GE Renewable Energy

Cypress 5.5-158

Onshore Wind Turbine

Product Environmental Profile

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PEP Ecopassport N°GERE-00001-V01.01-EN	Cypress 5.5-158 Onshore Wind Turbine	Version 1.0	Issued 04/2021	Page 1/11

INTRODUCTION

This document provides the results of the Life Cycle Assessment (LCA) of the Cypress 5.5-158 onshore wind turbine quantifying environmental impact across its entire life cycle, from cradle to grave (materials, manufacturing, distribution and installation, use and end of life).

The LCA was performed in accordance with ISO standards 14040 and 14044.

It is important to point out that these LCA results depend on:

- **the scope of the study**
- **assumptions**
- **calculation method**
- **data used**

In consequence, results cannot be compared to other environmental declarations without checking if all these elements are the same.

PRODUCT DESCRIPTION

The Cypress platform, GE's largest high efficiency onshore turbine platform, ranges from 4.8MW to 6.0MW power output and is suitable for low and medium wind sites. The platform advances the proven technology of GE's 2MW and 3MW models, which serves an installed base of more than 20 GW.

https://www.ge.com/renewableenergy/wind-energy/onshore-wind/cypress-platform

COMPANY DETAILS

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Environmental policy

GE Renewable Energy is committed to achieving environmental, health and safety (EHS) excellence. This is a responsibility shared by all employees in all functions. GE Renewable Energy has reached Carbon Neutrality of its operations at the end of 2020. At group level, GE targets Carbon Neutrality for its operations by 2030.

https://www.ge.com/renewableenergy/about-us/carbon-neutral

REFERENCE PRODUCT

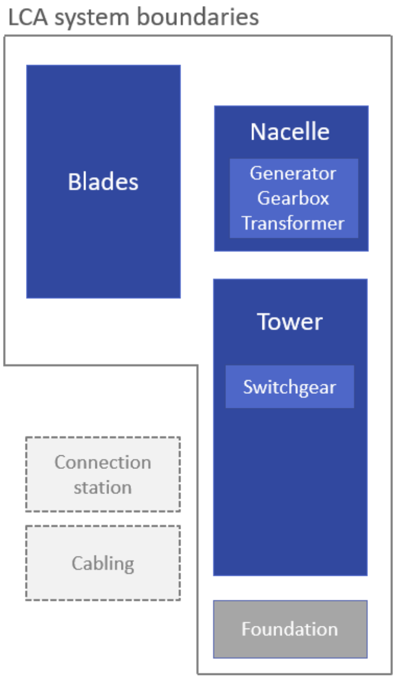
Cypress 5.5-158 onshore wind turbine

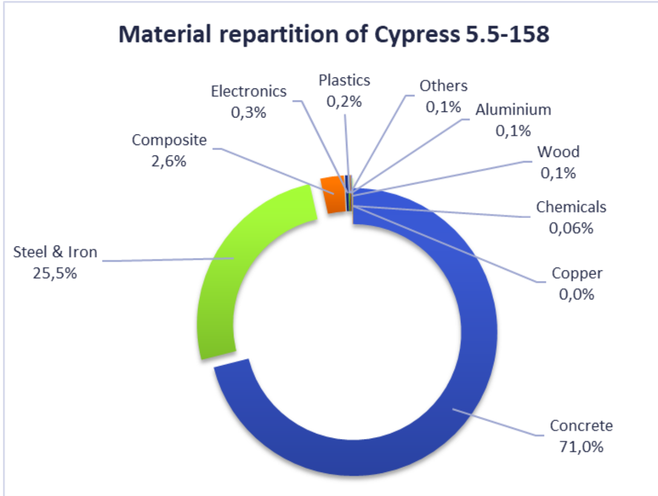
The product evaluated is the Cypress 5.5-158 onshore wind turbine. The functional unit of this study is "**production of one kWh of electricity generated by a wind turbine rated at 4.8 to 6 MW with an expected lifetime of 25 years**".

The analysis considers the entire life cycle of the product including: materials extraction, processing, and transport; product manufacturing; distribution and installation; operation and maintenance; and end-of-life disposal.

Foundations of the wind turbine are included in the study. Connection of the wind turbine to the existing grid (cabling, connection station) are not included in this analysis.

The wind turbine has been designed for a project in Germany, thus following the DIBt guideline Version Oct 2012 (modified version March 2015).





MATERIAL CONTENT

The total mass of the wind turbine studied is 594 tons, the mass of the foundation is 1685 tons. Here the material breakdown:

	Materials	Mass (%)
Metals (25.6%)	Other ferrous alloys, non-stainless steels	20.1
	Cast and sintered irons	3.2
	Stainless steel	2.2
	Aluminium and its alloys	0.1
	Copper and its alloys	<0.1
Plastics (2.8%)	Polyester resin	2.6
	Epoxy resin	0.1
	PolyEthyleneTerephthalate (PET)	0.1
	Other unfilled thermoplastics	<0.1
	Rubber	<0.1
Others (71,6%)	Concrete	71.1
	Electronics	0.3
	Wood	0.1
	Chemicals	0.1
	Ceramics	0.1
	Miscellaneous	<0.1

METHODOLOGY

The analysis was performed with SimaPro LCA software version 9.1.1.1 and a set of impact assessment methods (CML-IA Baseline, Cumulative Energy Demand for energy, Recipe midpoint H for water depletion). Secondary data are from Ecoinvent version 3.6 life cycle inventory database.

Environmental impact evaluation is carried out on the whole life cycle of the product across and on each of the environmental indicators. For an explanation of each indicator, see the appendix.

MANUFACTURING

This phase includes production of the raw materials and the manufacturing of components of the wind turbine, as well as their transportation from supplier's site to GE Renewable Energy facilities for their assembly.

Bill of materials from GE's suppliers were compiled by GE's team. The wind turbine materials were grouped into for major components:

- Tower (6 tower sections, service lift, switchgear, cables)
- Blades
- Hub and Nacelle (gearbox, generator, transformer, coupling …)

Manufacturing data from the GE facilities in Castellon, Spain, and Salzbergen, Germany, were provided by facility managers for the manufacturing of blades and nacelle. Data for manufacturing of the tower were provided by the supplier.

For other components, data for manufacturing were estimated based on industry-average data for parts shaping of different material types (Ecoinvent 3.6 life cycle inventory database).

DISTRIBUTION

This phase includes the transport of wind turbine's components to the installation site. For this study, the installation site was assumed to be located in north of Germany, at Remmels. Transport impacts were calculated based on road and ocean transport of components to the installation site.

INSTALLATION

Installation phase includes processes for:

- Construction of the foundation: concrete, steel, diesel consumption for cranes, concrete pump and mixing machine
- Tower, machine head assembly and blades installation: diesel consumption for cranes, truck and tools
- Electrical assembly: diesel consumption for heating cables
- Commissioning electricity consumption for testing and initial set of consumables (e.g., greases, oils, fluids, coolants).
- Treatment of packaging wastes.

USE

Electricity production

The assessment considers a capacity factor of 0.385, a wind turbine lifetime of 25 years, and the following losses:

- Availability losses (when the turbine is not operating): 2%
- Wake losses (which result from turbine losses downstream of each other): 1,3%

Thus, the total energy produced by the wind turbine is 448 275MWh over 25 years.

Electricity consumption

A stand-by consumption of 70000kWh/year is considered for the consumption of transformer, fans, and components in the nacelle.

Maintenance

Transportation of maintenance crew to and from the site during operation phase is estimated to be 1500km per plant per year.

Activities related to maintenance are replacement of consumables (greases, oils, fluids, coolants, filters). The transport of these consumables to the operation site is also included.

END OF LIFE

This phase includes the decommissioning and transport of components to end-of-life treatment either landfill disposal, incineration or recycling.

Decommissioning was assumed to be the reverse of installation. Components are then transported by road to a processing facility. The following component and material disposal scenarios were assumed based on available data for wind turbines:

Materials	End of life scenarios
Large mono-material metal parts[1]	98% recycled, 2% landfilled
Steel	92% recycled, 8% landfilled
Aluminium	92% recycled, 8% landfilled
Copper	92% recycled, 8% landfilled
Composites	10% recycled, 90% landfilled
Polymers	50% incinerated, 50% landfilled

[1] tower sections, bedplate, rotor hub, shaft, gearbox structure

The metholodological choices for allocation for recycling and recovery have been set according to the polluter pays principle (PPP), compliant with PEP Ecopassport program rules. This means that the study considers the impact of the material disposal processes (incineration and landfilling), but the environmental benefits and loads relating to recycling are not included. They will be considered by the subsequent user of the waste.

LIFE CYCLE ASSESSMENT RESULTS

Representativeness of the study:

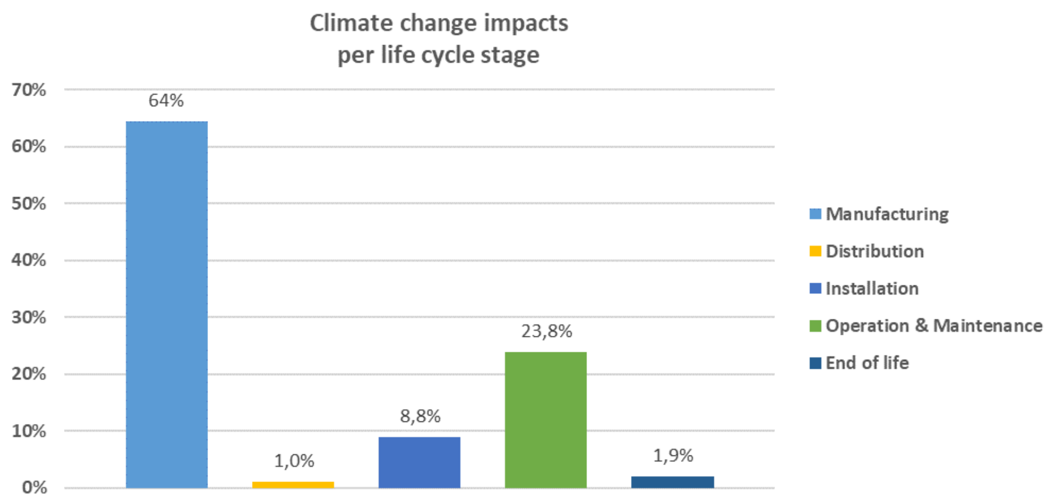
- Technology coverage: This study assesses the production of a Cypress 5.5-158 onshore wind turbine
- Temporal coverage : This study has been performed in 2020.
- Geophical coverage: It is representative from products manufactured and installed in Europe.

Energy model used:

- Manufacturing: Energy models used: “Electricity, medium voltage {ES}| market for | Cut-off, U” for the blades, “Electricity, medium voltage {DE}| market for | Cut-off, U” for the nacelle, “Electricity, medium voltage {TR}| market for | Cut-off, U” for the tower.
- Distribution: not applicable, no energy consuming operations
- Installation: “Electricity, medium voltage {DE}| market for | Cut-off, U”
- Operation and maintenance: “Electricity, medium voltage {DE}| market for | Cut-off, U”
- End of life: not applicable, no energy consuming operations

Life cycle environmental impacts of Cypress onshore wind turbine (per kWh) excluding recycling benefits

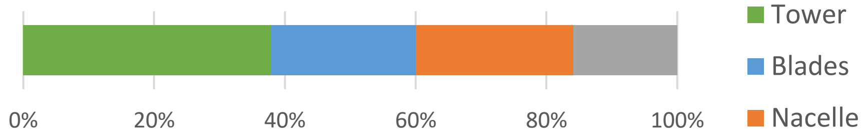
Distribution of GHG emissions



The majority of climate change impacts comes from materials production and manufacturing phase. The end of life does not brings benefits here as recycling of materials was excluded in the scope of the study to comply to program operator rules.

The next plots show the distribution of climate change impacts as a function of component materials:

Climate change impact distribution per component materials

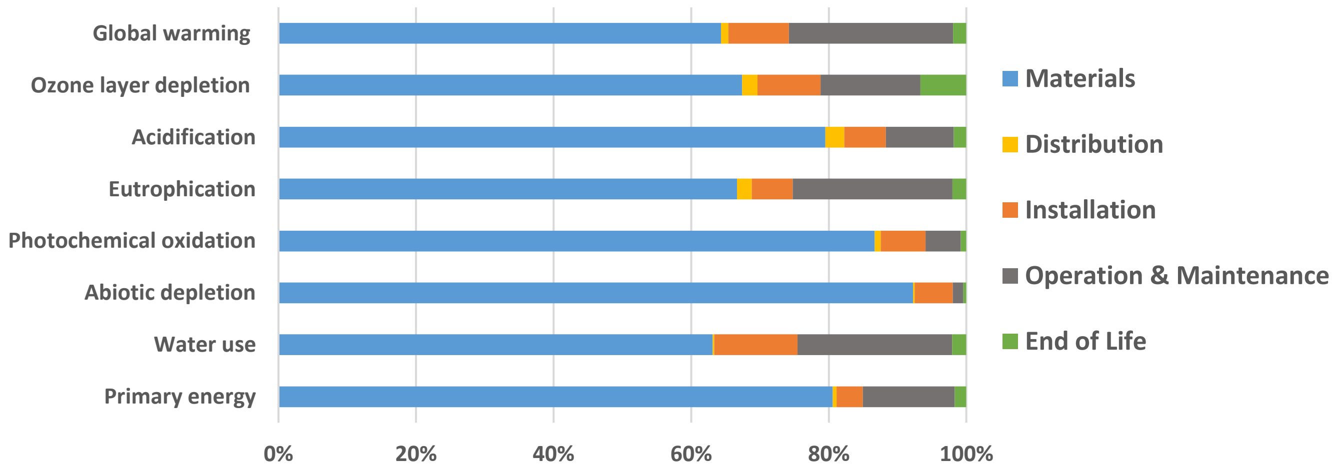


Full multi-environmental impact category results

For each environmental indicator in the table below, the results are shown separately for each life cycle stage: materials, manufacturing, distribution, use and end of life (where benefits of recycling are excluded to comply with PEP Ecopassport program rules).

Impact category	Unit (per kWh)	Materials	Distribution	Installation	Operation & Maintenance	End of Life	Total
Global warming	kg CO2 eq	6.59E-03	1.07E-04	9.04E-04	2.44E-03	1.99E-04	1.02E-02
Ozone layer depletion	kg CFC-11 eq	5.66E-10	1.88E-11	7.71E-11	1.22E-10	5.61E-11	8.40E-10
Acidification	kg SO2 eq	4.06E-05	1.39E-06	3.08E-06	5.03E-06	9.42E-07	5.10E-05
Eutrophication	kg PO4--- eq	5.03E-06	1.61E-07	4.50E-07	1.75E-06	1.53E-07	7.54E-06
Photochemical oxidation	kg C2H4 eq	3.78E-06	3.91E-08	2.84E-07	2.22E-07	3.53E-08	4.36E-06
Abiotic depletion - Elements	kg Sb eq	5.86E-07	1.39E-09	3.50E-08	9.78E-09	2.78E-09	6.35E-07
Water use	m3	3.96E-05	1.40E-07	7.61E-06	1.41E-05	1.30E-06	6.27E-05
Primary energy	MJ	2.26E-01	1.56E-03	1.08E-02	3.75E-02	4.72E-03	2.81E-01

LCA Results for Cypress 5.5-158 Onshore Wind Turbine



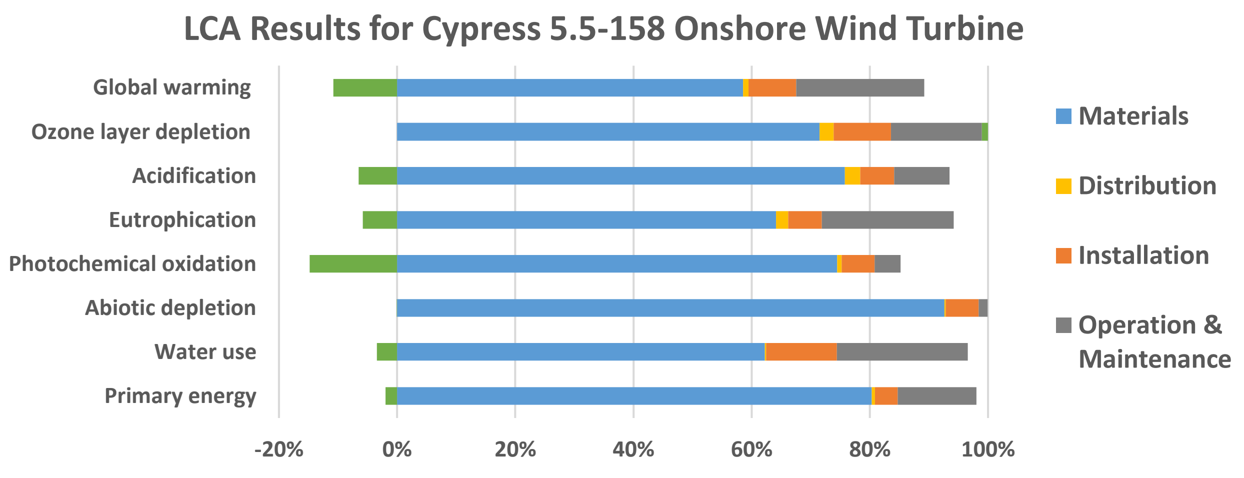
ADDITIONNAL INFORMATION

Life cycle environmental impacts of Cypress onshore wind turbine (per kWh) considering recycling benefits

In the results presented previously, benefits of the end-of-life (recycling, and energy recovery by incineration) were excluded, to comply with PCR V3 of PEP Ecopassport program.

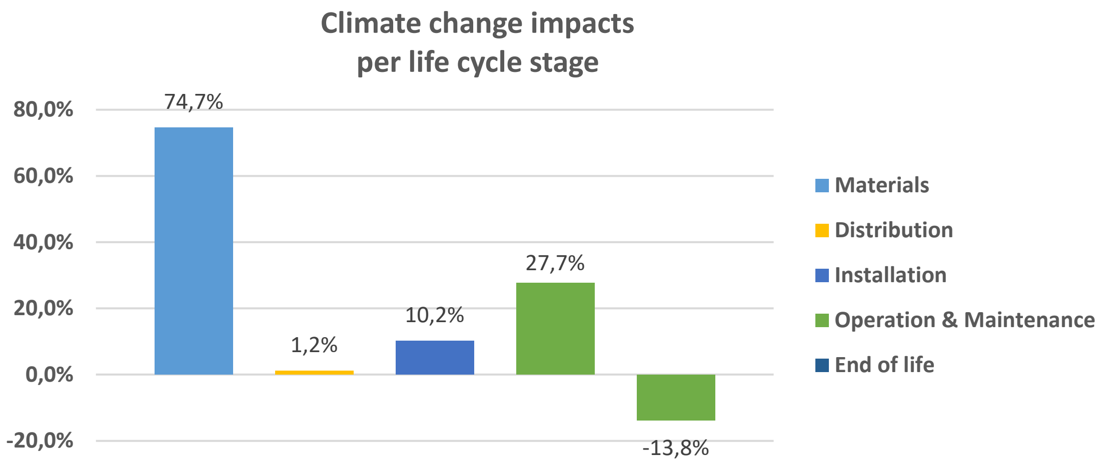
The following table presents the results considering both impact of the material disposal processes (load of recycling, incineration and landfilling), as well as the environmental benefits of recycling and energy recovery by incineration.

Impact category	Unit (per kWh)	Materials	Distribution	Installation	Operation & Maintenance	End of Life	Total
Global warming	kg CO2 eq	6.59E-03	1.07E-04	9.04E-04	2.44E-03	-1.22E-03	8.83E-03
Ozone layer depletion	kg CFC-11 eq	5.66E-10	1.88E-11	7.71E-11	1.22E-10	8.27E-12	7.92E-10
Acidification	kg SO2 eq	4.06E-05	1.39E-06	3.08E-06	5.03E-06	-3.48E-06	4.66E-05
Eutrophication	kg PO4--- eq	5.03E-06	1.61E-07	4.50E-07	1.75E-06	-4.56E-07	6.93E-06
Photochemical oxidation	kg C2H4 eq	3.78E-06	3.91E-08	2.84E-07	2.22E-07	-7.50E-07	3.57E-06
Abiotic depletion - Elements	kg Sb eq	5.86E-07	1.39E-09	3.50E-08	9.78E-09	-3.35E-10	6.32E-07
Water use	m3	3.96E-05	1.40E-07	7.61E-06	1.41E-05	-2.18E-06	5.92E-05
Primary energy	MJ	2.26E-01	1.56E-03	1.08E-02	3.75E-02	-5.59E-03	2.71E-01



Compared to previous results, we can see that the end of life brings benefits as recycling of materials was included in the scope of the study and allows to reduce the global environmental impact of the wind turbine over its whole life cycle.

Distribution of GHG emissions



REFERENCES

- ISO 14040: 2006, Environmental management – Life cycle assessment – Principles and framework
- ISO 14044: 2006, Environmental management – Life cycle assessment – Requirements and guidelines
- ISO 14020: 2000, Environmental labels and declarations – General principles
- ISO 14025: 2000, Environmental labels and declarations – Type III environmental declarations

APPENDIX

Life Cycle Assessment (LCA)
A life cycle assessment is an evaluation of all incoming and outgoing materials as well as the potential environmental impacts of a product or process over the whole life cycle, i.e. « from cradle to grave ».

Product Environmental Profile (PEP)
The Product Environmental Profile is an information sheet on a certain product describing the environmental impacts of this product, based on the LCA results.

Impact indicators:

CML-IA baseline version 3.04

Climate change: There are several gaseous emissions that cause global warming such as, carbon dioxide, methane, nitrous oxides and fluorinated gases. This category combines the effect of differing times greenhouse gases remain in the atmosphere and their relative effectiveness in absorbing outgoing infrared radiation. The concentration of greenhouse gases is measured as kg equivalents of CO_2, i.e., the relative global warming potential of a gas as compared to CO_2. The IPCC model with a 100-year time horizon is used for characterization. The uptake of carbon dioxide from the air (sequestration of CO_2 by plants) and the subsequent emission of biogenic carbon dioxide (from the burning of biomass) are not included. Characterization factors are according to IPCC 2013 report. The unit of measure for this category is kg CO_2 equivalents.

Ozone depletion: Impacts due to increased UV radiation resulting from the emission of ozone depleting substances. These impacts are mainly linked to a group of substances that includes Chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), halons, methyl bromide, methyl chloroform and carbon tetrachloride. These substances are unstable in stratosphere where they catalyze ozone depleting reactions and reduce the concentration of beneficial ozone. Characterization factors are measured as kg equivalent CFC-11 into air (kg CFC-11 eq.).

Acidification: Acidifying gaseous emissions of ammonia and oxides of nitrogen and sulfur adversely affect the terrestrial ecosystems quality. Anthropogenic activities like fossil fuel and biomass combustion are the main contributor of these emissions. The impacts are characterized by using fate models (models that describe the concentration and impact of contaminants in environment), as kg equivalents of SO_2 into air.

Eutrophication: Eutrophication is a result of increased levels of nitrogen and phosphorous containing compounds in water bodies. High levels of phosphorous and nitrogen cause excessive plant growth and then decay leading to an oxygen deficit environment. Eutrophication favors simple algae and planktons over other more complicated plants, causing a severe reduction in water quality. The unit is PO4- equivalents.

Photochemical oxidation: This category quantifies particulate matter formation due to the emissions of dust (particulates), sulfur and nitrogen oxides, primarily found in winter smog. The particulate matter formation is measured by using atmospheric deposition models and empirical observations, as kg equivalent of C_2H_4.

Abiotic depletion – Elements: This category is related to extraction of minerals due to inputs in the system. The Abiotic Depletion Factor (ADF) is determined for each extraction of minerals based on concentration reserves and rate of deaccumulation. This category is characterized as Antimony equivalents (kg Sb equivalent).

ReCiPe Midpoint H version 1.04

Water use: This category represents the use of water in such a way that the water is evaporated, incorporated into products, transferred to other watersheds or disposed into the sea. Water that has been consumed is thus not available anymore in the watershed of origin for humans nor for ecosystems. The unit is m^3.

Cumulative Energy Demand (CED) version 1.09

Primary energy: Characterization factors are given are given for the energy resources divided in 5 impact categories: non-renewable, fossil; non-renewable, nuclear; renewable, biomass; renewable, wind, solar, geothermal; and renewable, water. The unit is MJ.

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PEP verifier accreditation n.: VH29	**Program information:** www.pep-ecopassport.org
Date of issue: 04/2021	**Validity period:** 5 years
Independent verification of the declaration and data, according to ISO 14025:2010:	☐Internal ☒External
The PCR review was conducted by a panel of experts chaired by Philippe Osset, Solinnen.	PEP eco PASS PORT®
The content of this PEP cannot be compared with content based on another program.	
Document in compliance with ISO 14025:2010 « Environmental labels and declarations. Type III environmental declarations »	

The results presented in this report are unique to the assumptions and practices of the General Electric Company. The results are not meant as a platform for comparability to other companies and/or products. Even for similar products, differences in functional unit, use and end-of-life stage assumptions, and data quality may produce incomparable results.

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