage represents 37.7% of the impacts (in average). The most relevant environmental aspects for the construction stage are the materials consumption when building the foundations and the materials used for the inter-array cables.

Finally, the rest of the modules such as use and maintenance, end of life, electrical losses in the network and logistics, have a minor contribution to the life cycle environmental impacts of the generated and distributed energy using SG 14-222 WTGs. More detailed conclusions on the environmental impacts were made in the full LCA report. Please, refer to Siemens Gamesa Renewable Energy for further information.

4. Additional environmental impact

4.1. Biodiversity protection

Siemens Gamesa products and services, use certain natural resources to perform its activities, thereby interacting with, and potentially affecting, ecosystems, landscapes and species. This mainly happens across our operations over the product life cycle, for example:

- When we establish new facilities;
- When constructing our wind power plants.

Some impacts to biodiversity can include, for example:

- Potential land use changes by using vehicles and machinery to open up paths and remove vegetation;
- Prolonged human presence which temporarily affects the behavior of species of fauna in a generally reversible way;
- Potential species mortality due to collisions with our customers' wind turbines.

Despite these potential impacts on biodiversity, Siemens Gamesa's wind projects are constructed in a sustainable way allowing a balanced coexistence with the environment, thus conserving and protecting natural assets, i.e., biodiversity and climate. This respect for biodiversity and ecosystems plays a leading role in the company's business strategy. There are different regulatory and voluntary instruments to achieve a positive net balance in relation to biodiversity and the environment, including:

- Company policies and procedures under the integrated management system;
- Full compliance with permits granted by environmental and conservation authorities at each region, which set out requirements to ensure the local environment's protection;
- Setting environmental and control plans and implementing management systems, the majority of which have been certified according to the ISO 14001 standard to prevent and control environmental risks;
- Fulfilling legislation on conducting environmental impact studies, which include analysis and prevention mechanisms that consider different alternatives and lay down corrective measures to avoid, mitigate or offset any possible damage.

As a general rule, protected areas and areas of high biodiversity value without protection are avoided during the design stage of new infrastructures. Potential environmental impacts are analyzed through a formal HSE aspects evaluation and by conducting environmental impact assessments beforehand, with measures to correct and minimize the impacts. In case that they cannot be completely mitigated, offsetting measures are taken.

The company has activities in some areas where threatened species included in the IUCN Red List and in other national conservation lists live or could be present. This, however, does not mean that they are affected or threatened by such activities. Hence, the identification of species on the IUCN Red List and other species included in national conservation lists which could be affected by Siemens Gamesa's activities is permanently monitored to take the necessary measures to avoid endangering them.

4.2. Land use

As this EPD is not relative to one specific site in Europe, but to an average European Siemens Gamesa location, a specific land use analysis cannot be performed. Alternatively, a description on the land uses across Europe, has been performed.

The data source used for the land use and land cover classes information in Europe, are the maps published by the Copernicus Land Monitoring system. Copernicus, is a European system for monitoring the Earth. Data is collected by different sources, including Earth observation satellites and in-situ sensors. The data is processed and provides reliable and up-to-date information in six thematic areas: land, marine, atmosphere, climate change, emergency management and security.

4.2.1. Description of land cover classes across Europe

The following table shows the land cover classes across the area for which the study is representative. The surface is expressed in hectares. The bigger areas in Europe are occupied by non-irrigated arable lands as well as by coniferous and mixed forest. It is important to highlight that as the analysis is being performed on an offshore windfarm, only water bodies will be affected when a new wind farm of this type is built.

Land cover classes	Surface (ha)	%
Urban fabric	21,587,189	4.1%
Other artificial areas	1,606,124	0.3%
Non-irrigated arable land	109,894,155	21.0%
Permanently irrigated arable land	4,695,274	0.9%
Pastures	41,045,873	7.9%
Other agricultural areas	55,442,269	10.6%
Broad-leaved forest	55,083,970	10.5%
Coniferous and mixed forest	104,911,554	20.1%
Other shrub and/or herbaceous areas	76,061,803	14.6%
Beaches, sands and rocks	23,490,231	4.5%
Burnt areas	223,000	0.0%
Wetlands	14,410,030	2.8%
Water bodies	13,962,613	2.7%
TOTAL	522,414,084	100.0%

Table 6.- Land cover classes across Europe

4.2.2. Description of the activities on the occupied areas

The area of land occupied by artificial elements in a 80 offshore wind turbine windfarm will be approximately of 9,623.8 m², affecting to water bodies. This area will be mainly occupied by the following artificial elements during 25 years and 6 months, including the construction, operation and dismantling periods of the windfarm:

- Foundations;
- Turbines;
- Electrical substation compounds;

4.3. Environmental risks

Although the probability and severity of undesirable events is very low, the most representative environmental risk is an accidental oil spill. This chance is quite reduced if we compare this wind turbine model to an onshore machine, because direct drive offshore turbines do not have gearbox component, thus greatly reducing the oil quantity at the site. Operational controls are implemented at all Siemens Gamesa production facilities and project sites to protect water and soil from spills e.g., through the establishment of prevention and response plans and the use of control measures such as spill trays, loading and unloading areas, proper storage of substances, routine inspections, etc. Should a spill occur, Siemens Gamesa is equipped with detection, reporting and correction methods to reduce the extent of the spill and prevent a recurrence.

A total of 894 spills were recorded in FY 2022 (861 spills in FY 2021), of which 442 were contained and another 452 affected either water or soil to some degree. None of these spills required any exceptional corrective measures. When using the declared windfarm as reference, these spills happen less frequent than once in three years.

4.4. Electromagnetic fields

The 2014/35/UE Directive regulates the electromagnetic compatibility of equipment. It aims to ensure the functioning of the internal market by requiring equipment to comply with an adequate level of electromagnetic compatibility. The directive makes a clear distinction between apparatus and fixed installations with regard to documentation of compliance with the protection requirements. The term “fixed installation”, in the view of the European Commission, is a comprehensive term for electrical installations consisting of different types of apparatus and other devices that are combined permanently at an unchangeable location.

A formal conformity assessment of such installations is often difficult to perform and, in some cases, even impossible due to their size and complexity. In addition, fixed installations are often subject to constant change through which the formal conformity assessment of their undefined and changeable EMC conditions also appears to be problematic. Wind turbine is transported to its site of installation in separate parts and assembled on-site, erected and put into operation. It is operated exclusively at that location. According to these requirements, a wind turbine is a fixed installation according to the definition of terms in the EMC Directive.

For these reasons, the EMC Directive foregoes a formal conformity assessment and CE marking of fixed installations. However, it stipulates that such installations must be installed according to generally accepted rules of technology, and that the specifications for the intended use of the installed components have been observed. The measures for compliance with the essential requirements of the EMC Directive also has been documented in the technical file. In addition, the basic standard for the design of wind turbines, EN 61400-1, obligates to EMC assessment and to the respective measurements. According to the design risk assessment, there are not person exposed to electromagnetic radiation hazards in the wind turbine.

4.5. Noise

The noise produced by a wind turbine is twofold, one mechanics and other aerodynamics. The first comes from the machine components, and can easily be reduced by conventional techniques. Aerodynamic noise produced by the air flowing on the blades tends to increase with the speed rotation of the blades and with wind flow turbulent conditions noise may increase. Although inside the backend mechanical noise exists, it is low compared to aerodynamic noise, and at ground level, the only relevant noise is the aerodynamic one.

The emitted noise values are within the normal values within the wind industry. It is noteworthy that offshore wind farms are located in uninhabited areas and distances greater than 300 m the noise level is greatly reduced and is considered negligible to be lower than the ambient noise threshold in nature, wind, etc.

Nevertheless, for locations with strict noise requirements, low noise operation modes are available. In those versions, the total noise is limited to the required maximum value by reducing the power generated in the most critical wind speed bins.

4.5.1. Noise calculation

There are two international standards establishing noise measurement procedure and noise levels declaration:

- IEC 61400-11 (Ed. 3 2012): Wind turbine generator systems - Acoustic noise measurement techniques. Definition of how to perform noise measurements of a wind turbine;
- IEC 61400-14 (Ed. 2005): Wind turbines - Declaration of apparent sound power level. Definition of how to declare the noise generated by an AEG.

According to the measures carried out for the SG 14-222 DD wind turbine generator according to IEC 61400-14: 2005 and IEC 61400-11; 3rd Ed.; noise level is lower than 119 dBA.

4.6. Absolute global warming emissions

In addition to the already declared GWP results under section 3.3, the following chapter contains the absolute global warming emissions for the life cycle of solely 1 SG 14-222 DD wind turbine, instead of providing the results referenced to the functional unit of 1 kWh of energy distributed, considering an 80 turbine European location.

The downstream stage of the life cycle has been excluded of this new set of results, as that stage is not dependent on the number of turbines. In addition, the common elements of the wind farm construction stage, which are shared between many turbines, have been scaled down to 1 WTG.

It is important to highlight that the energy performance of the turbine is not influencing these results, as they represent the raw results of commissioning the infrastructure.

Life cycle stage	Group	Absolute GWP [Ton CO ₂ eq]
RAW MATERIALS AND WTG MANUFACTURING	Backend	638.99
	Generator	887.04
	Hub	537.81
	Backend assembly	32.37
	Electronic components	2,653.83
	Blades	579.79
	Tower	1,942.74
LOGISTICS	Transport between suppliers	72.35
	Transport to preassembly site	50.23
WIND FARM CONSTRUCTION	Wind farm construction	358.29
	Foundation	3,196.40
	Inter array cable	454.82
	Off-shore substation	1,106.43
	Export cable	451.78
OPERATION & MAINTENANCE	Corrective maintenance	122.92
	Preventive maintenance	14.56
	Maintenance travel	802.28
	Maintenance waste management	26.82
END OF LIFE	End-of-life transport	28.58
	End-of-life treatments	354.23
TOTAL		14,312.25

Table 7.- Absolute global warming emissions per turbine

4.7. Share by materials of the GWP emissions

This last section is meant to provide deeper insight on which materials are the ones responsible of most of the global warming potential emissions during the life cycle of the SG 14-222 DD wind turbine. In this wind turbine model, materials consumption account to 72.1% of the total life cycle global warming impacts (10,312.65 Ton CO₂eq), being the rest of the impacts caused by other aspects such as transport related emissions, manufacturing facilities related impacts, operation and maintenance efforts or end-of-life treatments.

The following figure contains the global warming potential impacts split by the different materials used when manufacturing the wind turbine. For this calculation, all the groups involving most of the materials consumption have been considered. It should be noted that common elements of the wind farm such as the inter array cables, the export cables and the offshore substation, have been excluded from the calculation.

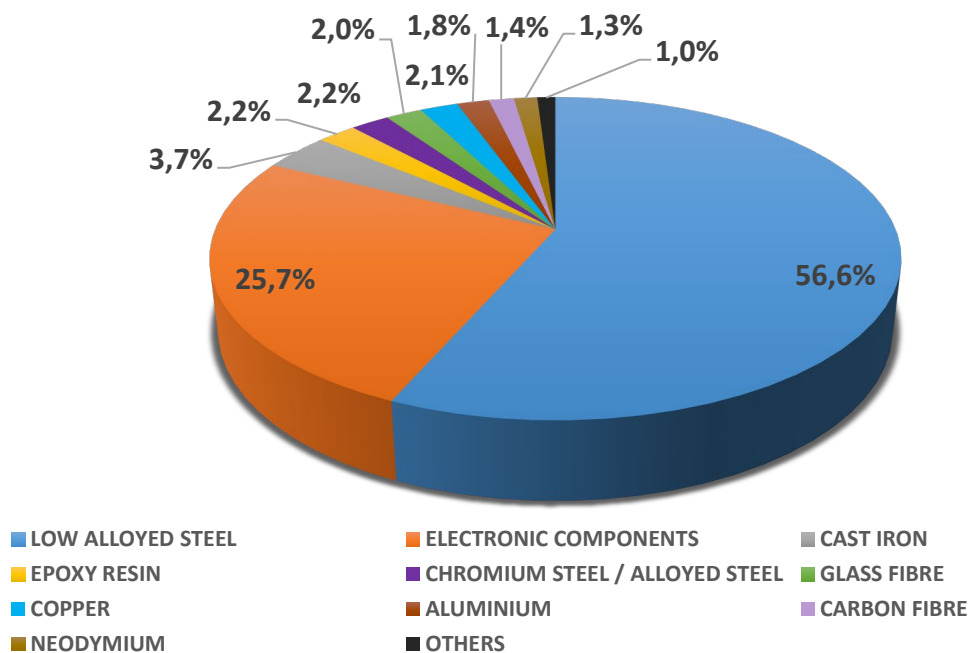


Figure 7.- Share of the GWP emissions by materials

4.8. Visual impact

The landscape impact caused by the presence of wind turbines and power lines is a subjective aspect, which affects differently, depending on the location of the wind farm. The location of wind farms is also determined by analyzing the different points from which they are visible to, thereby causing minimal visual impact. Each wind farm prior to the decision to its location has had an environmental impact assessment that has been approved by the relevant environmental authority.

The addition of any novel structure can drastically alter a landscape or seascape. With regards to wind energy and marine renewable energy devices, some people appreciate their presence as they may attract tourism, while others dislike the new addition as an imposition on the natural environment. However, marine renewable energy devices are typically lower profile, closer to the surface, or submerged underwater, all of which reduce their visibility and perceived visual impacts.

In many cases, as part of the assessment process, interactive maps are used to illustrate the potential effects of the wind turbines. These maps allow viewing the theoretical visibility of the proposed turbines, zooming into an area and viewing photomontages from some particular viewpoints in the surrounding area to see what the wind farm would look like.

5. Certification body and mandatory statements

5.1. Information from the certification body

The verification process of this environmental product declaration has been carried on by Tecnalía R&I Certificación, accredited certification body by ENAC (the Spanish National Accreditation Body) and the International EPD[®] System, which verifies that the attached Environmental Product Declaration complies with the applicable reference documents and also certifies that the data presented by the manufacturer are complete and traceable in order to provide supporting evidence of the environmental impacts declared in this EPD document, according to the International EPD[®] System General Programme Instructions.

The EPD has been made in accordance with the General Programme Instructions for the International EPD[®] System, published by EPD International AB, and PCR 2007:08 - Electricity, steam, and hot water generation & distribution - Version 4.2, valid until 2024-03-16.

This certification is valid until 2028-09-11.

5.2. Mandatory statements

5.2.1. Comparability between EPDs from other Programmes

Note that Environmental Product Declarations (EPD) within the same product category but from different programmes may not be comparable.

5.2.2. Life cycle stages omitted

According to the reference PCR, the phase of electricity use has been omitted, since the use of electricity fulfils various functions in different contexts.

5.2.3. Means of obtaining explanatory materials

The ISO 14025 standard requires that the explanatory material should be available if the EPD will be communicated to end users. This EPD is industrial consumer oriented (B2B) and communication is not intended for B2C (Business-to-consumer).

5.2.4. Responsibility of the verifier and the programme operator

The verifier and the programme operator do not make any claim nor have any responsibility of the legality of the product.

5.2.5. Ownership, liability and responsibility

The EPD owner has the sole ownership, liability and responsibility of the EPD.

5.2.6. EPD validity

An EPD should provide current information, and may be updated if conditions change. The stated validity is therefore subject to the continued registration and publication at www.environdec.com.

5.3. Programme and verification information

Programme and verification information	
EPD programme	EPD International AB (Programme operator) Box 210 60, SE-100 31 Stockholm, Sweden www.environdec.com info@environdec.com
Registration number	S-P-09791
Publication date	2023-09-13
EPD validity	2028-09-11
Geographical validity of the EPD	This EPD has European validity
Scope of the declaration	Cradle-to-grave
Independent verification of the declaration and data, according to ISO 14025:2006	<input checked="" type="checkbox"/> EPD verification <input type="checkbox"/> EPD process certification
Third party verifier	Tecnalia R&I Certificación, S.L. Verifier: Eva Larzabal info@tecnaliacertificacion.com
Third party verifier accredited or approved by	ENAC. Accreditation no.125/C-PR283
Procedure for follow-up of data during EPD validity involves third-party verifier	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No
LCA study developed by	IK Ingenieria
Reference Product Category Rules (PCR)	PCR 2007:08 - Electricity, steam and hot water generation and distribution – UN CPC 171 & 173 – Version 4.2
PCR review conducted by	Technical Committee of the International EPD® System. Full list of members available on www.environdec.com The review panel may be contacted via info@environdec.com PCR review chair: Claudia A. Peña
PCR prepared by	Technical Committee of the International EPD® System. PCR Moderator: Mikael Ekhagen – Vattenfall AB Mikael.ekhagen@vattenfall.com

6. Links and references

Additional information about Siemens Gamesa Renewable Energy:

www.siemensgamesa.com/en-int

Siemens Gamesa Renewable Energy sustainability commitment:

www.siemensgamesa.com/en-int/sustainability

Additional information about the International EPD[®] System:

www.environdec.com

The International EPD[®] System is based on a hierarchical approach using the following international standards:

- ISO 9001, Quality management systems;
- ISO 14001, Environmental management systems;
- ISO 14040, LCA - Principles and procedures;
- ISO 14044, LCA - Requirements and guidelines;
- ISO 14025, Type III environmental declarations.

Data base used for the LCA:

Ecoinvent 3.8 Database, published by the Swiss Centre for Life Cycle Inventories

<http://www.ecoinvent.org>

VERIFICATION STATEMENT CERTIFICATE CERTIFICADO DE DECLARACIÓN DE VERIFICACIÓN

Certificate No. / Certificado nº: EPD01613

TECNALIA R&I CERTIFICACION S.L., confirms that independent third-party verification has been conducted of the Environmental Product Declaration (EPD) on behalf of:

TECNALIA R&I CERTIFICACION S.L., confirma que se ha realizado verificación de tercera parte independiente de la Declaración Ambiental de Producto (DAP) en nombre de:

SIEMENS GAMESA RENEWABLE ENERGY
Parque Tecnológico de Bizkaia, Ed. 222
48170 ZAMUDIO (Bizkaia) - SPAIN

for the following product(s):
para el siguiente(s) producto(s):

**ELECTRICITY FROM A EUROPEAN OFFSHORE WIND FARM USING SG 14-222
WIND TURBINES.**
**ELECTRICIDAD GENERADA POR UN PARQUE EÓLICO MARINO EUROPEO CON
AEROGENERADORES SG 14-222.**

with registration number **S-P-09791** in the International EPD® System (www.environdec.com)
con número de registro **S-P-09791** en el Sistema Internacional EPD® (www.environdec.com)

it's in conformity with:
es conforme con:

- **ISO 14025:2010 Environmental labels and declarations. Type III environmental declarations.**
- **General Programme Instructions for the International EPD® System v.3.01.**
- **PCR 2007:08 Electricity, steam and hot water generation and distribution v 4.2.**
- **UN CPC 171 Electrical energy.**

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Carlos Nazabal Alsua
Manager



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