ENVIRONMENTAL PRODUCT DECLARATION

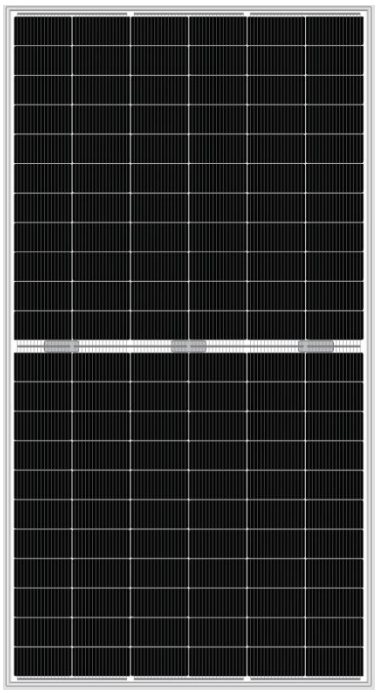
In accordance with ISO 14025 and EN 15804 for:

N-type TOPCon Bifacial Module

From

Yingli Energy Development Co., Ltd.

Declared product:



Programme operator:	EPD China
Registration number:	EPD-CN-00051
Issued date:	2026-02-04
Valid until:	2031-02-03

Programme Information

EPD Owner	Name: Yingli Energy Development Co., Ltd. Contact information of EPD owner No. 2599, Xiangyang North Street, High Tech Zone, Baoding, Hebei, China Email: 254456456@qq.com Website: https://www.yinglisolar.com/
Product Name	N-type TOPCon Bifacial Module
Production Site	No. 5 Haihang East Road, Modern Industrial Zone, Ninghe District, Tianjin, China No. 655, High-tech Industrial Park, North Yongsheng Street, Li County, Baoding, Hebei, China
Identification of product	UN CPC 461
Field of Application	Photovoltaic power generation systems, solar energy projects
Programme Operator	EPD China Address of Headquarter: Tianping Road, Xuhui District, Shanghai Website: www.epdchina.cn Email: info@epdchina.cn | secretary@epdchina.cn
LCA Practitioner	China Classification Society Certification Co., Ltd. (CCSC)
Responsibility	The EPD owner has the sole ownership, liability, and responsibility for the EPD
Comparability	EPDs within same category of product in different programme operator are not suggested to be compared. 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 even applying the same PCR.
Liability	The EPD owner has the sole ownership, liability, and responsibility for the EPD.
Validity	The EPD is published on 2026-02-04 and valid to 2031-02-03
LCA Software (version)	SimaPro 10.2
LCI Dataset (version)	Ecoinvent 3.10 (JRC characterization factors: EF 3.1)
Year(s) of Primary Data	01/2024-12/2024
PCR	PCR: EPDItaly007 – PCR for Electronic and Electrical Products and Systems, Rev. 3.2, 2025/12/10;
Other Reference Document	ISO 14025:2006; ISO 14040:2006; ISO 14044:2006; EN 15804:2012 +A2:2019/AC:2021
Verification statement according EN 15804	
Independent verification of the declaration and data according to EN ISO 14025:2006 ☐ internal ☑ external Third-party institution verification: CTI Certification Co., Ltd. (CTI) is an approved certification body accountable for third-party verification Approved by: EPD China	
Procedure for follow-up of data during EPD validity involves a third-party certification body: ☐ Yes ☑ No	

General Information

1.1 Company information

Yingli Energy Development Co., Ltd. is a photovoltaic energy solution provider engaged in PV technology R&D, intelligent manufacturing, and power plant development, construction and operation. Headquartered in Baoding, Hebei Province, the company has bases in Baoding, Tianjin, Hengshui and other cities.

The company has put forward goals, solutions and pathways for carbon neutrality. It is developing a green supply chain and conducting research on green recycling technologies for decommissioned crystalline silicon PV modules to support life-cycle management of PV products. It intends to further promote the development of the energy industry through improvements in energy efficiency, carbon market development and carbon resource management.

Name and location of production site(s) within the organization.

Table 1-1: Location of PV module assembly sites

Module		
Manufacturing company name	**Manufacturing company site**	**Manufacturing country**
Yingli Energy Development (Tianjin) Co., Ltd.	No. 5 Haihang East Road, Modern Industrial Zone, Ninghe District, Tianjin, China.	China
Yingli Energy Development (Lixian) Co., Ltd.	No. 655, High-tech Industrial Park, North Yongsheng Street, Li County, Baoding, Hebei, China	China

The Tianjin plant produces PV module specifications 144GG615 and 132GG630, while the Lixian plant produces 144GG615 and 156GG670.The PV module specification 144GG615 is manufactured at both plants based on the same bill of materials (BOM).

At each manufacturing site, energy consumption in the A3 production stage is based on the total annual site-level energy use and is allocated among all products produced at the site in proportion to their annual production volumes.

This EPD represents an average result for multiple PV module specifications manufactured at multiple plants. After the allocation of site-level impacts to each product at each plant, the environmental impacts of all products are aggregated using production-weighted averaging based on their respective production shares across the two plants.

1.2 Scope and type of EPD

The system boundary of this study is "Cradle to grave with module D", which includes the Product stage (A1-A3), Construction process stage (A4-A5), Use stage (B1-B7), End of life stage (C1-C4), benefits and loads beyond the system boundary (D).

According to the PCR, the following EPD category is selected in accordance with the requirements of EPD China:

Declaration of an average product as an average from several of the manufacturer’s plants.

In this study, A1-A3 stage includes raw materials supply, which are Cell, Interconnection bar, Busbar, Frame, Junction box, Solar glass, EVA, POE, Flux, Sealant, Potting adhesive (A1), transportation of raw materials to the factory (A2) and the manufacturing of Module products (A3) providing inputs for raw materials, energy and auxiliary materials, and the treatment and discharge of exhaust gases and solid wastes from the Module products manufacturing process.

A4-A5 stage includes transportation of Module products to the installation site and the construction installation process.

B stage includes the maintenance of the Module products (B2). As for the maintenance stage (B2), water used for cleaning the PV panels is assumed to be 2 L/m², 2 times per year. It is assumed that there are no relevant maintenance and renewal operations for B1 and B3-B7.

End of life stage includes waste deconstruction(C1), waste transport (C2), waste processing (C3) and disposal (C4).

Due to the lack of region-specific data on PV module end-of-life management, a WEEE-based recycling assumption is applied (minimum recycling rate 85%). Based on this requirement, it is assumed that 85% of the PV module components are recovered, while the remaining 15% of the waste components, including photovoltaic cells, glass and waste plastics, are disposed of in the disposal stage (C4). Photovoltaic cells are treated as inert materials and are assumed to be disposed of by landfill. Metal components are assumed to be recycled at a rate of 85%, with the remaining 15% disposed of by landfill. Plastic components and other combustible materials are assumed to be fully incinerated.

Module D reports the potential benefits beyond the system boundary from the assumed recovery routes, including avoided burdens from substituting virgin materials with recycled metals and other recovered materials, and from energy recovery of incinerated fractions (where applicable).

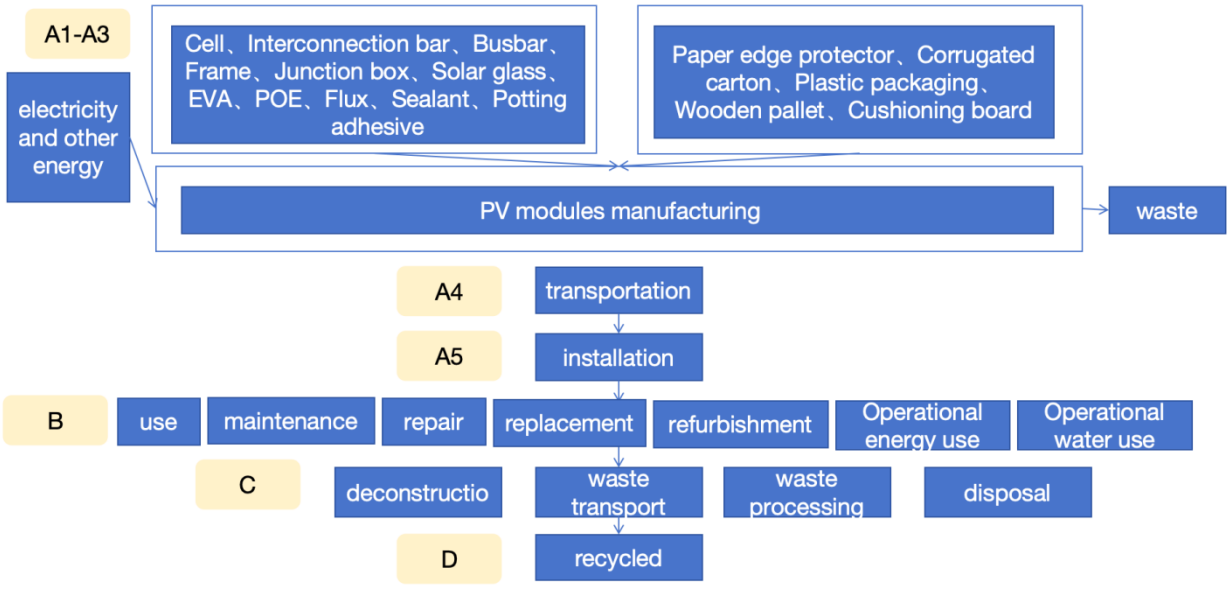


Figure 1-1: Flow diagram of main production processes and visualization of system boundaries

Detailed information on the module breakdown of the product life cycle is set out below. For a clearer presentation of the content of each module, interpretations and comparisons of each life cycle phase are also provided, as shown in the following table.

Table 1-2: System boundary.

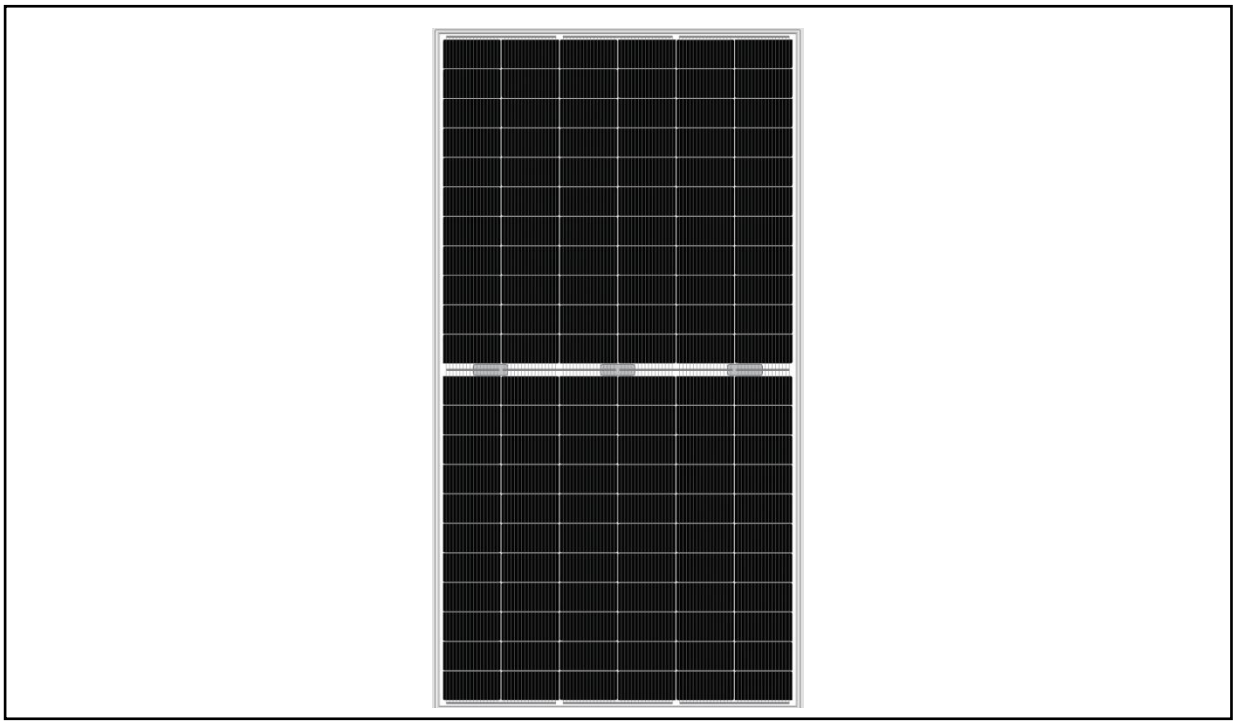
PRODUCT STAGE			CONSTRUCTION PROCESS STAGE		USE STAGE							END OF LIFE STAGE				BENEFITS AND LOADS BEYOND THE SYSTEM BOUNDARIES
Raw material supply	**Transport**	**Production**	**Transport from the gate to the**	**Assembly**	**Use**	**Maintenance**	**Repair**	**Replacement**	**Refurbishment**	**Operational energy use**	**Operational water use**	**Deconstruction/ demolition**	**Transport**	**Waste processing**	**Disposal**	**reuse- recovery- recycling- potential**
A1	**A2**	**A3**	**A4**	**A5**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**C1**	**C2**	**C3**	**C4**	**D**
x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
mdt	mdt	mdt	op	op	op	op	op	op	op	op	op	mdt	mdt	mdt	mdt	mdt

Note: X=Declared Module, ND=Module not Declared in this LCA study

2 Detailed Product Description

1. Description of the product

Figure 2-1: Picture of the declared product.



Yingli N-type TOPCon Bifacial Module (hereinafter referred to as PV module) is suitable for industrial and commercial roof and ground power stations. The PV module has high power generation and low cost per hour. It also has dual-sided power generation capabilities, significantly enhancing power output and efficiency under various back gains. The reference service life of the Module products is 30 years.

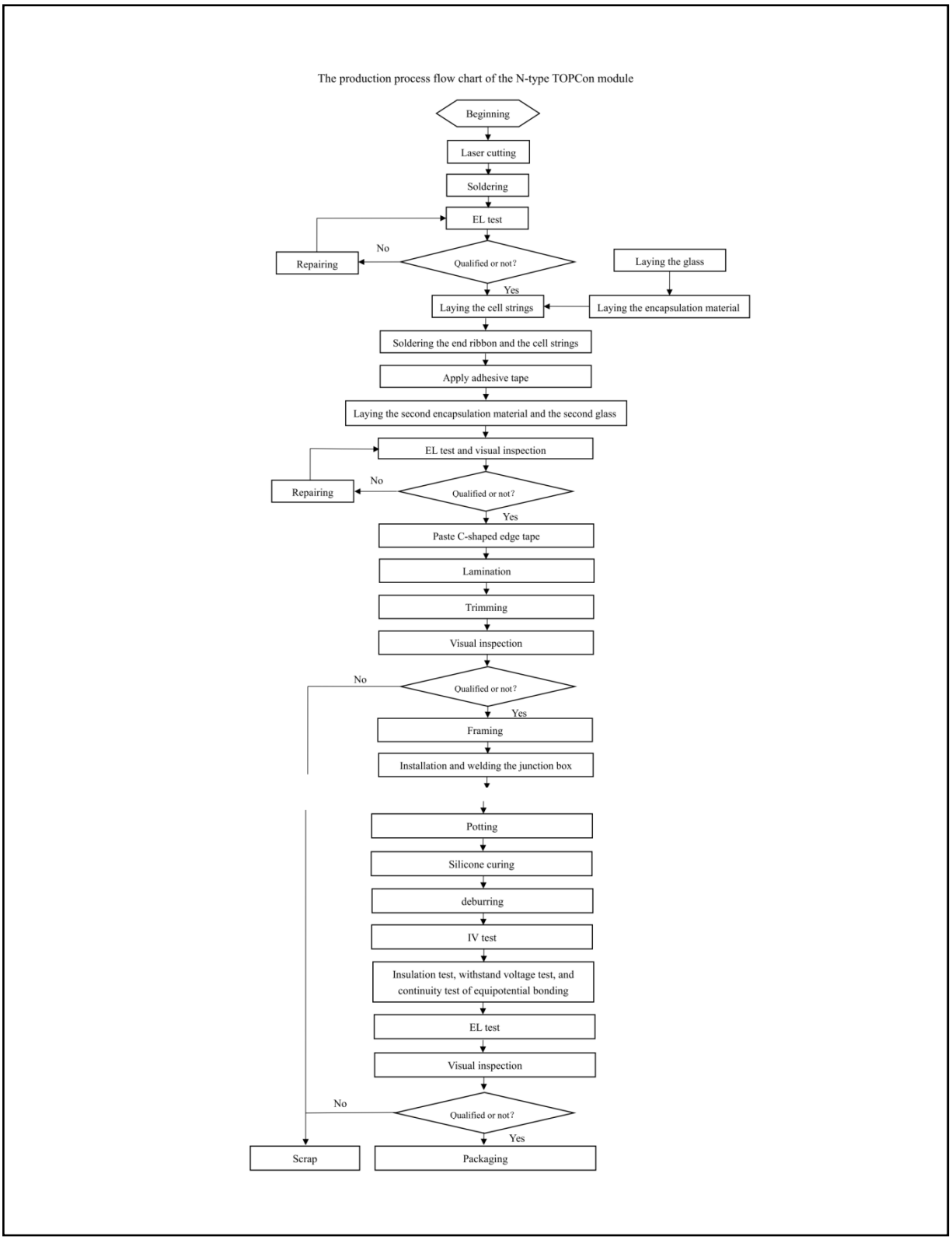
The technology requirements employed for Module products are presented in Table 2-1.

Table 2-1: Technical requirements

Series	144GG615	132GG630	156GG670
Power output range (W)	615	630	670
Dimensions (mm)	2278/ 1134/ 30	2382 / 1134 / 30	2465/ 1134 / 30
Area (m^2)	2.58	2.70	2.80
Converting factor (Wp/m^2)	238.07	233.23	239.69
Module efficiency (%)	23.80%	23.30%	24%
Weight (kg)	32	33.9	35
Weight (incl. package)	33.67	35.54	36.64
First year degradation (%)	1%	1%	1%
Annual degradation (%)	0.40%	0.40%	0.40%

2. Description of the production processes preferably visualised, application, technical data, condition of delivery

Figure 2-2: The production process in selected stages.



The manufacturing process of photovoltaic (PV) modules is a sophisticated assembly line that transforms raw silicon wafers into functional solar panels. It begins with cell sorting, where high-efficiency solar cells are selected and often laser-scribed to reduce current and resistance. The cells are then string-welded to form series connections,

and tabbing is used to connect these strings, creating the overall electrical circuit of the module. These interconnected cells are carefully laminated between a front glass layer and a backsheet using EVA film and subjected to high temperature and pressure to form a sealed, robust sandwich structure. The laminated sheet is then trimmed, framed with an aluminum alloy frame for structural support, and equipped with a junction box for external connections. Finally, the modules undergo a series of rigorous tests, including IV (current-voltage) testing, EL (electroluminescence) testing, and insulation testing, to ensure performance standards are met before packaging and shipping.

3. Product components, main product content, packaging materials, SVHC.

Product composition data reported in this section represent a single kWp-weighted average of the three PV module variants (144GG615, 132GG630 and 156GG670), calculated based on their respective production outputs (kWp).

Table 2-2: Main product components and packaging materials per functional unit.

Product components	IEC 62474 Code	Weight, kg	Weight-% (versus the product)
cell	MCL: 02.01.01	1.19E+00	2.30%
Interconnection bar	MCL: 02.02.03	2.68E-01	0.52%
Busbar	MCL: 02.02.03	3.47E-01	0.67%
Frame	MCL: 02.02.01	4.16E+00	8.06%
Junction box	MCL: 04.01.01	1.71E-01	0.33%
Solar glass	MCL: 01.01.01	4.17E+01	80.87%
EVA	MCL: 03.02.01	1.61E+00	3.11%
POE	MCL: 03.02.01	1.58E+00	3.07%
Sealant	MCL: 03.04.01	4.82E-01	0.93%
Potting adhesive	MCL: 03.04.02	3.77E-02	0.07%
Flux	MCL: 05.01.01	2.35E-02	0.05%
TOTAL	/	5.15E+01	100.00%
Packaging materials		**Weight, kg**	**Weight-% (versus the product)**
Paper edge protector	MCL: 01.01.02	2.69E-01	0.52%
Corrugated carton	MCL: 01.01.02	2.90E-01	0.56%
Plastic packaging	MCL: 03.03.01	1.19E-01	0.23%
Wooden pallet	MCL: 01.02.01	1.96E+00	3.81%
Cushioning board	MCL: 03.03.01	5.14E-02	0.10%
TOTAL	/	2.69E+00	5.23%

No SVHC substances are employed in the current.

3 LCA results according to EN 15804

3.1 Environmental Impacts

This EPD is a Manufacturer's EPD declared as an average product from several of the manufacturer's plants; therefore, the LCA results are reported as a single kWp-weighted average value, calculated based on the respective production outputs (kWp) of the three PV module variants (144GG615, 132GG630 and 156GG670).The results of the underlying LCA are provided in this section as environmental impacts, resource use, output flows and additional information on biogenic carbon. All pre-set parameters of EN 15804 are required.

All environmental performance indicators disclosed in this Environmental Product Declaration (EPD) are calculated and declared based on average values. The variation of the core indicator Global Warming Potential (GWP-total) is less than 10%, and the measured variation of other environmental indicators is also all below 10%, which fully confirms that the declared average values in this EPD are highly representative of both the carbon footprint and the overall environmental performance of the product group, and the environmental performance among products shows good consistency and stability.

Table 3-1: Environmental impacts according to EN 15804

RESULTS OF THE LCA – Environmental impacts per functional unit for average												
Core indicator	Unit	A1-A3	A4	A5	B1	B2	B3-B7	C1	C2	C3	C4	D
Global Warming Potential total (GWP-total)	[kg CO_2 eq.]	4.08E+02	8.76E+00	6.13E+00	0.00E+00	4.36E-01	0.00E+00	1.39E+00	5.04E-01	1.07E+01	9.24E-02	-1.17E+02
Global Warming Potential fossil fuels (GWP-fossil)	[kg CO_2 eq.]	4.10E+02	8.76E+00	1.70E+00	0.00E+00	4.34E-01	0.00E+00	1.39E+00	5.04E-01	1.02E+01	9.16E-02	-1.17E+02
Global Warming Potential biogenic (GWP-biogenic)	[kg CO_2 eq.]	-2.15E+00	-3.17E-03	4.43E+00	0.00E+00	1.31E-03	0.00E+00	2.03E-04	6.31E-06	5.21E-01	7.51E-04	-1.11E-01
Global Warming Potential land use and land use change (GWP-luluc)	[kg CO_2 eq.]	4.66E-01	4.75E-03	1.87E-04	0.00E+00	5.30E-04	0.00E+00	1.75E-04	2.00E-04	2.90E-03	5.05E-05	-2.33E-01
Depletion potential of the stratospheric ozone layer (ODP)	[kg CFC 11 eq.]	5.86E-06	1.21E-07	2.13E-08	0.00E+00	6.23E-08	0.00E+00	2.08E-08	7.04E-09	1.87E-08	2.34E-09	-8.75E-07
Acidification potential, Accumulated Exceedance (AP)	[mol H+ eq.]	2.63E+00	2.39E-01	1.25E-02	0.00E+00	2.27E-03	0.00E+00	1.23E-02	1.68E-03	1.35E-02	7.15E-04	-8.99E-01
Eutrophication potential, fraction of nutrients reaching	[kg P eq.]	1.58E-01	3.99E-04	6.08E-05	0.00E+00	1.77E-04	0.00E+00	5.79E-05	3.95E-05	9.56E-04	4.03E-05	-2.88E-02

freshwater end compartment (EP-freshwater)												
Eutrophication potential, fraction of nutrients reaching marine end compartment (EP-marine)	[kg N eq.]	4.62E-01	6.02E-02	5.73E-03	0.00E+00	4.58E-04	0.00E+00	5.66E-03	5.44E-04	3.81E-03	2.43E-04	-1.43E-01
Eutrophication potential, Accumulated Exceedance (EP-terrestrial)	[mol N eq.]	4.96E+00	6.68E-01	6.26E-02	0.00E+00	4.65E-03	0.00E+00	6.19E-02	5.92E-03	3.73E-02	2.63E-03	-1.58E+00
Formation potential of tropospheric ozone (POCP)	[kg NMVOC eq.]	1.51E+00	1.81E-01	1.87E-02	0.00E+00	1.42E-03	0.00E+00	1.85E-02	2.34E-03	1.07E-02	9.13E-04	-4.85E-01
Abiotic depletion potential for non-fossil resources (ADP-minerals&metals)	[kg Sb eq.]	1.02E-02	9.93E-06	6.05E-07	0.00E+00	1.97E-06	0.00E+00	5.07E-07	1.61E-06	2.36E-06	1.99E-07	-1.07E-03
Abiotic depletion potential for fossil resources (ADP-fossil)	MJ, net calorific value	4.84E+03	1.07E+02	1.85E+01	0.00E+00	5.52E+00	0.00E+00	1.81E+01	7.07E+00	3.06E+01	2.01E+00	-1.19E+03
Water (user) deprivation potential, deprivation-weighted water consumption (WDP)	[m^3 world eq. Deprived]	3.93E+02	4.00E-01	7.70E-02	0.00E+00	2.12E+01	0.00E+00	6.12E-02	3.86E-02	8.71E-01	-1.29E+00	-5.72E+01

3.2 Resource use and waste categories

Table 3-2: Resource use and waste categories according to EN 15804

RESULTS OF THE LCA –Resource use and waste categories per functional unit for average												
Core indicator	**Unit**	**A1-A3**	**A4**	**A5**	**B1**	**B2**	**B3-B7**	**C1**	**C2**	**C3**	**C4**	**D**
Use of renewable primary energy excluding renewable primary energy resources used as raw materials (PERE)	MJ	8.91E+02	1.22E+00	1.82E-01	0.00E+00	6.13E-01	0.00E+00	1.75E-01	9.28E-02	3.30E+00	2.81E-02	-1.99E+02
Use of renewable primary energy resources used as raw materials (PERM)	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total use of renewable primary energy resources (PERT) (primary energy and primary	MJ	8.91E+02	1.22E+00	1.82E-01	0.00E+00	6.13E-01	0.00E+00	1.75E-01	9.28E-02	3.30E+00	2.81E-02	-1.99E+02

RESULTS OF THE LCA –Resource use and waste categories per functional unit for average												
Core indicator	**Unit**	**A1-A3**	**A4**	**A5**	**B1**	**B2**	**B3-B7**	**C1**	**C2**	**C3**	**C4**	**D**
energy resources used as raw materials)												
Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials (PENRE)	MJ	4.85E+03	1.07E+02	1.85E+01	0.00E+00	5.52E+00	0.00E+00	1.81E+01	7.07E+00	3.06E+01	2.01E+00	-1.19E+03
Use of non-renewable primary energy resources used as raw materials (PENRM)	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total use of non-renewable primary energy resources (PENRT) (primary energy and primary energy resources used as raw materials)	MJ	4.85E+03	1.07E+02	1.85E+01	0.00E+00	5.52E+00	0.00E+00	1.81E+01	7.07E+00	3.06E+01	2.01E+00	-1.19E+03
Use of secondary material (SM)	kg	1.73E+00	6.25E-02	7.56E-03	0.00E+00	1.55E-02	0.00E+00	7.35E-03	3.17E-03	5.24E-03	7.34E-04	-2.02E-01
Use of renewable secondary fuels (RSF)	MJ	9.91E-02	1.59E-04	2.31E-05	0.00E+00	1.28E-05	0.00E+00	1.93E-05	4.04E-05	6.43E-05	1.38E-05	-2.29E-02
Use of non-renewable secondary fuels (NRSF)	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Net use of fresh water (FW)	m^3	9.75E+00	9.95E-03	1.89E-03	0.00E+00	4.95E-01	0.00E+00	1.52E-03	9.43E-04	2.22E-02	-3.01E-02	-1.39E+00
Hazardous waste disposed (HWD)	kg	4.97E+01	2.02E-01	2.89E-02	0.00E+00	4.77E-02	0.00E+00	2.34E-02	1.24E-02	3.41E-01	3.71E-03	-1.73E+01
Non-hazardous waste disposed (NHWD)	kg	8.56E+02	2.61E+00	5.03E-01	0.00E+00	8.69E+00	0.00E+00	3.59E-01	2.33E-01	8.80E+00	4.05E+01	-1.92E+02
Radioactive waste disposed (RWD)	kg	6.56E-03	1.70E-05	3.47E-06	0.00E+00	1.28E-05	0.00E+00	3.37E-06	1.42E-06	6.99E-05	4.48E-07	-1.06E-03
Components for re-use (CRU)	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Materials for recycling (MFR)	kg	2.54E-01	1.17E-02	7.13E-05	0.00E+00	4.01E-04	0.00E+00	6.80E-05	5.21E-05	9.13E-03	3.37E-05	-3.38E-02
Materials for energy recovery (MER)	kg	4.54E-04	3.93E-06	2.98E-07	0.00E+00	4.18E-07	0.00E+00	2.67E-07	4.56E-07	1.48E-06	1.40E-07	-2.02E-04
Exported electricity energy (EEE)	MJ	1.59E+00	6.33E-03	1.37E-03	0.00E+00	5.86E-03	0.00E+00	1.34E-03	5.14E-04	2.62E-02	4.34E-04	-1.22E-01
Exported heat energy (EHE)	MJ	2.43E+00	1.91E-02	5.24E-04	0.00E+00	7.69E-04	0.00E+00	4.46E-04	1.04E-03	2.05E-03	2.43E-04	-8.58E-01

3.3 Information on biogenic carbon content

Information on biogenic carbon content which shall be included in the EPD as follows:

Biogenic carbon content	Unit (per functional unit for average)
Biogenic carbon content in product	0 kg C
Biogenic carbon content in accompanying packaging	1.21E+00 kg C
NOTE：1 kg biogenic carbon is equivalent to 44/12 kg of CO_2.	

4 Supplementary information

4.1 Calculation rules

Functional unit

Functional unit: 1 kWp of manufactured photovoltaic module, from cradle-to-grave, with activities needed for a study period for a defined reference service life.

Cut-off criteria

This study includes all raw material and energy consumption. All inputs and outputs of the unit processes for which data is available are included in the calculation. Minor auxiliary materials such as adhesive tapes, barcodes, and labels have been excluded based on the cut-off criteria, as their total mass accounts for less than 0.1% of the total input. There is no neglected unit process more than 1% of total mass and energy flows per unit process. The total neglected input flows per module is less than 5% of energy usage and mass.

Allocation

The PV modules covered by this EPD are manufactured at production facilities located in Tianjin and Lixian. In addition to the products included in this EPD, the production lines at both facilities also manufacture other PV module specifications of the same product family. At each manufacturing site, total energy consumption associated with PV module production is allocated among all PV module specifications produced at that site. The allocation is performed based on the nominal power output, with energy consumption distributed proportionally according to the unit output power of each module type. No by-products are generated during the PV module manufacturing process; therefore, no allocation to by-products is required.

Both of Tianjin and Lixian plants are connected to the North China Grid. Electricity consumed during the production process was purchased from the State Grid, No contractual renewable electricity or on-site electricity generation is applied. The GWP-GHG data for grid electricity are taken from the ecoinvent 3.10 database (The grid electricity factor is represented by the dataset “Electricity, medium voltage {CN-NCGC}| market for electricity, medium voltage | EN15804, U”, with an emission factor of 1.05 kg CO_2e/kWh).Electricity consumption during the construction and dismantling stages is modelled using global electricity datasets (The grid electricity factor is represented by the dataset “Electricity, medium voltage {GLO}| market group for electricity, medium voltage | EN15804, U”, with an emission factor of 0.725kg CO_2e/kWh). The datasets used for modelling electricity include the impacts associated with the construction of the related infrastructure.

For the end-of-life stage, the allocation approach follows the cut-off principle in accordance with EN 15804 and the applicable PCR. All environmental impacts related to deconstruction, transport and waste processing are attributed to the declared product. Recycled materials leave the system without environmental burdens. Potential benefits from recycling or energy recovery beyond the system boundary are reported in Module D.

Reference service life (RSL)

RSL: stands for reference service life. According to the PCR, the RSL for PV modules is defined as 30 years.

Data quality

Table 4-1: Data quality information

Field	Information
Data Collection	1/1/2024 – 31/12/2024
Sites used	2 sites in No. 5 Haihang East Road, Modern Industrial Zone, Ninghe District, Tianjin, China and No. 655, High-tech Industrial Park, North Yongsheng Street, Li County, Baoding, Hebei, China owned by Yingli Energy Development Co., Ltd.
Geography	The photovoltaic module products are manufactured in CN and sold within GLO
Technology	PV modules are manufactured by laser-cutting cells into half-cells, soldering them into strings, and assembling a lay-up (glass/EVA/cell strings) before vacuum lamination and edge trimming. The laminated module is then framed, the junction box is installed/welded and potted, followed by IV/EL and electrical safety tests, and finally packaged for shipment. The emission factor of the solar cells is modelled based on datasets provided by the supplier.
Averaging	The declared unit for this product is 1 kWp; as this EPD is declared as an average product from several of the manufacturer's plants, the reported LCA results represent a single weighted-average value, calculated by weighting the results of the different module variants according to their respective production output in kWp
LCI/LCA database	Ecoinvent 3.10
EPD used	No EPD used
Data Quality Scheme	EN 15804:2012+A2:2019, Annex E, Table E.2
Use of Fair data with more than 30 % of a core impact	No Fair data with more than 30 % of a core impact used
Use of Poor relevant data	No Poor relevant data used
Use of Very Poor relevant data	No very poor data used

4.2 Scenarios and additional technical information

Description of the processes included in Raw material supply, transport and manufacture

A1-A3 stage includes raw materials supply, which are Cell, Interconnection bar, Busbar, Frame, Junction box, Solar glass, EVA, POE, Flux, Sealant, Potting adhesive (A1), transportation of raw materials to the factory (A2) and the manufacturing of Module products (A3) providing inputs for raw materials, energy and auxiliary materials, and the treatment and discharge of exhaust gases and solid wastes from the Module products manufacturing process.

Recycling, Reuse and Recovery

This product is a photovoltaic (PV) module. For the end-of-life stage, due to the absence of specific data on the recycling rate of waste PV modules in the studied region, this assessment refers to the legal requirements defined under the Waste Electrical and Electronic Equipment (WEEE) Directive. According to Directive 2012/19/EU, Article 11 and Annex V, the minimum required recycling rate for waste PV modules is 85%.

Based on this requirement, it is assumed that 85% of the PV module components are recovered, while the remaining 15% of the waste components, including photovoltaic cells, glass and waste plastics, are disposed of in the disposal stage (C4). Photovoltaic cells are treated as inert materials and are assumed to be disposed of by

landfill. Metal components are assumed to be recycled at a rate of 85%, with the remaining 15% disposed of by landfill. Plastic components and other combustible materials are assumed to be fully incinerated.

All environmental impacts associated with disposal processes are reported in the relevant C modules, while the potential environmental benefits resulting from material recycling and energy recovery from incineration are reported in Module D.

Assumptions

To avoid incorrect assumptions or unjustified premises, a conservative and standards-compliant approach was consistently applied throughout the LCA modelling and result interpretation.

Infrastructure (e.g., buildings, production equipment, and related construction or end-of-life processes) is not modelled as a supporting activity in this study.

The key assumptions applied in this study are summarized as follows:

Categories	Key assumptions
Transportation stage (A2, and A4)	For transport without detailed information, EURO 5 type vehicle with 16-32 ton capacity is used.
Installation stage（A5）	No construction waste is considered.
	Packaging materials for PV modules are assumed be transported at a distance 50km.
	Energy consumption for the construction process is sourced from the Ecoinvent dataset “Photovoltaic plant, 570kWp, multi-Si, on open ground {GLO}| photovoltaic plant construction, 570kWp, multi-Si, on open ground	Cut-off, U”. Based on this dataset, the energy use for installation is modelled as 0.06 kWh of electricity per 1 kWp of installed capacity and 13.4 MJ of diesel per 1 kWp.
Use & Maintenance（B）	The use stage requires no energy and materials inputs, and has no emissions.
	Water used for cleaning the PV panels is assumed 2L/m^2 for 2 times per year.
	No replacement is assumed for the PV module, as the reference service life (RSL) is set to 30 years. The PV module does not require operational water or energy during the use stage.
End-of-life（C1-C4）	The de-construction of PV plant is assumed to be consuming the same energy as the installation stage.
	Waste transportation distance from the de-installation plant to the waste treatment facilities is assumed to be 50km.
	Report IEA-PVPS T12-19:2020 December 2020 is referenced for the energy and diesel consumption to treat and dissemble the PV modules.
	For the end-of-life stage, due to the absence of existing data on the recycling rate for photovoltaic (PV) modules, this study references the legal requirements set forth by Waste Electrical and Electronic Equipment (WEEE). The required recycling rate for waste PV modules is 85%, as stipulated by 2012/19/EU-Article 11 & ANNEX V. 15% of the waste components, including cells, glass, and waste plastics end up to disposal (C4). The photovoltaic cells are treated as inert materials and are disposed of by landfill. Metal components are assumed to be recycled at a rate of 85%, while the remaining 15% are disposed of by landfill. Plastic components and other combustible materials are assumed to be fully incinerated.

Module D	For incineration with energy recovery, the net energy production depends on the waste type. In the case of plastic waste, the net energy production is assumed to be 4.5 MJ/kg of electric energy and 8.7 MJ/kg of thermal energy. For other combustible waste fractions, the net energy production is assumed to be 1.39 MJ/kg of electric energy and 2.85 MJ/kg of thermal energy.

4.3 Dangerous substances

No SVHC substances are employed in the current production process and product manufacturing of photovoltaic modules.

4.4 Other optional additional environmental information

Not involve.

References

ISO 14025:2006 Environmental labels and declarations – Type III environmental declarations Principles and procedures.
ISO 14040:2006 Environmental management. Life cycle assessment. Principles and frameworks.
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