Electricity from a European onshore wind farm using SG 4.5-145 wind turbines

Environmental Product Declaration according to ISO 14025
UN CPC 171 – Electricity, steam, and hot/cold water generation & distribution. PCR 2007:08 Version 3.1

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Contents

Acronyms and abbreviations

AEP	Annual Energy Production
BoM	Bill of Materials
B2B	Business to Business
B2C	Business to consumer
LCoE	Levelized Cost of Energy
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
MW	Megawatt
WTG	Wind Turbine Generator

1. Introduction

1.1. Declared unit

This document represents the certified Environmental Product Declaration (EPD), of the electricity generated through an Onshore wind farm of SG 4.5-145 wind turbine generators, located in an European scenario and operating under medium wind conditions (IEC IIB 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 declared unit, to which all outcomes are referred to is:

Declared unit

1 kWh net of electricity generated through an Onshore wind farm of SG 4.5-145 wind turbines, located in an European scenario and operating under medium wind conditions (IEC IIB), and thereafter distributed to a 132 kV European electrical grid.

A total reference flow of 3,244,975.458 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 8 SG 4.5-145 WTG under medium wind solutions during its service life, which has been set to 20 years.

Siemens Gamesa is able to supply different kind of towers, seeking a right placement of the rotor at the height which optimizes the energy harvested. The baseline scenario includes 107.5 meters high towers.

Wind energy is the most reliable and effective renewable energy to meet the growing electricity demand[1], 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, PCR 2007:08 version 3.1 CPC 171 & 173: Electricity, Steam, and Hot and Cold Water Generation and Distribution;
- 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 a LCA-based environmental behavior statement. It also contains additional environmental information, in accordance with the corresponding PCR:

- 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 89.5 GW installed globally and 23,000 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 76.9 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 14006:2011 - Environmental management systems. Guidelines for incorporating eco-design:

Verified eco-designed wind turbines

- SG 114 - 2.1 MW
- SG 114 - 2.625 MW
- SG 126 - 2.625 MW
- SG 132 - 3.465 MW

- ISO 14064:2006 - Greenhouse gases;
- ISO 9001:2015 - Quality management systems;
- OHSAS 18001:2007 - Occupational health and safety management systems.

2.2. Product system description

The baseline system under study is an European onshore wind farm using SG 4.5-145 wind turbines with 107.5-meter 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 4.5-145 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 farm is directly related to the environmental impact caused in the product distribution stage. The farther the wind farm is from the production centers, the more logistics needed.

To determine the geographical location of an average Siemens Gamesa 4.5 MW European wind farm, an analysis has been performed including the location of all the WTGs with a nominal power over 3.0 MW which have been sold by Siemens Gamesa during the last 5 years (2014-2018). Starting from that information, 6 different European countries have been considered, covering a 79.1% of the total installed power in Europe.

The following table, contains the 6 selected locations including their relative representativeness within the LCA and the number of installed machines in the virtual site.

Country	Area	Representativeness	Reference wind farm	Nº WTG
Sweden	Västernorrland	26.4 %	Sidensjö	8
UK	Higland – Scotland	21.3 %	Lochluichart	
Ireland	Offaly	17.1 %	Mount Lucas	
Germany	Schleswig-Holstein	17.0 %	Süderlügum	
France	Marne	10.4 %	Les Gourlus	
Denmark	Mariagerfjord - Nordjylland	7.8 %	Dostrup	

Table 1: European average wind farm description

The countries analyzed are Sweden, UK, Ireland, Germany, France and Denmark. These 6 countries are considered representative of the European situation of Siemens Gamesa over 3.0 MW clients. For each of these countries, one specific wind farm has been selected as geographical reference.

Regarding the size of the wind farm, the average size of a wind site in Europe has been calculated dividing the total installed power between the total number of windfarms, and rounding the number up to 8 wind turbines. Therefore, the installed power considered for the European average wind farm is set to 36 MW. When modelling the infrastructures shared by many wind turbines (i.e. transformer substation, internal wiring, connection infrastructure to the electrical network, road conditioning to allow access to machinery…), this average wind farm size of 36 MW installed has been used to reference all the values.

2.2.2. SG 4.5-145 Wind turbine

This wind turbine generator is a 4.5 MW rated power turbine, with a three-blade rotor. Boasting a 145-meter rotor combined with a 4.5 MW generator, the SG 4.5-145 is especially suited to Class IIB sites. The SG 4.5-145 is the first Siemens Gamesa onshore product launch and the first proposal of the Siemens Gamesa 4.X platform. Exemplar of a new generation of turbines, it is based on the operational experience accumulated by the company in the wind power market, and on the application of proven technological solutions. This new model fits into the catalog with a clear objective: to complement the product offer in the markets in which our clients require solutions with nominal powers greater than 4 MW, and with an excellent Cost of Energy. Given these premises and based on a design optimized for medium-wind speeds, its modularity and flexibility enable it to adapt to a wide range of sites.

General details	
Rated power	4.5 MW
Wind class	IEC IIB
Flexible power rating	4.2-4.8 MW
Control	Pitch and variable speed
Standard operating temperature	Range from -20ºC to 35ºC (1)
Rotor	
Diameter	145 m
Swept area	16,513 m²
Rotational speed	10.77 rpm
Power density	254.35 W/m²
Blades	
Length	71 m
Airfoils	Siemens Gamesa
Material	Fiberglass reinforced with epoxy resin

Tower	
Type	Multiple technologies available
Height	107.5, 127.5, 157.5 m and site-specific
Gearbox	
Type	3 stages
Ratio	1:103.99 (50 Hz) 1:124.79 (60 Hz)
Generator	
Type	Doubly-fed induction machine
Voltage	690 V AC
Frequency	50 Hz/60 Hz
Protection class	IP 54
Power factor	0.9 CAP-0.9 IND throughout the power range (2)

(1) Different versions and optional kits are available to adapt machinery to high or low temperatures and saline or dusty environments.
(2) Power factor at generator output terminals, on low voltage side before transformer input terminals.

Table 2: SG 4.5-145 WTG Technical specifications

The knowledge acquired through our latest products, specifically in the optimization of design and industrialization processes, has been a key factor in the development of the SG 4.5-145 turbine. Siemens Gamesa has adopted proven technologies into this model, such as the combination of a three-stage gearbox (two planetary and one parallel) and a doubly-fed induction generator, greatly reducing technological risks. The inclusion of an optional premium converter also allows for compliance with the most demanding grid connection requirements.

It also has a new 71-meter blade made of fiberglass reinforced with epoxy resin, and integrates the aerodynamics and noise reduction know-how of Siemens legacy turbines. This is how, thanks to the incorporation of DinoTails® Next Generation technology, the SG 4.5-145 turbine guarantees a high production of energy and reduced noise emission levels.

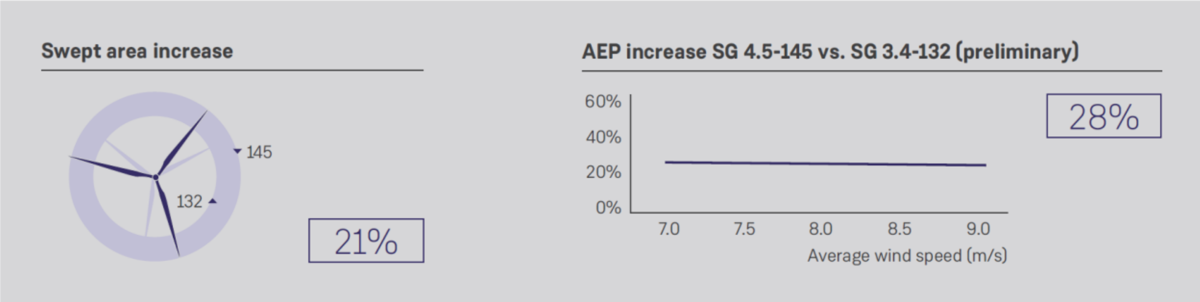

Figure 1: Swept area and AEP increase vs. SG 3.4-132 model

The SG 4.5-145 model includes control technology and strategies from the Siemens legacy, which optimize the efficiency of the wind turbine depending on the site conditions. It offers a flexible power rating from 4.2 MW to 4.8 MW depending on the noise, temperature and electrical requirements of the project. With an increase of 21% of the swept area and 28% of AEP over the SG 3.4-132 wind turbine, this new model will become a reference in the market for its high levels of efficiency and profitability.

The expected service life of the product is stated in 20 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 107.5 m high towers.

2.2.3. Electricity transmission and distribution infrastructure

Once the wind is converted into electricity by the SG 4.5-145 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, we must consider the environmental impacts associated with the construction and dismantling of the infrastructure needed to transport all the electricity generated by the WTGs. The materials used to build these overhead 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 (690 V). This voltage is increased in the transformer located inside the nacelle reaching medium voltage level to minimize electricity losses (30 kV). At the exit of the wind farm there is another transformer station allowing the delivery of high voltage electricity (132 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 could be assumed to be 15 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 3.3 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 for CPC 171.

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 the form of raw material consumptions 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 onshore wind farm using SG 4.5-145 wind turbines, located on an European scenario, operating under medium wind conditions (IEC IIB) and thereafter distributed to an European 132 kV power transmission grid.

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 following 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 blocks in the graph below whose boundary is a dashed line, have not been considered in the LCA, as permitted by the associated PCR. The arrows represent the different transport of materials, parts or bigger components.

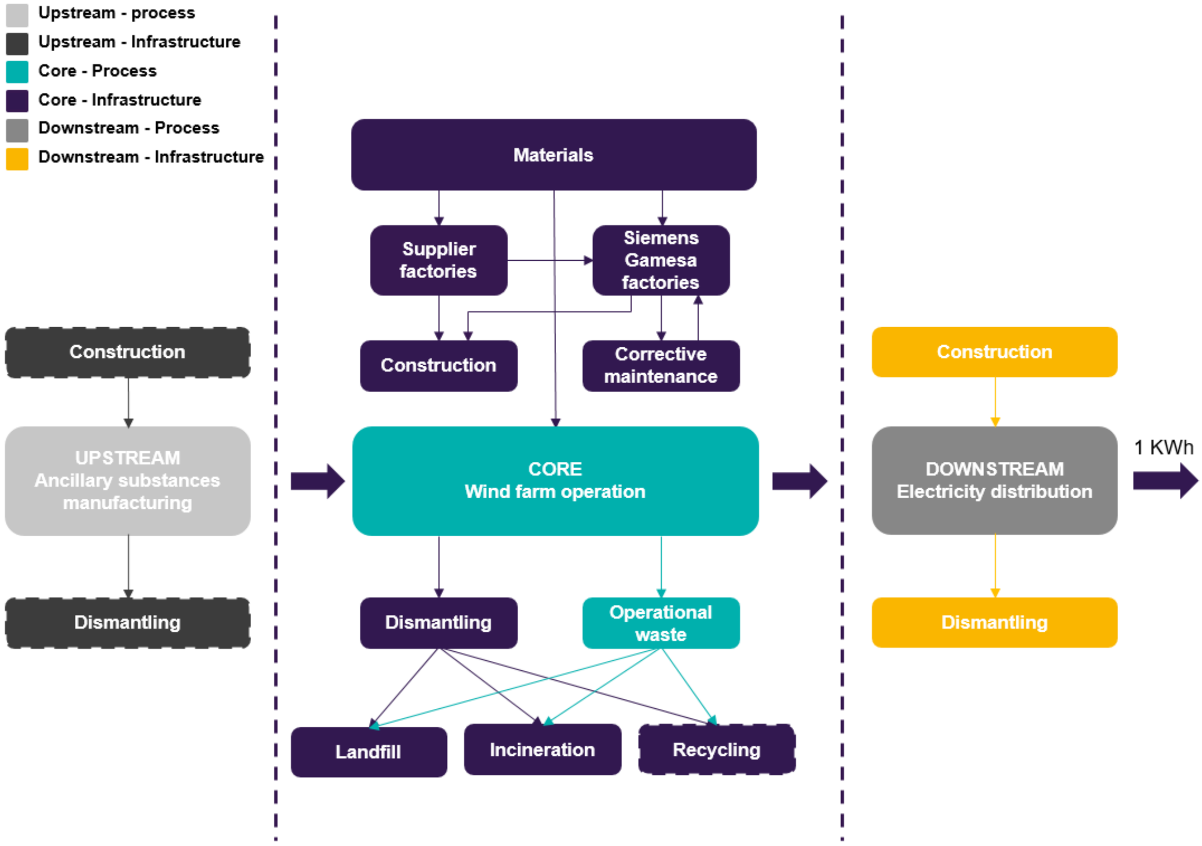

Figure 2: System boundaries

The data used to create the models 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 a 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, 99.31% 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 3.3 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 onshore wind farm using SG 4.5-145 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 PCR.

In the manufacturing stage of the wind turbine, three different manufacturing centers required physical criteria to allocate their global impacts to every produced component, given the fact that they produce components not only for the SG 4.5-145 wind turbine but also for other machines. These centers were Nellore (blades), Valencia power converters (electrical cabinets), and Ágreda (Rotor/Nacelle assembly).

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 20 years of service life.

Since wind power requires no fuel for equipment operation, this module mainly includes the required quantities of hydraulic oil, lubricating oils 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 the lubrication charts and from the maintenance manual of the SG 4.5-145 wind turbine. These documents specify the maintenance needs of this equipment and are considered representative provided that no substantial variations related to the maintenance of the wind turbine occur.

The infrastructure and the equipment of the suppliers of the auxiliary substances necessary for the operation of the wind farm (Upstream infrastructure module) have been excluded from the analysis, as allowed by the PCR.

3.2.2. Core – Infrastructure

The core infrastructure phase encompasses all the steps related to the construction, and decommissioning of the wind farm from the cradle to the 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 and terrain adaptation.

For this EPD, Siemens Gamesa has calculated the environmental impacts arisen from the construction of a virtual 8 WTG wind farm model, as explained in section 2.2.1, and not from a single specific wind site. Siemens Gamesa holds reliable primary data on wind farm construction in a European context from two specific wind projects commissioned in 2019, which have been used as data sources. These are Ballestas windfarm (20 turbines) and El Valle windfarm (14 turbines), both located in Spain. These data have been adapted accordingly for the simulation of this virtual European 8 WTG wind farm.

Figure 3: SG 4.5-145

Different items have been considered in the LCA model of the wind farm construction stage, such as the energy consumed by the machinery when building the foundations, the terrain adaptation and the WTG assembly, or the consumption of construction materials for the foundations and underground wiring networks. All the assets and materials needed for the construction of the on-site electrical substation, 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 a 1 year period (from January 2018 to December 2018, both included). In addition, the material breakdown of the WTGs has been extracted from the BoM of the turbine models actually manufactured during the year 2018.

In the case of an onshore SG 4.5-145 wind turbine delivered to any 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
Blades manufacturing	Nellore – INDIA	SIEMENS GAMESA
Assembly of converter and electrical cabinets	Benissanó - SPAIN	SIEMENS GAMESA
Nacelle & rotor assembly	Ágreda – SPAIN	SIEMENS GAMESA
Generator manufacturing	Reinosa – SPAIN	SIEMENS GAMESA
Gearbox manufacturing	Asteasu – SPAIN	SIEMENS GAMESA
Gearbox assembly	Lerma – SPAIN	SIEMENS GAMESA
Hub manufacturing	Agurain – SPAIN	WEC
Tower manufacturing	Avilés – SPAIN	WINDAR

Table 3: Manufacturing plants included in the core infrastructure module

These facilities are responsible for the manufacturing and assembly of the main components of the SG 4.5-145 wind turbine, given an European client.

In addition to these processes, which are the ones related to the main components, in the previous table, other suppliers that have been considered for the LCA are also listed. The manufacturing processes carried out by these suppliers, have been analyzed using manufacturing processes from Ecoinvent 3.3 database.

Component	Supplier
Main shaft	Vitkovice
Main shaft bearings	Timken
Blade bearings	Rollix
Low speed coupling	Vitkovice
High speed coupling	KTR
Transformer	SGB Stakstrom
Yaw ring	Reducel
Hydraulic group	Glual
Nacelle / Rotor cover	Inpre
Crane system	Amenabar

Table 4: Main suppliers of the core infrastructure module components

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 4.5-145 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 4.5-145 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	Above ground surface is removed and the rest is left in situ
Tower	Fully recyclable.
Blades	95 % Landfilled 5 % Repaired
Blade bearings	Fully recyclable
Hub	Fully recyclable
Rotor cover	Landfilled
Nacelle cover	Landfilled
Beam system / Nacelle structure	Fully recyclable
Main shaft	Fully recyclable
High speed shaft	Fully reusable / repairable
Gearbox	Fully reusable / repairable
Generator	90 % Recycled 10 % Landfilled
Transformer	85 % Recycled 15 % Landfilled
Pitch system	Fully reusable / repairable
Hydraulic group	Fully reusable / repairable
Yaw system	Fully recyclable
Crane system	Fully repairable
Electrical cabinets / converter	90 % Recycled 10 % Landfilled
Wind farm wiring and WTG cables	95 % Recycled 5 % Landfilled

Table 5: End of life hypotheses

3.2.3. Core – Process

All the environmental impacts associated with the operation of the wind farm, given its 20 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 staff trips to the wind farm;
- 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 4: 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 declared 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.

Given the fact that the present study does not cover a specific site but an average European location, the electrical losses that occur between the wind farm electrical substation and the main electricity network, can’t be directly measured. 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 132 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 could be assumed to be 15 km average, which is the length of the line modeled for the LCA. The data used for the modelization of this electrical network have been obtained from the ecoinvent 3.3 database.

3.3. Eco-profile

In the following tables, the environmental behavior of the SG 4.5-145 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 extracted from the CML-IA environmental impact assessment methodology (version 4.8 - August 2016), the Intergovernmental Panel on Climate Change (IPCC 2013 – AR5) and the LOTOS-EUROS methodology as applied in the ReCiPe LCIA method 2008.

The EPD verifier had access to more comprehensive information on the LCA, which supports this declaration.

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

Declared unit

1 kWh net of electricity generated through an Onshore wind farm of SG 4.5-145 wind turbines, located in a European scenario and operating under medium wind conditions (IEC IIB), and thereafter distributed to a 132 kV European electrical grid.

3.3.1. Use of resources

Non - renewable material resources	Unit	Upstream	Core process	Core infrastructure	Total generated	Downstream process	Downstream infrastructure	Total distributed
Gravel	g	2.46E-06	2.03E-05	1.62E-02	1.63E-02	3.58E-04	3.68E-05	1.66E-02
Iron	g	2.51E-07	1.67E-06	1.10E-03	1.10E-03	2.42E-05	4.46E-05	1.17E-03
Calcite	g	2.67E-07	1.17E-06	9.59E-04	9.60E-04	2.11E-05	1.84E-05	1.00E-03
Clay, unspecified	g	2.56E-07	2.31E-07	1.24E-04	1.25E-04	2.74E-06	9.55E-06	1.37E-04
Sodium chloride	g	3.11E-08	3.05E-07	1.18E-04	1.18E-04	2.59E-06	2.11E-06	1.23E-04
Gangue, bauxite	g	1.27E-07	8.55E-07	8.87E-05	8.97E-05	1.97E-06	1.86E-04	2.77E-04
Colemanite	g	6.05E-11	3.57E-10	4.50E-05	4.50E-05	9.90E-07	1.32E-10	4.60E-05
Manganese	g	1.26E-09	1.03E-08	3.54E-05	3.54E-05	7.79E-07	1.97E-08	3.62E-05
Magnesite	g	1.91E-09	1.24E-08	2.48E-05	2.48E-05	5.45E-07	2.58E-08	2.53E-05
Gypsum	g	5.16E-09	1.80E-08	1.72E-05	1.73E-05	3.80E-07	1.15E-07	1.78E-05
Clay, bentonite	g	7.42E-09	2.19E-08	1.30E-05	1.30E-05	2.87E-07	5.31E-07	1.38E-05
Chromium	g	5.89E-09	2.25E-08	1.09E-05	1.09E-05	2.40E-07	5.17E-08	1.12E-05
Aluminium	g	1.19E-08	8.05E-08	8.46E-06	8.55E-06	1.88E-07	1.75E-05	2.62E-05
Other non-renewable resources	g	1.53E-07	1.55E-07	6.29E-06	6.32E-06	5.30E-05	5.30E-05	5.93E-05

Table 6: Non- renewable material resources

Renewable material resources	Unit	Upstream	Core process	Core infrastructure	Total generated	Downstream process	Downstream infrastructure	Total distributed
Wood	g	2.15E-07	3.04E-07	1.52E-04	1.53E-04	3.36E-06	4.56E-06	1.61E-04

Table 7: Renewable material resources

Water use	Unit	Upstream	Core process	Core infrastructure	Total generated	Downstream process	Downstream infrastructure	Total distributed
Total amount of water use	m3	1.43E-07	1.91E-07	7.42E-05	7.45E-05	1.64E-06	1.58E-06	7.77E-05
Direct amount of water used in the core process	m3	-	4.39E-09	-	4.39E-09	9.66E-11	-	4.49E-09

Table 8: Water use

Non - renewable energy resources	Unit	Upstream	Core process	Core infrastructure	Total generated	Downstream process	Downstream infrastructure	Total distributed
Nuclear	MJ	2.45E-05	2.28E-05	9.12E-03	9.17E-03	2.02E-04	1.20E-04	9.49E-03
Crude oil	MJ	8.76E-04	5.33E-04	3.27E-02	3.41E-02	7.51E-04	5.07E-04	3.54E-02
Brown coal	MJ	9.62E-06	1.07E-05	4.51E-03	4.53E-03	9.97E-05	2.24E-04	4.86E-03
Hard coal	MJ	2.60E-05	6.50E-05	3.00E-02	3.01E-02	6.61E-04	2.15E-03	3.29E-02
Natural gas	MJ	6.81E-05	6.09E-05	2.19E-02	2.20E-02	4.84E-04	5.22E-04	2.30E-02

Table 9: Non- renewable energy resources

Renewable energy resources	Unit	Upstream	Core process	Core infrastructure	Total generated	Downstream process	Downstream infrastructure	Total distributed
Energy from hydro power	MJ	5.23E-06	9.75E-06	3.41E-03	3.43E-03	7.54E-05	3.44E-04	3.84E-03
Energy from biomass	MJ	7.58E-06	5.80E-06	2.70E-03	2.71E-03	5.96E-05	7.88E-05	2.85E-03
Wind electricity	MJ	1.40E-06	9.94E-07	7.28E-04	7.31E-04	1.61E-05	4.00E-06	7.51E-04
Solar electricity	MJ	1.48E-08	3.58E-08	1.13E-04	1.13E-04	2.49E-06	1.02E-08	1.15E-04
Geothermal energy	MJ	1.02E-08	1.79E-07	6.15E-05	6.17E-05	1.36E-06	7.62E-07	6.38E-05
Electricity use in the wind farm (3)	kWh	-	1.06E-02	-	1.06E-02	2.33E-04	-	1.08E-02

Table 10: Renewable material resources

Recycled material resources	Unit	Upstream	Core process	Core infrastructure	Total generated	Downstream process	Downstream infrastructure	Total distributed
Steel	g	-	-	5.85E-01	5.85E-01	1.29E-02	1.62E-02	6.14E-01
Aluminium	g	-	-	1.09E-02	1.09E-02	2.40E-04	1.18E-02	2.29E-02
Copper	g	-	-	1.26E-03	1.26E-03	2.78E-05	3.63E-04	1.65E-03

Table 11: Recycled material resources

(3) The electricity used in the wind farm is generated by the wind turbines itself. The environmental impact in conjunction with this electricity consumption has been included in the results.

3.3.2. Pollutant emissions

Potential environmental impacts	Unit	Upstream	Core process	Core Infrastructure	Total generated	Downstream process	Downstream infrastructure	Total distributed
Global warming potential (100yrs)	g CO2 eq	2.31E-02	7.88E-02	7.17E+00	7.27E+00	1.60E-01	3.67E-01	7.80E+00
Photochemical oxidant potential	g NMVOC eq	1.86E-04	1.83E-04	4.20E-02	4.24E-02	9.32E-04	1.31E-03	4.46E-02
	g C_2H_4 eq	7.10E-06	9.07E-06	3.02E-03	3.03E-03	6.67E-05	1.79E-04	3.28E-03
Acidification potential	g SO2 eq	1.07E-04	1.84E-04	4.94E-02	4.97E-02	1.09E-03	2.56E-03	5.34E-02
Eutrophication potential	g PO43- eq	2.40E-05	6.25E-05	3.69E-02	3.70E-02	8.14E-04	9.32E-04	3.87E-02

Table 12: Potential environmental impacts

Emissions to air contributing most to the environmental impact categories	Unit	Upstream	Core process	Core infrastructure	Total generated	Downstream process	Downstream infrastructure	Total distributed
Carbon dioxide, fossil	g	1.38E-02	7.68E-02	6.42E+00	6.51E+00	1.43E-01	3.15E-01	6.97E+00
Methane, fossil	g	4.61E-05	6.00E-05	2.11E-02	2.13E-02	4.68E-04	1.36E-03	2.31E-02
Methane, biogenic	g	6.24E-07	9.71E-07	2.21E-03	2.21E-03	4.86E-05	2.29E-05	2.28E-03
Dinitrogen monoxide	g	4.83E-07	9.50E-07	2.56E-04	2.58E-04	5.67E-06	7.21E-06	2.71E-04
Sulfur hexafluoride	g	3.21E-07	1.42E-09	6.35E-07	9.58E-07	2.11E-08	5.50E-08	1.03E-06
Nitrogen oxides	g	3.71E-05	1.32E-04	2.96E-02	2.97E-02	6.54E-04	8.41E-04	3.12E-02
NMVOC	g	1.36E-04	3.55E-05	7.33E-03	7.50E-03	1.65E-04	1.68E-04	7.83E-03
Carbon monoxide, fossil	g	2.39E-05	8.10E-05	4.34E-02	4.35E-02	9.56E-04	2.86E-03	4.73E-02
Sulfur dioxide	g	7.85E-05	8.68E-05	2.68E-02	2.70E-02	5.94E-04	1.79E-03	2.94E-02
Ammonia	g	7.94E-07	1.10E-06	5.69E-04	5.71E-04	1.26E-05	1.78E-05	6.01E-04
Benzene	g	2.17E-07	2.00E-06	3.20E-04	3.23E-04	7.10E-06	1.23E-05	3.42E-04
Ethyl acetate	g	1.45E-08	9.62E-08	2.60E-04	2.60E-04	5.72E-06	7.26E-09	2.66E-04
Hydrogen chloride	g	6.99E-07	1.48E-06	5.64E-04	5.66E-04	1.25E-05	4.96E-05	6.28E-04
Hydrogen fluoride	g	1.11E-07	4.04E-07	8.70E-05	8.75E-05	1.93E-06	5.98E-05	1.49E-04
Methyl ethyl ketone	g	1.45E-08	1.43E-07	2.60E-04	2.60E-04	5.72E-06	7.28E-09	2.66E-04

Table 13: Emissions to air contributing most to the environmental impact categories

Emissions to water contributing most to the environmental impact categories	Unit	Upstream	Core process	Core infrastructure	Total generated	Downstream process	Downstream infrastructure	Total distributed
Phosphate	g	1.28E-05	3.59E-05	3.13E-02	3.14E-02	6.91E-04	7.77E-04	3.29E-02
COD, Chemical Oxygen Demand	g	1.99E-04	3.47E-04	2.98E-02	3.04E-02	6.68E-04	5.56E-04	3.16E-02
Nitrate	g	1.38E-05	7.47E-06	6.34E-03	6.36E-03	1.40E-04	2.39E-04	6.74E-03
Hydrogen sulfide	g	1.56E-08	1.57E-07	8.75E-05	8.76E-05	1.93E-06	2.32E-06	9.19E-05

Table 14: Emissions to water contributing most to the environmental impact categories

Emissions of radioactive isotopes	Unit	Upstream	Core process	Core infrastructure	Total generated	Downstream process	Downstream infrastructure	Total distributed
C-14	KBq	4.22E-07	2.68E-07	2.86E-05	2.93E-05	6.44E-07	4.44E-07	3.03E-05
Rn-222	KBq	8.54E-04	7.24E-04	2.70E-01	2.71E-01	5.97E-03	3.94E-03	2.81E-01
Kr-85	KBq	1.56E-08	7.83E-09	3.29E-06	3.32E-06	7.30E-08	6.11E-08	3.45E-06

Table 15: Emissions of radioactive isotopes

Emissions of biogenic carbon dioxide	Unit	Upstream	Core process	Core infrastructure	Total generated	Downstream process	Downstream infrastructure	Total distributed
Carbon dioxide, biogenic	g	5.21E-04	4.15E-04	1.83E-01	1.84E-01	4.04E-03	3.12E-03	1.91E-01

Table 16: Emissions of biogenic carbon dioxide

Emissions of toxic substances	Unit	Upstream	Core process	Core infrastructure	Total generated	Downstream process	Downstream infrastructure	Total distributed
Particulates, <2,5 um to air	g	6.96E-06	2.02E-05	1.15E-02	1.15E-02	2.53E-04	4.47E-04	1.22E-02
Particulates, >10 um to air	g	7.00E-06	3.29E-05	9.80E-03	9.84E-03	2.17E-04	6.73E-04	1.07E-02
Particulates, >2,5 um, and <10 um to air	g	2.74E-06	1.42E-05	5.98E-03	5.99E-03	1.32E-04	2.78E-04	6.40E-03
PAH, polycyclic aromatic hydrocarbons to air	g	2.07E-09	8.97E-09	2.99E-06	3.00E-06	6.60E-08	9.80E-07	4.05E-06
PAH, polycyclic aromatic hydrocarbons to water	g	5.64E-09	3.85E-09	1.80E-06	1.81E-06	3.98E-08	1.10E-08	1.86E-06
Arsenic to air	g	4.00E-09	8.67E-09	1.04E-05	1.04E-05	2.28E-07	5.59E-07	1.12E-05
Cadmium to air	g	1.83E-09	3.16E-09	3.41E-06	3.41E-06	7.51E-08	1.89E-07	3.68E-06
Dioxins to air	g	3.13E-15	5.18E-14	1.13E-11	1.13E-11	2.49E-13	3.36E-13	1.19E-11

Table 17: Emissions of toxic substances

Emissions of oil to water and ground	Unit	Upstream	Core process	Core infrastructure	Total generated	Downstream process	Downstream infrastructure	Total distributed
Oils, unspecified to water	g	5.99E-05	3.56E-05	2.01E-03	2.10E-03	4.63E-05	5.77E-05	2.21E-03
Oils, unspecified to soil	g	6.58E-05	3.90E-05	2.11E-03	2.22E-03	4.87E-05	3.64E-05	2.30E-03

Table 18: Emissions of oil to water and ground

3.3.3. Waste and material subject to recycling

Hazardous waste – Non radioactive	Unit	Upstream	Core process	Core infrastructure	Total generated	Downstream process	Downstream infrastructure	Total distributed
Hazardous waste - To incineration	g	-	1.20E-02	-	1.20E-02	2.63E-04	3.09E-04	1.25E-02
Hazardous waste - To recycling	g	-	-	8.53E-03	8.53E-03	1.88E-04	6.19E-04	9.33E-03

Table 19: Hazardous waste – Non radioactive

Hazardous waste – Radioactive	Unit	Upstream	Core process	Core infrastructure	Total generated	Downstream process	Downstream infrastructure	Total distributed
Volume for deposit of low-active radioactive waste	m3	2.61E-12	1.57E-12	1.15E-10	1.20E-10	2.63E-12	1.89E-12	1.24E-10
Volume for deposit of radioactive waste	m3	1.52E-14	1.47E-14	5.91E-12	5.94E-12	1.31E-13	8.80E-14	6.16E-12

Table 20: Hazardous waste – Radioactive

Other waste	Unit	Upstream	Core process	Core infrastructure	Total generated	Downstream process	Downstream infrastructure	Total distributed
Non-hazardous waste - To landfill	g	-	-	5.59E+00	5.59E+00	1.23E-01	3.88E-04	5.71E+00
Non-hazardous waste - To recycling	g	-	-	1.23E+00	1.23E+00	2.70E-02	5.33E-02	1.31E+00

Table 21: Other waste

3.4. Hot spot analysis and conclusions

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

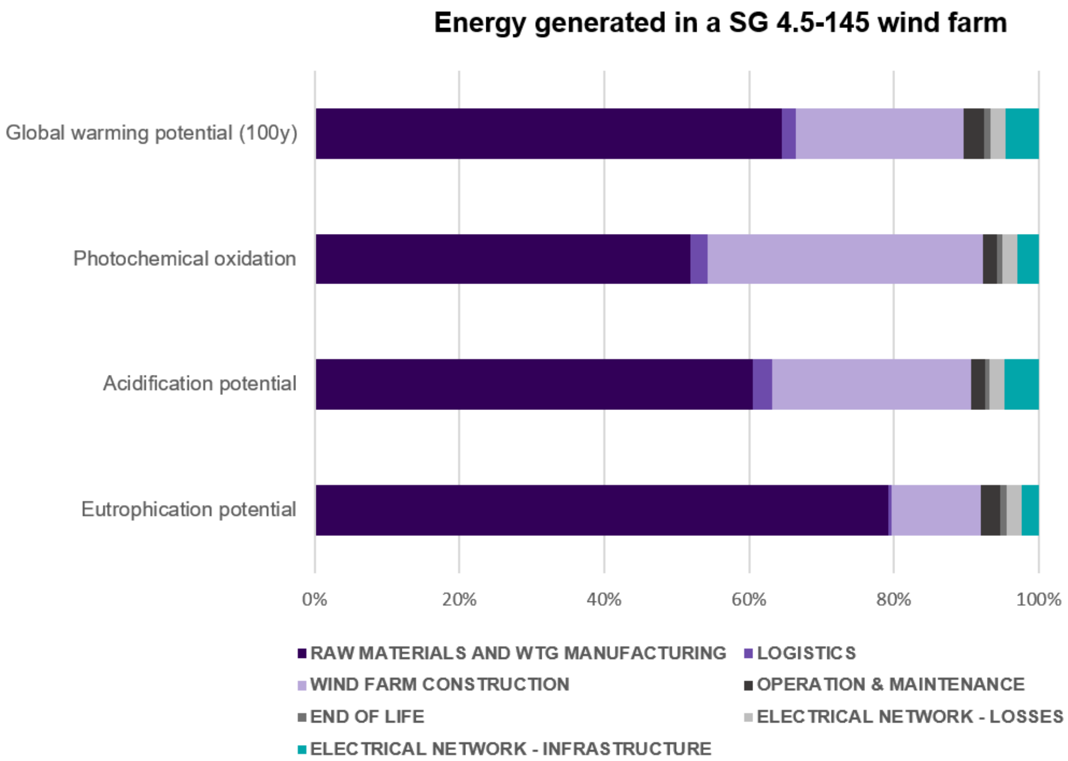

Figure 5: Environmental hot spots

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 the 89% of the total environmental impacts for the 4 assessed impact categories.

From a life cycle point of view, these two stages are the main hot-spots of the energy generated in the SG 4.5-145 windfarm, and should be carefully designed in future projects.

Nearly 64% (in average for the 4 impact categories) of the environmental impacts of the energy generated and distributed by a SG 4.5-145 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 blades.

Concerning the wind farm construction, this stage represents 25.3% of the impacts (in average). The most relevant environmental aspects for the construction stage are the materials which compose the foundation (mainly concrete and steel), followed by the terrain adaptation required when building the wind farm.

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 4.5-145 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 (water, fossil fuels and wind) 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 wind projects are constructed in a sustainable way that allows a balanced coexistence, 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, which will be the most common affected areas when a new wind farm 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 22: 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 8 wind turbine windfarm will be approximately of 333,545 m^2. This area will be mainly occupied by the following artificial elements during 20 years and 6 months, including the construction, operation and dismantling periods of the windfarm:

- Foundations;
- Turbines;
- Tracks / roads;
- Control buildings;
- Electrical substation compounds;
- Trenches for internal wiring.

4.3. Environmental risks

Although the probability and severity of undesirable events is very low, the most representative environmental risk is the accidental oil spill. The environmental management system currently in place at Siemens Gamesa, prevents accidental spills through technical control elements (spill trays, loading and unloading areas, storage of chemical products, protection of the rainwater network, etc.), along with management mechanisms.

Should spills happen, Siemens Gamesa is equipped with environmental anomaly detection, reporting and correction methods which are aimed at preventing this kind of events from being repeated. Significant spills are construed as spills that cause damage to the facility's external surroundings. Small spills are defined as spills with an actual consequence of moderate or lower corresponding to level 3 on a 1-5 scale.

A total of 308 small spills were recorded during 2018. There was just one significant spill in the reporting period, amounting to 1,700 liters of oil released from a pad-mounted transformer. All spills were reported and corrected in accordance with internal procedures. None of these spills required any exceptional corrective measures. When using the declared windfarm as reference, these spills happen less frenquent 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 nacelle 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 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 according to IEC 61400-14: 2005 and IEC 61400-11; 3rd Ed.; noise level is lower than 110.1 dBA.

4.6. 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.

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 Tecnalia 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 EPD-System General Programme Instructions.

The EPD has been made in accordance with the General Programme Instructions for an Environmental Product Declaration, EPD, published by the International EPD Consortium and PCR version 3.1 for CPC 171 & 173: Electricity, Steam, and Hot and Cold Water Generation and Distribution, valid until 2020-02-05.

This certification is valid until 2022-10-30.

5.2. Mandatory statements

5.2.1. General

Note that EPDs 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.

5.3. Information on verification

Information about the certification body	
EPD programme	The International EPD® System EPD International AB (Programme operator) Box 210 60, SE-100 31 Stockholm, Sweden www.environdec.com info@environdec.com
Registration Nº	S-P-01723
Publication date	2019-10-30
EPD validity	2022-10-30
EPD valid within the following geographical area	This EPD has European validity
EPD type	Cradle-to-grave
Independent verification of the declaration and data, according to ISO 14025:2006	☒ EPD verification ☐ EPD process certification
Third party verifier	Tecnalia R&I Certificación, S.L. Verifier: Cristina Gazulla
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	☐ Yes ☒ No
LCA study developed by	IK Ingenieria
Reference Product Category Rules (PCR)	PCR 2007:08 UN CPC 171 & 173 Version 3.1 Electricity, steam and hot/cold water generation and distribution
PCR review conducted by	The Technical Committee of the International EPD® System Full list of TC members available on www.environdec.com/TC
PCR prepared by	The Technical Committee of the International EPD® System PCR Moderator: Mikael Ekhagen - VATTENFALL Contact via Mikael.ekhagen@vattenfall.com

SIEMENS Gamesa
RENEWABLE ENERGY

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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 3.3 Database, published by the Swiss Centre for Life Cycle Inventories

http://www.ecoinvent.org