阳光电源
SUNGROW

Sungrow Power Supply Co., Ltd.

EPD ITALY

ENVIRONMENTAL PRODUCT DECLARATION

Product Name:	**String Power Inverters** **SG350HX, SG285HX, SG320HX, SG333HX**
Site Plant:	**Hefei, Anhui Province, China**

in accordance with ISO 14025 and EN 50693: 2019

Program Operator	EPDItaly
Publisher	EPDItaly
Declaration Number	*SG-EPD01*
Registration Number	EPDITALY0458
Issue Date	10 / 06 / 2023
Valid to	10 / 06 / 2028

阳 光 电 源
SUNGROW

1. GENERAL INFORMATION

EPD Owner:	Sungrow Power Supply Co., Ltd. Address: No.1699, Xiyou Road, New & High Technology Industrial Development Zone, HeFei City, Anhui Province,P.R.China
Product Name:	String Power Inverters SG350HX, SG285HX, SG320HX, and SG333HX
Production site:	No. 608, Changning Avenue, New & High Technology Industrial Development Zone, HeFei City, Anhui Province, P.R.China
Field of application:	DC/AC power conversion
Program Operator:	EPDITALY (www.epditaly.it) Add: via Gaetano De Castillia n° 10 - 20124 Milano, Italy
CPC Code:	4612 "Electrical transformers, static converters and inductors"
Company Contact:	Bai Rongfang Email: bairongfang@sungrowpower.com
External Audit:	This declaration has been developed referring to EPDItaly, following the General Program Instruction; further information and the document itself are available at: www.epditaly.it. Independent verification of the declaration and data, according to EN ISO 14025:2010. ☐ INTERNAL ☒ EXTERNAL Third party verifier: ICMQ SpA - Via Gaetano De Castillia, 10 - 20124 – Milano/Italy
LCA Consultant:	This life cycle assessment was conducted in accordance with ISO 14044 and the reference PCR by: TÜV SÜD (www.tuvsud.cn)
Reference PCR and version number:	Core PCR: EPDItaly007 – PCR for Electronic and Electrical Products and Systems, Rev. 3, 2023/01/13. Sub PCR: EPDItaly032 - Power Inverter, Rev. 0, 2022/12/22.
Other reference documents:	Regulations of the EPDItaly Program rev. 5.2 published on 2022/02/16. EN 50693:2019 - Product category rules for life cycle assessments of electronic and electrical products and systems.
Comparability:	EPDs relating to the same category of products but belonging to different programmes may not be comparable. Full conformance with a PCR allows EPD comparability only when all stages of a life cycle have been considered. However, variations and deviations are possible. Example of variations: Different LCA software and background LCI datasets may lead to differences results for upstream or downstream of the life cycle stages declared.
Liability:	The owner of the declaration will be responsible for the information and supporting evidence. EPDItaly disclaims any liability regarding the manufacturer's information data.
Reference document:	This declaration is based on the EPDItaly regulation, available on the website www.epditaly.com

2. COMPANY INTRODUCTION

Located in Hefei High-tech Industrial Development Zone, Sungrow Power Supply Co., Ltd. (Stock code: 300274) is a national key high-tech enterprise specializing in R&D, manufacturing, sales and service of solar energy, wind energy, energy storage, hydrogen energy, electric vehicles, and other new energy power supply equipment. Sungrow provides world-class solutions for the full life-cycle of clean energy, including photovoltaic inverters, wind energy converters, energy storage systems, floating PV systems, new energy automotive driving system, EV charging station, renewable hydrogen production system, renewable hydrogen production systems, and smart energy operation and maintenance service.

Since the establishment in 1997, the Company has been concentrating on the field of new energy power generation, adhering to market demand orientation, and taking technological innovation as the propellant for development. Photovoltaic inverters, Sungrow's core products, have been accredited by TUV, CSA, SGS, and other international certification authorities, and sold to more than 150 countries and regions in the world. Sungrow's cumulatively installed capacity of inverter equipment across the world has been above 224GW by the end of December 2021.

Sungrow is transforming towards green production. The production site in Hefei has PV modules installed on site. A part of the electricity consumption on site are supplied by renewable solar energy.

3. SCOPE AND TYPE OF EPD

3.1. Scope of EPD

The system boundary of this study on Sungrow's power inverters encompasses the entire life cycle of the product, from cradle to grave, including the manufacturing, distribution, installation, use, and end-of-life stage, as defined in the PCR.

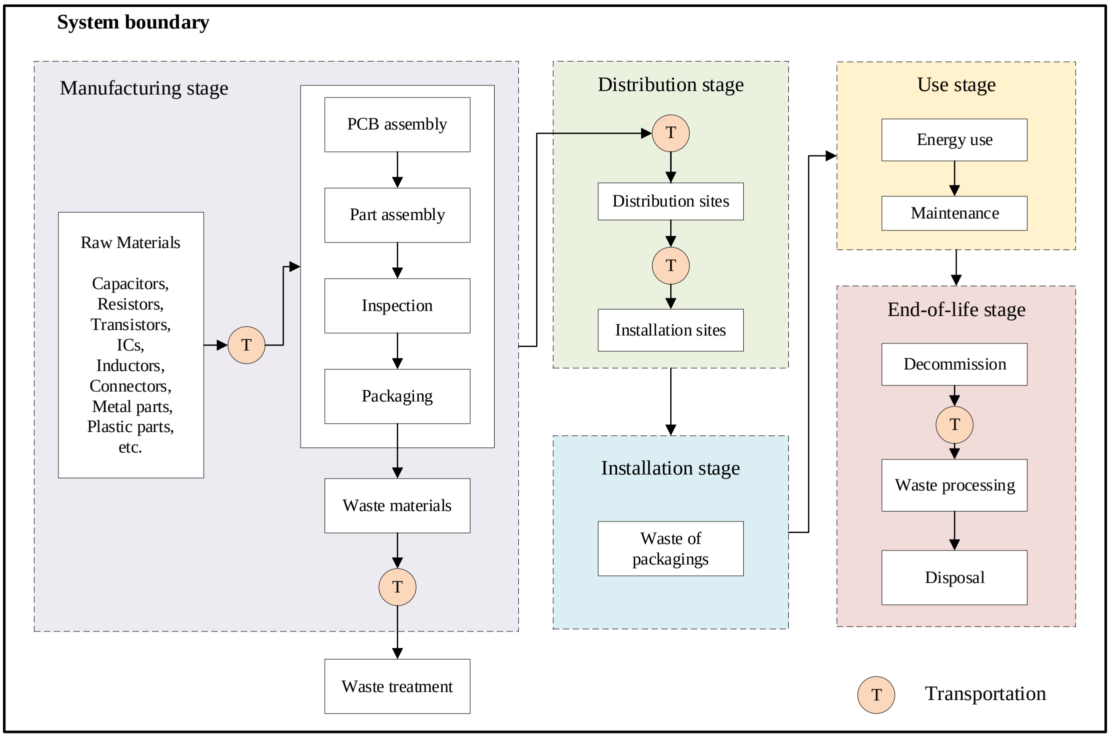

Figure 3-1 System boundary

3.2. Type of EPD

This EPD is a product specific EPD. The declaration covers in total 4 series of inverters, including SG350HX, SG285HX, SG320HX, and SG333HX.

3.3. Geographical scope

The geographical boundary for this LCA study is defined with manufacturing of power inverters taking place in mainland China, while use phase and end-of-life treatment stage will be modelled with a case study taken place in Italy. It is noted that the inverter products can be installed and operated worldwide. Therefore, when interpretating the LCA results, the location where the products is installed and operated shall be considered.

3.4. Time representativeness

All manufacturing data has been collected by Sungrow based on their production inventory in the reference period from May 2022 to April 2023. Datasets have been selected according to the actual processes used by the manufacturer. For generic products where no upstream data was available, such as packaging, manufacturing has been modelled according to current industry practices.

3.5. Database and LCA software used

In this study, generic data for materials, energy as well as waste disposal and transportation were taken from the database Ecoinvent 3.8. LCA-software SimaPro 9.4 was used for the modeling and calculation.

4. DETAILED PRODUCT DESCRIPTION

4.1. Description of the Product

An inverter converts current from direct current (DC) to alternating current (AC), and it is sometimes referred to as a DC/AC converter. Sungrow offers a wide range of products for residential, commercial, and utility-scale applications. For commercial and utility-scale applications, Sungrow offers string inverters and central inverters that are designed to be highly efficient and reliable, while also being easy to install and maintain. These products are suitable for use in large-scale solar power plants, as well as commercial and industrial buildings. The four series of inverters covered in this study are all string inverters. String inverters transform the DC from your PV panels into an AC that can be fed into the electrical grid. String inverters are mostly used in residential and commercial solar projects such as rooftop, carport, ground mount and tracker installations. Sungrow string inverters come in a power range between 2kW and 352kW.

4.2. Technical parameters

Table 4-1 technical parameters of different power inverters

Series	SG350HX	SG285HX	SG320HX	SG333HX
Nominal PV input voltage (V)	1080	1080	1080	1080
Nominal AC voltage (V)	800	800	800	800
Max AC current (A)	254	206	254	240.5
Topology	3 phases	3 phases	3 phases	3 phases
Dimension (mm)	1136*870*361	1136*870*361	1136*870*361	1136*870*361
Weight (kg)	124.5	121.4	122.0	118.6

Efficiency (Max/EU)	99.02%/98.8%	99.02%/98.8%	99.02%/98.8%	99.02%/98.8%
AC power	352 kVA @ 30°C / 320 kVA @ 40 °C / 295 kVA @ 50°C	285 kVA @ 40 ℃	352 kVA @ 30 ℃ / 320 kVA@ 40 ℃ / 295 kVA @ 50 ℃	333 kVA @ 35 ℃ / 320 kVA @40 ℃
Standby power (W)	<6	<6	<6	<6

The inverters are sold worldwide, but in this study, it is only analyzed considering that the inverters will be installed in Italy.

4.3. Materials compositions

Table 4-2 Materials compositions (Mass ratio)

Materials classes	IEC62474 Code	SG350HX	SG285HX	SG320HX	SG333HX
Aluminium and its alloys	M-120	42.0%	42.9%	42.4%	43.3%
Stainless steel	M-100	5.2%	5.5%	5.0%	4.6%
Other ferrous alloys, non-stainless steels	M-119	12.0%	12.3%	12.2%	12.6%
Copper and its alloys	M-121	15.9%	14.3%	14.2%	13.9%
Plastic components (PP+PC+PA)	M-252, M-254 M-208	23.7%	23.9%	24.9%	24.4%
Other non-ferrous metals and alloys	M-149	0.5%	0.5%	0.5%	0.6%
Other organic materials	M-399	0.7%	0.7%	0.7%	0.7%

4.4. Description of the production process

Figure 4-1 describes the production processes of Sungrow inverter products. All inverters follow the same manufacturing processes. For simplification purposes, only main stages of manufacturing are presented. Generally, the production of inverter includes printed circuit board Assembly (PCBA), subparts assembly, housing compartment assembly, final assembly, inspection, and packaging and warehousing.

Printed circuit board assembly (PCBA)

The PCBA process involves surface and thorough-hole mounting of electronic components to different printed wiring boards (PWBs) using automated equipment to ensure accuracy and efficiency. Subsequently, automated optical inspection (AOI) process uses high-resolution cameras and image processing algorithms to automatically inspect the printed circuit board (PCB) of the inverter. This non-contact inspection method can quickly and accurately detect various quality issues on the PCB, such as missing components, position deviation, and soldering defects.

Subparts assembly

Subparts assembly process comprises a step-wise assembly and interconnections of multiple control units alongside cables to different power modules via busbars, screws and washers.

Housing compartment assembly

Housing compartment assembly includes casing and cooling heat sink etc. The cooling system includes assembly of components such as heat sinks, fans, tubing, and coolant or thermal paste.

Final assembly

The finished components, includes PCBA, electronic subparts, housing compartment, and mounting components will be assembled in this workshop to produce the inverter.

Aging test

Aging test applies continuous environmental stress to components at a certain temperature for a long time, including high temperature stress and other types of stress like temperature cycling and random vibration. The goal is to accelerate physical and chemical reactions and expose potential defects early, eliminating early failures of products.

Packaging and warehousing

Packing finished components in specified quantity for easy transportation and sale, and put the packed components into the warehouse procedure.

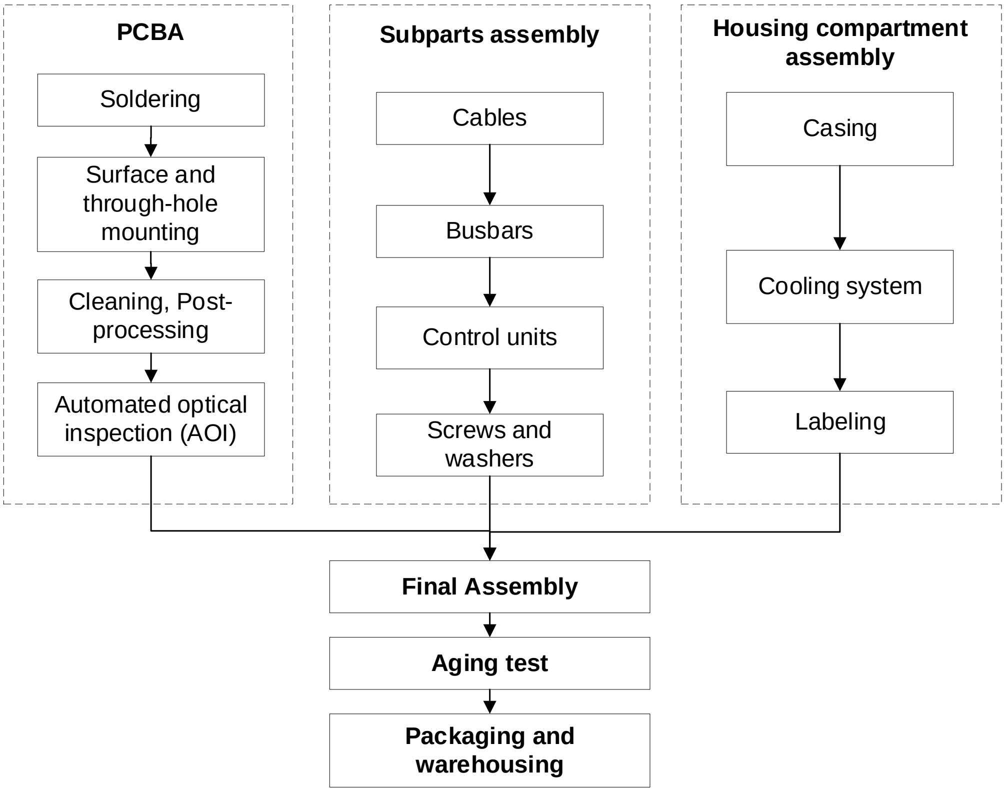

Figure 4-1 Manufacturing process flow diagram of power inverter

5. LCA RESULTS

The LCA results show the environmental impacts and resource input and output flows calculated according to EN 50693. The results are shown per functional unit (1 pcs of inverter). The LCA results have been calculated using the LCA software SimaPro 9.4.

System boundaries (X = included, MND = module not declared, MNR = module not relavant)							
Phases	Manufacturing Stage	Distribution stage	Installation Stage	Use & Maintenance Stage	End-of-life stage De-Installation		Beyond the system boundaries
Phases declared	X	X	X	X	X		MND

5.1. Environmental impacts

Table 5-1 Environmental impacts – SG350HX

Category	Unit	Manufacturing	Distribution	Installation	Use & Maintenance	End-of-life	Total
GWP-total	kg CO_2 eq	4.26E+03	2.85E+01	2.95E+01	1.55E+04	3.33E+01	1.98E+04
GWP-fossil	kg CO_2 eq	4.26E+03	2.85E+01	1.16E+01	1.53E+04	3.33E+01	1.97E+04
GWP-biogenic	kg CO_2 eq	-5.51E+00	1.18E-02	1.78E+01	1.18E+02	2.38E-02	1.31E+02
GWP-luluc	kg CO_2 eq	7.84E+00	1.50E-02	1.14E-04	2.85E+01	1.22E-02	3.63E+01
ODP	kg CFC11 eq	2.40E-04	6.07E-06	4.79E-08	1.74E-03	6.15E-07	1.99E-03
AP	mol H+ eq	4.08E+01	3.87E-01	5.84E-03	9.42E+01	4.71E-02	1.35E+02
EP-Freshwater	kg P eq	3.64E+00	1.65E-03	7.67E-05	7.07E+00	3.31E-03	1.07E+01
EP-Marine	kg N eq	5.27E+00	9.29E-02	3.16E-03	1.75E+01	1.38E-02	2.29E+01
EP-Terrestrial	mol N eq	5.50E+01	1.03E+00	2.90E-02	1.77E+02	1.17E-01	2.33E+02
POCP	kg NMVOC eq	2.45E+01	2.81E-01	7.20E-03	5.88E+01	3.05E-02	8.36E+01
ADP- M&M	kg Sb eq	8.87E-01	7.78E-05	1.27E-06	6.77E-01	1.04E-04	1.56E+00
ADP-fossil	MJ	5.42E+04	4.03E+02	3.36E+00	1.88E+05	1.04E+02	2.42E+05
WDP	m^3 depriv.	1.37E+03	1.14E+00	1.21E-01	1.44E+04	1.50E+00	1.58E+04

Table 5-2 Environmental impacts - SG285HX

Category	Unit	Manufacturing	Distribution	Installation	Use & Maintenance	End-of-life	Total
GWP-total	kg CO_2 eq	4.33E+03	2.78E+01	2.95E+01	1.26E+04	3.11E+01	1.70E+04
GWP-fossil	kg CO_2 eq	4.33E+03	2.78E+01	1.16E+01	1.25E+04	3.10E+01	1.69E+04
GWP-biogenic	kg CO_2 eq	-5.23E+00	1.15E-02	1.78E+01	1.03E+02	2.32E-02	1.16E+02
GWP-luluc	kg CO_2 eq	7.93E+00	1.46E-02	1.14E-04	2.31E+01	1.18E-02	3.10E+01
ODP	kg CFC11 eq	2.37E-04	5.91E-06	4.79E-08	1.42E-03	5.97E-07	1.67E-03
AP	mol H+ eq	3.87E+01	3.77E-01	5.84E-03	7.66E+01	4.56E-02	1.16E+02
EP-Freshwater	kg P eq	3.51E+00	1.61E-03	7.67E-05	5.75E+00	3.22E-03	9.26E+00
EP-Marine	kg N eq	5.26E+00	9.05E-02	3.16E-03	1.42E+01	1.29E-02	1.96E+01

EP-Terrestrial	mol N eq	5.43E+01	1.00E+00	2.90E-02	1.44E+02	1.13E-01	2.00E+02
POCP	kg NMVOC eq	2.48E+01	2.74E-01	7.20E-03	4.78E+01	2.94E-02	7.29E+01
ADP- M&M	kg Sb eq	8.12E-01	7.58E-05	1.27E-06	5.49E-01	1.01E-04	1.36E+00
ADP-fossil	MJ	5.51E+04	3.93E+02	3.36E+00	1.53E+05	1.02E+02	2.09E+05
WDP	m^3 depriv.	1.36E+03	1.11E+00	1.21E-01	1.17E+04	1.45E+00	1.31E+04

Table 5-3 Environmental impacts - SG320HX

Category	Unit	Manufacturing	Distribution	Installation	Use & Maintenance	End-of-life	Total
GWP-total	kg CO_2 eq	4.32E+03	2.79E+01	2.95E+01	1.55E+04	3.49E+01	1.99E+04
GWP-fossil	kg CO_2 eq	4.31E+03	2.79E+01	1.16E+01	1.53E+04	3.48E+01	1.97E+04
GWP-biogenic	kg CO_2 eq	-5.88E+00	1.16E-02	1.78E+01	1.18E+02	2.39E-02	1.30E+02
GWP-luluc	kg CO_2 eq	7.87E+00	1.47E-02	1.14E-04	2.85E+01	1.19E-02	3.64E+01
ODP	kg CFC11 eq	2.40E-04	5.94E-06	4.79E-08	1.74E-03	6.08E-07	1.99E-03
AP	mol H+ eq	3.90E+01	3.79E-01	5.84E-03	9.42E+01	4.67E-02	1.34E+02
EP-Freshwater	kg P eq	3.60E+00	1.62E-03	7.67E-05	7.07E+00	3.25E-03	1.07E+01
EP-Marine	kg N eq	5.28E+00	9.10E-02	3.16E-03	1.75E+01	1.40E-02	2.29E+01
EP-Terrestrial	mol N eq	5.48E+01	1.01E+00	2.90E-02	1.77E+02	1.17E-01	2.33E+02
POCP	kg NMVOC eq	2.46E+01	2.75E-01	7.20E-03	5.88E+01	3.05E-02	8.37E+01
ADP- M&M	kg Sb eq	8.48E-01	7.62E-05	1.27E-06	6.77E-01	1.02E-04	1.53E+00
ADP-fossil	MJ	5.50E+04	3.95E+02	3.36E+00	1.88E+05	1.03E+02	2.43E+05
WDP	m^3 depriv.	1.36E+03	1.11E+00	1.21E-01	1.44E+04	1.48E+00	1.58E+04

Table 5-4 Environmental impacts- SG333HX

Category	Unit	Manufacturing	Distribution	Installation	Use & Maintenance	End-of-life	Total
GWP-total	kg CO_2 eq	4.28E+03	2.76E+01	2.95E+01	1.47E+04	3.30E+01	1.90E+04
GWP-fossil	kg CO_2 eq	4.28E+03	2.75E+01	1.16E+01	1.45E+04	3.30E+01	1.89E+04
GWP-biogenic	kg CO_2 eq	-5.90E+00	1.15E-02	1.78E+01	1.14E+02	2.35E-02	1.26E+02
GWP-luluc	kg CO_2 eq	7.82E+00	1.45E-02	1.14E-04	2.69E+01	1.18E-02	3.48E+01
ODP	kg CFC11 eq	2.39E-04	5.86E-06	4.79E-08	1.65E-03	5.97E-07	1.90E-03
AP	mol H+ eq	3.83E+01	3.74E-01	5.84E-03	8.92E+01	4.57E-02	1.28E+02
EP-Freshwater	kg P eq	3.50E+00	1.60E-03	7.67E-05	6.70E+00	3.20E-03	1.02E+01
EP-Marine	kg N eq	5.21E+00	8.98E-02	3.16E-03	1.66E+01	1.30E-02	2.19E+01
EP-Terrestrial	mol N eq	5.39E+01	9.95E-01	2.90E-02	1.68E+02	1.14E-01	2.23E+02
POCP	kg NMVOC eq	2.43E+01	2.71E-01	7.20E-03	5.57E+01	2.97E-02	8.03E+01
ADP- M&M	kg Sb eq	8.17E-01	7.52E-05	1.27E-06	6.41E-01	1.00E-04	1.46E+00
ADP-fossil	MJ	5.45E+04	3.89E+02	3.36E+00	1.78E+05	1.01E+02	2.33E+05
WDP	m^3 depriv.	1.34E+03	1.10E+00	1.21E-01	1.37E+04	1.46E+00	1.50E+04

Caption:

1E+01 is equal to 1 x 10^1

GWP-total: Global Warming Potential; **GWP-fossil**: Global Warming Potential fossil fuels; **GWP-biogenic**: Global Warming Potential biogenic; **GWP-luluc**: Global Warming Potential land use and land use change; **ODP**: Depletion potential of the stratospheric ozone layer; **AP**: Acidification potential, Accumulated Exceedance; **EP-Freshwater**: Eutrophication potential, fraction of nutrients reaching freshwater and compartment; See "additional Norwegian requirements" for indicator given as PO4 eq. **EP-Marine**: Eutrophication potential, fraction of nutrients reaching freshwater end compartment; **EP-Terrestrial**: Eutrophication potential, Accumulated Exceedance; **POCP**: Formation potential of tropospheric ozone; **ADP-M&M**: Abiotic depletion potential for non-fossil resources (minerals and metals); **ADP-fossil**: Abiotic depletion potential for fossil resources; **WDP**: Water deprivation potential, deprivation weighted water consumption

5.2. Resources uses

Table 5-5 Resource use - SG350HX

Category	Unit	Manufacturing	Distribution	Installation	Use & Maintenance	End-of-life	Total
PERE	MJ	6.20E+03	4.30E+00	1.82E-01	8.48E+05	1.13E+01	8.54E+05
PERM	MJ	3.30E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.30E+02
PERT	MJ	6.53E+03	4.30E+00	1.82E-01	8.48E+05	1.13E+01	8.54E+05
PENRE	MJ	5.34E+04	4.03E+02	3.36E+00	1.88E+05	1.04E+02	2.42E+05
PENRM	MJ	8.86E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.86E+02
PENRT	MJ	5.42E+04	4.03E+02	3.36E+00	1.88E+05	1.04E+02	2.42E+05
SM	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RSF	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NRSF	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FW	m3	4.43E+01	3.89E-02	2.35E-02	4.86E+02	1.49E-01	5.31E+02

Table 5-6 Resource use - SG285HX

Category	Unit	Manufacturing	Distribution	Installation	Use & Maintenance	End-of-life	Total
PERE	MJ	6.23E+03	4.19E+00	1.82E-01	6.87E+05	1.10E+01	6.93E+05
PERM	MJ	3.30E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.30E+02
PERT	MJ	6.56E+03	4.19E+00	1.82E-01	6.87E+05	1.10E+01	6.93E+05
PENRE	MJ	5.43E+04	3.93E+02	3.36E+00	1.53E+05	1.02E+02	2.08E+05
PENRM	MJ	8.71E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.71E+02
PENRT	MJ	5.51E+04	3.93E+02	3.36E+00	1.53E+05	1.02E+02	2.09E+05
SM	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RSF	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NRSF	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FW	m3	4.43E+01	3.79E-02	2.35E-02	3.95E+02	1.46E-01	4.40E+02

Table 5-7 Resource use-SG320HX

Category	Unit	Manufacturing	Distribution	Installation	Use & Maintenance	End-of-life	Total
PERE	MJ	6.20E+03	4.21E+00	1.82E-01	8.48E+05	1.11E+01	8.54E+05
PERM	MJ	3.30E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.30E+02
PERT	MJ	6.53E+03	4.21E+00	1.82E-01	8.48E+05	1.11E+01	8.54E+05
PENRE	MJ	5.41E+04	3.95E+02	3.36E+00	1.88E+05	1.03E+02	2.42E+05
PENRM	MJ	9.10E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.10E+02
PENRT	MJ	5.50E+04	3.95E+02	3.36E+00	1.88E+05	1.03E+02	2.43E+05
SM	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RSF	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NRSF	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FW	m3	4.41E+01	3.81E-02	2.35E-02	4.86E+02	1.50E-01	5.31E+02

Table 5-8 Resource use-SG333HX

Category	Unit	Manufacturing	Distribution	Installation	Use & Maintenance	End-of-life	Total
PERE	MJ	6.14E+03	4.16E+00	1.82E-01	8.02E+05	1.09E+01	8.08E+05
PERM	MJ	3.30E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.30E+02
PERT	MJ	6.47E+03	4.16E+00	1.82E-01	8.02E+05	1.09E+01	8.09E+05
PENRE	MJ	5.37E+04	3.90E+02	3.36E+00	1.78E+05	1.01E+02	2.32E+05
PENRM	MJ	8.67E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.67E+02
PENRT	MJ	5.45E+04	3.90E+02	3.36E+00	1.78E+05	1.01E+02	2.33E+05
SM	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RSF	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NRSF	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FW	m3	4.37E+01	3.76E-02	2.35E-02	4.60E+02	1.48E-01	5.04E+02

Caption:

1E+01 is equal to 1×10^1

PENRE: Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials; **PERE**: Use of renewable primary energy excluding renewable primary energy resources used as raw materials; **PENRM**: Use of non-renewable primary energy resources used as raw materials; **PERM**: Use of renewable primary energy resources used as raw materials; **PERT**: Total use of renewable primary energy resources; **PENRT**: Total use of non-renewable primary energy resources; **SM**: Use of secondary materials; **RSF**: Use of renewable secondary fuels**; NRSF**: Use of non-renewable secondary fuels; **FW**: Use of net fresh water

5.3. End-of-life-Waste

Table 5-9 Waste-SG350HX

Category	Unit	Manufacturing	Distribution	Installation	Use & Maintenance	End-of-life	Total
HWD	kg	3.57E-01	8.37E-04	3.89E-05	1.06E+01	1.62E-04	1.09E+01
NHWD	kg	5.51E+02	1.44E+01	2.91E-01	2.72E+03	1.09E+01	3.30E+03
RWD	kg	1.46E-01	2.71E-03	8.78E-06	4.79E-01	3.94E-04	6.28E-01

Table 5-10 Waste-SG285HX

Category	Unit	Manufacturing	Distribution	Installation	Use & Maintenance	End-of-life	Total
HWD	kg	3.37E-01	8.16E-04	3.89E-05	8.55E+00	1.54E-04	8.89E+00
NHWD	kg	5.32E+02	1.41E+01	2.91E-01	2.21E+03	1.04E+01	2.76E+03
RWD	kg	1.47E-01	2.64E-03	8.78E-06	3.91E-01	3.84E-04	5.41E-01

Table 5-11 Waste-SG320HX

Category	Unit	Manufacturing	Distribution	Installation	Use & Maintenance	End-of-life	Total
HWD	kg	3.59E-01	8.20E-04	3.89E-05	1.06E+01	1.63E-04	1.09E+01
NHWD	kg	5.45E+02	1.41E+01	2.91E-01	2.72E+03	1.06E+01	3.29E+03
RWD	kg	1.47E-01	2.65E-03	8.78E-06	4.79E-01	3.87E-04	6.29E-01

Table 5-12 Waste-SG333HX

Category	Unit	Manufacturing	Distribution	Installation	Use & Maintenance	End-of-life	Total
HWD	kg	3.34E-01	8.09E-04	3.89E-05	9.99E+00	1.58E-04	1.03E+01
NHWD	kg	5.39E+02	1.39E+01	2.91E-01	2.57E+03	1.02E+01	3.14E+03
RWD	kg	1.46E-01	2.62E-03	8.78E-06	4.54E-01	3.81E-04	6.03E-01

Caption:
1E+01 is equal to 1 x 10^1
HWD = Hazardous waste disposed; **NHWD** = Non-hazardous waste disposed; **RWD** = Radioactive waste disposed

5.4. End-of-life-Output flows

Table 5-13 Output flows-SG350HX

Category	Unit	Manufacturing	Distribution	Installation	Use & Maintenance	End-of-life	Total
CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MFR	kg	8.21E+00	0.00E+00	1.65E+01	0.00E+00	1.05E+02	1.30E+02
MER	kg	3.09E-01	0.00E+00	1.69E+01	0.00E+00	9.22E+00	2.64E+01
ETE	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EEE	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 5-14 Output flows-SG285HX

Category	Unit	Manufacturing	Distribution	Installation	Use & Maintenance	End-of-life	Total
CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MFR	kg	8.21E+00	0.00E+00	1.65E+01	0.00E+00	1.04E+02	1.28E+02
MER	kg	3.09E-01	0.00E+00	1.69E+01	0.00E+00	8.32E+00	2.55E+01
ETE	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EEE	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 5-15 Output flows-SG320HX

Category	Unit	Manufacturing	Distribution	Installation	Use & Maintenance	End-of-life	Total
CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MFR	kg	8.74E+00	0.00E+00	1.65E+01	0.00E+00	1.02E+02	1.28E+02
MER	kg	3.29E-01	0.00E+00	1.69E+01	0.00E+00	9.96E+00	2.71E+01
ETE	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EEE	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 5-16 Output flows-SG333HX

Category	Unit	Manufacturing	Distribution	Installation	Use & Maintenance	End-of-life	Total
CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MFR	kg	8.21E+00	0.00E+00	1.65E+01	0.00E+00	1.00E+02	1.25E+02
MER	kg	3.09E-01	0.00E+00	1.69E+01	0.00E+00	9.15E+00	2.63E+01
ETE	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EEE	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

CRU = Components for re-use; **MFR** = Materials for recycling; **MER** = Materials for energy recovery; **EEE** = Exported electrical energy; **EET** = Exported thermal energy

6. Calculation rules

6.1. Declared or functional unit

A single power inverter unit intended for DC/AC voltage transformation.

6.2. Reference Service Life

The reference service life of the studied product is 25 years.

6.3. Assumptions

Table 6-1 List of assumptions

Categories	Items	Assumptions
Distribution stage	Transportation vehicle type	For the vehicle used for raw materials and product transportation, EURO 6 type vehicle with 16-32 ton capacity was assumed for modelling
Installation stage	Electricity and materials use	No electricity and materials used for installation as it can be done manually
Use & Maintenance	Replacement	No replacement for the module as the module has an RSL>25 years
End-of-life	De-construction	The de-construction of inverter was assumed to be done manually, no electricity and materials use in this stage
	Waste transportation	Waste transportation distance from the de-installation plant to the waste treatment facilities was assumed to be 50 km for simplification purposes
	Waste processing	The Ecoinvent waste processing data "waste electric and electronic equipment, treatment of, shredding" was applied
	Disposal	The disposal scenario follows the WEEE standards and disposal scenario of Huawei inverter carbon footprint report (Huawei, 2020)

6.4. Cut-off rules

For the processes within the system boundary, all available energy and material flow data have been included in the model. The cut-off criteria were set to 2% in this study according to PCR.

Table 6-2 Cut-off flows

Flow name	Process stage	Mass %	Criteria to cut-off
Coin battery, fuse etc.	Manufacturing stage	0.003	<2%
Devices external to the inverter itself required for installation	Installation stage	N/A	Cut-off due to small impact according to PCR
Any extraordinary maintenance done on the switch	Use & Maintenance	N/A	Specified in PCR
Total cut-off mass % estimated			<2%

6.5. Data quality

Primary data (such as materials or energy flows that enter and leave the production system) is from Sungrow manufacturing facilities in a reference period from May 2022 to April 2023 (annual average). Generic data related to the life cycle impacts of the material or energy flows that enter and leave the production system is sourced from Ecoinvent 3.8 "allocation, cut-off by allocation - unit" database. Specific information from supplier about the composition of the high frequency inductor have been used for modelling, and production data of DC-link capacitor was used referring to a study from Chalmers University of Technology.

6.6. Allocations

The allocation is made in accordance with the provisions of EN 50693. Allocation refers to the partitioning of input or output flows of a process or a product system between the product systems under study and one or more other product systems. In this study, there are three types of allocation procedures considered:

Multi-input allocation

For data sets in this study, raw materials as well as packaging materials of different inverters are based on the BOM from Sungrow, no allocation is used at the stage. As for the manufacturing process, the energy consumption and emission are allocated based on working hours of different inverter, i.e., the electricity consumption and the emissions are calculated based on the amount of time spent producing each type of inverter.

Multi-output allocation

No other by-products are produced from the production, hence there is no production of by-products that need to be used to allocate the situation.

End-of-life allocation

For end-of-life allocation of background data (energy and materials), the model "allocation cut-off by classification (ISO standard) is used. The underlying philosophy of this approach is that primary (first) production of materials is always allocated to the primary user of a material. If material is recycled, the primary producer does not receive any credit for the provision of any recyclable materials. Consequently, recyclable materials are available burden-free for recycling processes, and secondary (recycled) materials bear only the impacts of the recycling processes.

For end-of-life stage of the inverter products, the polluter pays principle (PPP) is followed in this report. This means that the waste transportation to the treatment site and the waste processing (mainly shredding) is considered in this report, while the benefit, the load from waste treatment for recycling purposes such as de-pollution and crushing, etc., is allocated to the next life cycle of substituted products, but not the primary producers, hence no burden or benefit will be allocated to the primary producer of the electric products (cut-off approach).

6.7. Electricity mix

The manufacturing stage of inverters takes place in China, note that no residual mix is available at this stage, the Chinese grid market average electricity mix is used for modelling. The installation and operation of inverters, as well as the end-of-life stage, are assumed taken place in Italy as a case study. Load consumption during the use stage is modelled with DC electricity generated from photovoltaic in Italy, while non-load consumption is modelled using average electricity market mix in Italy.

Table 6-3 Electricity mix used for modelling

Consumption type	Electricity process type
Electricity use in manufacturing stage	China electricity grid mix (market for electricity, medium voltage, Ecoinvent 3.8)
Electricity use in use stage (load consumption)	Electricity, low voltage {IT}| electricity production, photovoltaic, 570kWp open ground installation (DC output with inverter excluded, Ecoinvent 3.8)
Electricity use in use stage (non-load consumption)	Grid electricity mix in Italy (market for electricity, low voltage, Ecoinvent 3.8)

7. LCA calculation scenarios

7.1. Distribution

Italy is taken as the target market for a case study. The products are firstly transported from the manufacturing site to Shanghai Port. Then, they are transported through container ship from Shanghai Port to Italy, Genoa is chosen as the target port. Lastly, the product will be transported from Genoa to the customer, an estimated distance of 300km is assumed in this study.

7.2. Installation

In the installation stage, the energy use is negligible since the installation process is mainly done manually. According to the product category rules (PCR), only waste generation and treatment of packaging materials are considered in this stage. The waste generated from the product packaging, mainly consisting of waste wood pallets, is accounted for in this stage. The treatment of the waste wood pallets is modeled as 75% recycling and 25% incineration. Other packaging materials, including paper and plastic film, are modeled as 100% incineration.

7.3. Use & Maintenance

According to PCR, the following formula shall be used to calculate the load electricity used during the product's service life:

$$E_{use} = P_{AC} \times I_r \times (1 - eff) \times RSL$$

where:

E_{use} (kWh) is the power losses during the operation of power inverter;

P_{AC} (kW) is the output rated AC active power;

I_r (h) is average local annual sunshine in country where the inverter is installed, in this study Italy is taken as the target country, with annual sunshine hours of 2000 h.

eff (%) is average Energy Efficiency measured or form data sheet

RSL is the service life of the product, 25 years;

While non-load electricity consumption can be calculated using the standby power:

$$E_{\mathrm{standby}} = P_{\mathrm{standby}} \times (8760 - I_r) \times RSL$$

where E_{standby} is the standby electricity consumption of the inverter, P_{standby} (W) is the standby power of the inverter.

Table 7-1 Power consumption of inverter

Series	Standby power (W)	AC-power (kW)	Sunshine (h)	Efficiency	RSL (years)	E_{use} (kWh)	$E_{standby}$ (kWh)
SG350HX	6	352	2000	98.8%	25	211200	1014
SG285HX	6	285	2000	98.8%	25	171000	1014
SG320HX	6	352	2000	98.8%	25	211200	1014
SG333HX	6	333	2000	98.8%	25	199800	1014

For the maintenance of the inverter products, the Sungrow inverters are designed to be free of maintenance during its service life. Therefore, no inputs and outputs take place in the maintenance stage in this study.

7.4. End-of-life

For end-of-life (EoL) stage, assumptions are made due to a lack of data. De-installation of power inverters is assumed to be manually done with no energy use. Transportation distance from the plant site to the waste treatment site is assumed to be 50km according to PCR. For waste processing, power inverter is shredded and post-processed. The Ecoinvent waste processing data "waste electric and electronic equipment, treatment of, shredding" was employed here since it effectively represents today's EoL treatment of an inverter. The power inverters disposal and recycling stage involves removing hazardous valuable materials, metal scraps. The most recyclable materials constitute the metal components, printed circuit board (PCBs), and cables. In this study, both carbon footprint report of Huawei inverter (Huawei, 2020) and IEC/TR 62635 guidelines are referred. 90% of metals (steel, aluminium, copper) can be recycled and 10% will be disposed by landfill. 60% of plastics can be recycled and 40% will be disposed with incineration. 65% of electronic components (PCBA and cables) can be recycled and the rest will be disposed with 10% of incineration and 25% of landfill.

Table 7-2 End-of-Life disposal (Huawei, 2020)

Components	Recycling rate	Disposal rate	Disposal Treatment
Metals	90%	10%	Landfill
Plastics	60%	40%	Incineration
PCBA	65%	35%	10% Incineration/25% landfill
Cable	65%	35%	
Rubber	0%	100%	Incineration

8. REFERENCES

[1] EN 50693:2019, Product category rules for life cycle assessments of electronic and electric products and systems.

[2] Ecoinvent, 2021. Swiss Centre for Life Cycle Assessment, v3.8 (www.ecoinvent.ch).

[3] EPD Italy Regulation (rev. 5.2 published on 2022/02/16).

[4] Huawei, 2020. Product Carbon Footprint Report, s.l.: Ske Solar. Available at: Zertifikat-Product-Carbon-Footprint-Report-für-Huawei-SUN2000-12KTL-M0-Wechselrichter.pdf(ske-solar.com) [Accessed 14 January 2021].

[5] IEC/TR 62635: Guidelines for end-of-life information provided by manufacturers and recyclers and for recyclability rate calculation of electric and electronic equipment.

[6] ISO 14025:2006, Environmental labels and declarations-Type III environmental declarations-Principles and procedures.

[7] ISO 14040: 2006/Amd 1:2020 Environmental management - Life cycle assessment - Principles and framework Amendment 1 (ISO 2020).

[8] ISO 14044: 2006/Amd 2:2020 Environmental management - Life cycle assessment - Requirements and guidelines Amendment 2 (ISO 2020).

[9] LCA report of Sungrow String Power Inverters for Environmental Product Declaration, June 2023.

[10] PCR EPDItaly 007: Electronic and Electric Products and Systems (rev.3), 2023/01/13.

[11] PCR EPDItaly032: Power Inverter, 2022/12/22.

[12] PRé Consultants, 2021. Software SimaPro versione 9.3.0.3 (www.pre.nl).

[13] Nordelöf, A. & Alatalo, M. (2018). A Scalable Life Cycle Inventory of an Automotive Power Electronic Inverter Unit - Technical and Methodological Description, version 1.01. 2018, Gothenburg, Sweden: Divisions of Environmental Systems Analysis & Electric Power Engineering, Chalmers University of Technology.