OWNER OF THE DECLARATION

ENVIRONMENTAL PRODUCT DECLARATION

LR4-72HBD(VINA), LR5-72HBD(VINA), LR5-72HPH(VINA), LR5-72HIBD(VINA), LR5-72HIH(VINA), LR5-54HPH(VINA), LR5-54HIH(VINA), LR5-54HIB(VINA)

VINA SOLAR TECHNOLOGY CO., LTD

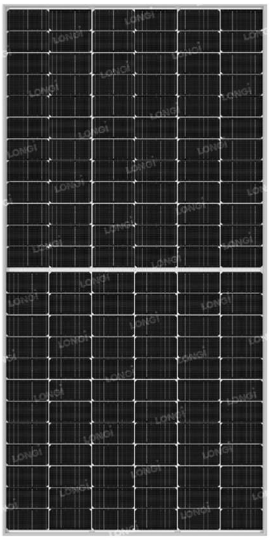
Lot CN-03 Factory E12, Van Trung Industrial park, Van Trung commune, Viet Yen District,Bac Giang Province, Viet Nam

in compliance with ISO 14025

Program Operator	UL
Publisher	EPDItaly

Declaration Number	4790547601.102.1
Registration Number	MR-EPDITALY0069

Issue Date	2023/07/ 01
Valid to	2028/07/ 01



Registered under the mutual recognition between EPDItaly and UL.
www.epditaly.it

LONGi

Photovoltaic Modules

LR4-72HBD(VINA)/ LR5-72HBD(VINA)/ LR5-72HPH(VINA)/ LR5-72HIBD(VINA)/ LR5-72HIH(VINA)/ LR5-54HPH(VINA)/ LR5-54HIH(VINA)/ LR5-54HIB(VINA)

ENVIRONMENTAL PRODUCT DECLARATION REPORT

LR4-72HBD(VINA)/ LR5-72HBD(VINA)/ LR5-72HPH(VINA)/ LR5-72HIBD(VINA)/ LR5-72HIH(VINA)/ LR5-54HPH(VINA)/ LR5-54HIH(VINA)/ LR5-54HIB(VINA)

LONGi

LONGi is a world leader in the clean energy transition. We provide a comprehensive suite of solar PV solutions that can optimize a wide range of project applications. LONGi's technological and manufacturing leadership in solar wafers, cells and modules underscores our commitment to helping accelerate the clean energy transition. By offering high-quality, reliable products and systems, we provide holistic solutions for the solar and renewables industry.

In 2020. LONGi solved a total of about 120 million KWh in production units, which is equivalent to the electricity consumption of 150,000 people for a whole year. In addition, LONGi hopes to work jointly with partners inside and outside the global energy industry to innovate and continuously improve the technology of PV power generation. LONGi also hopes to continuously expand the scale of the global PV industry to maximize the value of the eternal gift from our Sun.

For more information visit : https://www.longi.com/cn

CERTIFIED

ENVIRONMENTAL PRODUCT DECLARATION

UL.COM/EPD

EPD PROGRAM AND PROGRAM OPERATOR NAME, ADDRESS, LOGO, AND WEBSITE	UL Environment 333 Pfingsten Road Northbrook, IL 60611 HTTPS://WWW.UL.COM/ HTTPS://SPOT.UL.COM/
GENERAL PROGRAM INSTRUCTIONS AND VERSION NUMBER	UL Program Operator Rules v2.7 2022
MANUFACTURER NAME AND ADDRESS	VINA SOLAR TECHNOLOGY CO., LTD Lot CN-03 Factory E12, Van Trung Industrial park, Van Trung commune, Viet Yen District,Bac Giang Province, Viet Nam
DECLARATION NUMBER	4790547601.102.1
DECLARED PRODUCT & FUNCTIONAL UNIT OR DECLARED UNIT	LR4-72HBD(Vina), LR5-72HBD(Vina), LR5-72HPH(Vina), LR5-72HIBD(Vina), LR5-72HIH(Vina), LR5-54HPH(Vina), LR5-54HIH(Vina), LR5-54HIB(Vina) 1 kWh of electricity generated as output from the solar photovoltaic plant
REFERENCE PCR AND VERSION NUMBER	PCR EPDItaly014: Electricity Produced by Photovoltaic Modules.
DESCRIPTION OF PRODUCT APPLICATION/USE	LONGi solar monocrystalline silicon PV modules are widely used to generate electricity on rooftop and ground solar farms
PRODUCT RSL DESCRIPTION (IF APPL.)	30 years
MARKETS OF APPLICABILITY	Europe, North America, China
DATE OF ISSUE	July 1, 2023
PERIOD OF VALIDITY	5 years
EPD TYPE	Product-specific
RANGE OF DATASET VARIABILITY	N/A
EPD SCOPE	Cradle to Grave
YEAR(S) OF REPORTED PRIMARY DATA	July 2020 – June 2021
LCA SOFTWARE & VERSION NUMBER	Simapro 9.1.0
LCI DATABASE(S) & VERSION NUMBER	Ecoinvent 3.6
LCIA METHODOLOGY & VERSION NUMBER	EN 15804+A2:2019(version 1.00) & TRACI 2.1

The PCR review was conducted by:	EPDItaly Program PCR Moderator & Review Committee info@epditaly.it	
This declaration was independently verified in accordance with ISO 14025: 2006. ☐ INTERNAL ☒ EXTERNAL	Cooper McCollum, UL Environment	Cooper McCollum
This life cycle assessment was independently verified in accordance with ISO 14044 and the reference PCR by:	James Mellentine, Thrive ESG	James A. Mellentine

LIMITATIONS

EXCLUSIONS: EPDS DO NOT INDICATE THAT ANY ENVIRONMENTAL OR SOCIAL PERFORMANCE BENCHMARKS ARE MET, AND THERE MAY BE IMPACTS THAT THEY DO NOT ENCOMPASS. LCAS DO NOT TYPICALLY ADDRESS THE SITE-SPECIFIC ENVIRONMENTAL IMPACTS OF RAW MATERIAL EXTRACTION, NOR ARE THEY MEANT TO ASSESS HUMAN HEALTH TOXICITY. EPDS CAN COMPLEMENT BUT CANNOT REPLACE TOOLS AND CERTIFICATIONS THAT ARE DESIGNED TO ADDRESS THESE IMPACTS AND/OR SET PERFORMANCE THRESHOLDS – E.G. TYPE 1 CERTIFICATIONS, HEALTH ASSESSMENTS AND DECLARATIONS, ENVIRONMENTAL IMPACT ASSESSMENTS, ETC.

ACCURACY OF RESULTS: EPDS REGULARLY RELY ON ESTIMATIONS OF IMPACTS; THE LEVEL OF ACCURACY IN ESTIMATION OF EFFECT DIFFERS FOR ANY PARTICULAR PRODUCT LINE AND REPORTED IMPACT.

COMPARABILITY: EPDS FROM DIFFERENT PROGRAMS 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.

LONGi

Solar Modules

LR4-72HBD(Vina)/ LR5-72HBD(Vina)/ LR5-72HPH(Vina)/ LR5-72HIBD(Vina)/ LR5-72HIH(Vina)/ LR5-54HPH(Vina)/ LR5-54HIH(Vina)/ LR5-54HIB(Vina)

1. Product Definition and Information

1.1. Description of Company/Organization

LONGi is a world leader in the clean energy transition. We provide a comprehensive suite of solar PV solutions that can optimize a wide range of project applications. LONGi's technological and manufacturing leadership in solar wafers, cells and modules underscores our commitment to helping accelerate the clean energy transition. By offering high-quality, reliable products and systems, we provide holistic solutions for the solar and renewables industry.

In 2021. LONGi produce a total of about 38.69 GW modules. In addition, LONGi hopes to work jointly with partners inside and outside the global energy industry to innovate and continuously improve the technology of PV power generation. LONGi also hopes to continuously expand the scale of the global PV industry to maximize the value of the eternal gift from our Sun.

1.2. Product Description

1.2.1 Product Identification

The LONGi Solar's PV modules under analysis integrate various advanced technologies like half-cut cells and Gallium-doped wafer, with the highest power up to 560W and up to 21.8% module efficiency. Besides, the unique circuit design of half-cut cells can reduce temperature coefficient. Moreover, the gallium-doped technology overcomes the light attenuation of the module and ensures the long-term power generation stability of the module. Application of this modules can remarkably reduce the number of modules employed in a power station, thus lowering the corresponding cost of supports, cables, construction and land, improving the return on investment.

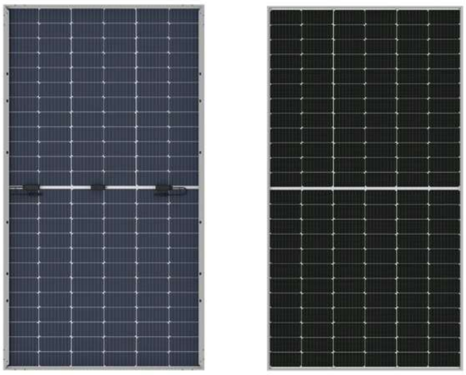


Figure 1. LONGi Solar PV Bifacial double glass modules

1.2.2 Product Specification

LONGi Solar produces more than a dozen series of mono-crystalline silicon PV modules. Within this project, LONGi Solar PV Bifacial double glass modules cover 4 PV modules that are analyzed, including LR4-72HBD(Vina), LR5-72HBD(Vina), LR5-72HPH(Vina), LR5-72HIBD(Vina), LR5-72HIH(Vina), LR5-54HPH(Vina), LR5-54HIH(Vina), LR5-54HIB(Vina). The full list of the modules under analysis is shown in table 1 below.

Table 1. Different PV module products models

SERIOUS (BRAND NAME)	POWER OUTPUT RANGE (W)	DIMENSIONS (MM2)	MODULE EFFICIENCY (%)
LR4-72HBD(Vina)	440-460	2094×1038	20.7
LR5-72HBD(Vina)	535-555	2278×1134	21.5
LR5-72HPH(Vina)	540-560	2278×1134	21.7
LR5-72HIBD(Vina)	530-550	2278×1134	21.3
LR5-72HIH(Vina)	535-555	2278×1134	21.5

LR5-54HPH(Vina)	405-425	1722×1134	21.8
LR5-54HIH(Vina)	400-420	1722×1134	21.5
LR5-54HIB(Vina)	395-415	1722×1134	21.3

1.3. Application

LONGi Solar PV modules are widely used to generate electricity on ultra-large ground power station and Large-scale industrial and commercial projects.

1.4. Material Composition

Table 2 contains a list of materials and substances in different modules.

Table 2. Components in different PV modules

Material	Main substance	Units	LR4-72HBD (Vina)	LR5-72HBD (Vina)	LR5-72HPH (Vina)	LR5-72HIBD (Vina)	LR5-72HIH (Vina)	LR5-54HPH (Vina)	LR5-54HIH (Vina)	LR5-54HIB (Vina)
Cells	silicon	kg/pcs	0.785	0.902	0.902	0.902	0.902	0.631	0.631	0.631
Solar Glass	glass	kg/pcs	21.57	25.39	20.31	25.39	20.31	14.86	14.86	14.86
Aluminum frame	Aluminum	kg/pcs	2.393	2.592	2.690	2.592	2.660	2.034	2.034	2.034
Back sheet PET	PET	kg/pcs	0.000	0.000	1.250	0.000	1.250	0.877	0.877	0.877
EVA	EVA	kg/pcs	0.650	1.238	1.081	1.238	1.081	1.022	1.022	1.022
POE	POE	kg/pcs	1.260	1.268	0.938	1.268	0.938	1.269	1.269	1.269
Insulating strip	EPE	kg/pcs	0.0026	0.0031	0.0026	0.0030	0.0026	0.0020	0.0020	0.0020
Assembly - Silicone Joint	silicone	kg/pcs	0.333	0.395	0.333	0.391	0.329	0.252	0.252	0.252
Ribbon String& Interconnection	Copper	kg/pcs	0.226	0.267	0.226	0.265	0.223	0.171	0.171	0.171
Junction Box	Plastic	kg/pcs	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180
Junction Box - Silicone joint	silicone	kg/pcs	0.066	0.078	0.066	0.078	0.065	0.050	0.050	0.050

1.5. Declaration of Methodological Framework

In this project, a full LCA approach was considered with some simplification on data modeling using generic data for most background systems. The EPD analysis uses a cradle-to-grave system boundary. No known flows are deliberately excluded from this EPD.

To calculate the LCA results for the product maintenance stage, a 30-year reference service life (RSL) was assumed for the declared products.

Additional details on assumptions, cut-offs and allocation procedures can be found in section 2.3,2.4,2.8 respectively.

1.6. Technical Requirements

The chart below lists all standards required for LONGi solar's PV modules.

Table 3. Standards required for LONGi solar's PV modules

Product	Standards
LR4-72HBD(Vina) **LR5-72HBD(Vina)** **LR5-72HPH(Vina)** **LR5-72HIBD(Vina)** **LR5-72HIH(Vina)** **LR5-54HPH(Vina)**	IEC 61215, IEC 61730, UL 61730 ISO9001:2015: ISO Quality Management System ISO14001:2015: ISO Environment Management System ISO45001:2018: Occupational Health and Safety TS62941: Guideline for module design qualification and type approval

LR5-54HIH(Vina)	
LR5-54HIB(Vina)	

Life Cycle Assessment Background Information

1.7. Functional or Declared Unit

The functional unit and declared unit provide a reference by means of which the material flows (input and output data) for each information module of a product are normalized (in mathematical sense) to produce data, expressed on a common basis. It is important that the functional units of these products are equivalent so that the results may be interpreted clearly.

In this report, the functional unit is defined as 1 kWh of electricity generated as output from the solar photovoltaic plant.

1.8. System Boundary

The system boundary considered in this LCA study is from cradle to grave. Figure 2 below illustrates the system boundaries for the LONGi Solar product, including raw material production and transportation, manufacture, delivery, solar plant installation, operation, maintenance and waste disposal.

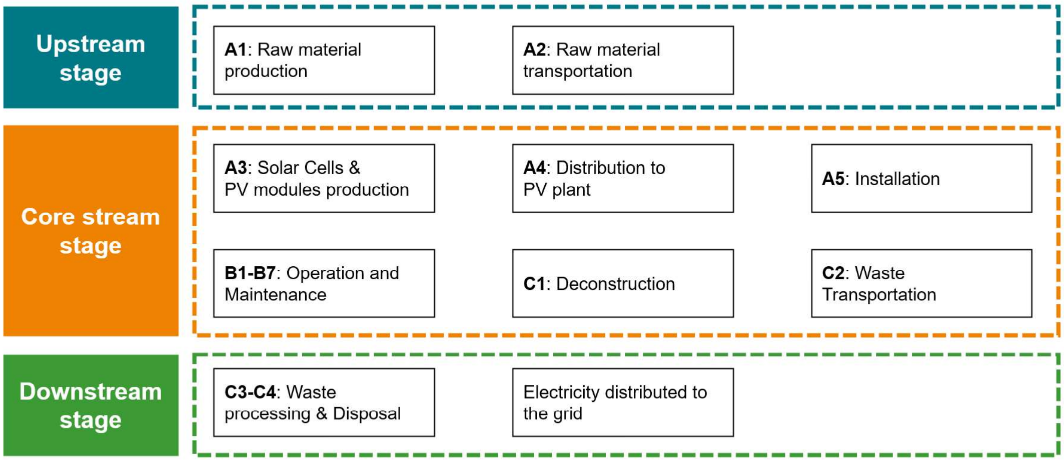


Figure 2. System boundaries

According to the PCR, the life cycle stage must refer to segmentation in the following three processes:

Upstream Stage for module: which includes extraction and processing of raw materials (A1), transportation of the raw material to the factory (A2);

Core Stage for module: which includes all the relevant processes managed by the Organization proposing the EPD. The core stage in this study includes manufacturing of solar cells and PV modules (A3) with the supply of the energy and water input, and gaseous emissions, wastewater and solid wastes; distribution of PV modules to solar PV plant (A4); construction of the solar plant (A5), the use (B1), maintenance (B2), repair (B3), replacement (B4), refurbishment (B5) and the operational energy use (B6) and water use (B7) during the RSL (30 years) period; de-construction and demolition of the solar plant (C1), transport to waste processing (C2). According to the PCR, the benefit and avoided loads beyond the product system boundary are not reported in module D separately within this study, neither will the benefit and loads be reported in other stages by following a cut off allocation approach. However, considering that the installation and operation is beyond the control of LONGi Solar. Therefore, the construction of the solar plant (A5) base on the data from Ecoinvent database value;

Downstream Stage for module: which includes waste processing (C3) and disposal (C4), dissipation related to voltage drop operations before feeding electricity into the grid, and environmental impacts of using booster station.which includes dissipation related to voltage drop operations before feeding electricity into the grid; and environmental impacts of using booster station.

1.9. Estimates and Assumptions

In order to carry out the LCA study, the following main assumptions were made:

- All products are modeled using the same assumptions.
- For missing background data, substitution of missing data using similar background data approach was taken to shorten the gap. A sensitivity analysis was conducted.
- The electricity consumption during PV plant construction stage is scaled up based on the data from Ecoinvent database value (36.03 kWh/570kWp) according to the power capacity;
- Electricity used during the PV plant operation is assumed to be powered by the plant itself, water used for cleaning the PV panels is assumed 0.23L (source: www.polywater.com) per module per time and two times per year, replacement of inverter is assumed 1 inverter/ 2 years during RSL (30 years);
- Materials conmsumtion during PV plants construction is scaled up based on the data from Ecoinvent database value according to the power capacity. Secondary data from Ecoinvent 3.6 (photovoltaics,electricity installation for 570kWp modules,open ground GLO);
- De-construction (C1) of the PV plant during the disposal stage consumes mainly electricity, and the electricity consumption was assumed the same as the electricity consumption in PV plant construction stage (A5); and electricity consumption for PV module demolition at waste processing stage (C3) is assumed same to the electricity consumption of PV module assembling;
- During the end-of-life stage, the transportation of the waste PV modules and other equipment from the solar PV plant to treatment facilities including recycling, landfill or incineration center was assumed to be 100 km for simplification purposes. A sensitivity analysis was conducted;
- Electricity loss during transmission of electricity from the plant distributed to the grid or the customer, pollution of PV module surface and inverter loss, etc. Assuming 8% dirty loss, 3% temperature loss, 2% module series loss, 4% cable loss, 2.5% inverter loss, 2% transformer loss, and 0.6% annual PV panel loss. The system efficiency η=0.95*0.97*0.98*0.96*0.975*0.98*0.994=0.797. Therefore, the loss of the system is assumed to be 20%.
- The photovoltaic installation site is assumed to be in San Francisco, California, USA, and the energy yield capacity of the plant is assumed to be 100MW

1.10. Cut-off Criteria

The following procedure was followed for the exclusion of inputs and outputs:

- All inputs and outputs to a (unit) process will be included in the calculation for which data is available. Data gaps may be filled by conservative assumptions with average or generic data. Any assumptions for such choices will be documented;
- The inspection personnale are based within 10 km of the plant.
- In case of insufficient input data or data gaps for a unit process, according to the PCR requirement, the cut-off criteria chosen is 2% of the total mass and energy of that unit process. (respectively, of the photovoltaic module's unit weight and the energy needed to produce and assemble it). The neglected flow is demonstrated in Table 4.

Table 4. Cut off flows

FLOW NAME	PROCESS STAGE	MASS %	REASON TO CUT OFF
Inspection during operation of solar plant	B	N/A	Cut off due to small impact according to PCR
Total cut off mass % estimated		1.43E-05	<2%

1.11. Reference Service life and Estimated Building Service Life

The reference service life of products is 30 years.

1.12. Data Sources

The module production data (materials, electricity) comes directly from LONGi's ERP data, the source of the secondary LCI data is the Ecoinvent database, and the wastewater treatment data comes from the wastewater treatment company's invoice.

On-site data mainly include the types and usage of raw materials in raw material production, energy consumption in parts processing and product assembly, transportation data in sales and transportation, energy consumption in product use, and waste generation in product disposal; Background data mainly include environmental impact factors in raw material production, parts processing and product assembly, sales and transportation, product use, and product disposal.

1.13. Data Quality

The data quality requirements for this study were as follows:

- Foreground data of the considered system: such as materials or energy flows that enter the production system. These data were directly extracted from ERP or calculated and submitted by LONGi.
- Generic data related to the life cycle impacts of the material or energy flows that enter the production system. These data were sourced from the Ecoinvent 3.6 database in SimaPro 9.1;
- Existing LCI data were, at most, 10 years old. Newly collected LCI data were current or up to 3 years old;
- The LCI data related to the geographical locations where the processes took place, disposal data from China and Europe were utilized;
- The scenarios represented the average technologies at the time of data collection.
- The electricity inventory is based on the electricity country mix (market group for electricity,medium voltage CN) which is mix grid of the Ecoinvent 3.6 database, and the grid combination data for a specific region is based on the State Grid Corporation of China (SGCC). The modules were assembled in Vietnam Electricity, medium voltage {VN} | market group for | Cut-off, S was chosen as electricity inventory.
- The module's data collection comes from Lot CN-03 Factory E12, Van Trung Industrial park, Van Trung commune, Viet Yen District,Bac Giang Province, Viet Nam , and the collection time is January 2020 - December 2020.

1.14. Allocation

Allocation refers to 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 processes

For data sets in this study, the allocation of the inputs from coupled processes is generally carried out via the mass. The consumption of raw materials is allocated by mass ratio. The transportation of raw materials is allocated by mass ratio.

Multi-output processes

In the production of Solar Cells and PV modules, the total consumption of energy and water during manufacturing is equally allocated to per unit mass. 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.

Allocation for recovery processes

For the allocation of residuals, the model “allocation cut-off by classification (ISO standard) (called “Allocation Recycle Content”, alloc rec, by Ecoinvent) was 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 a 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.

During the end of life stage of the solar plant, the extra benefit of recycling the waste modules as well as other equipment is cut off from the boundary, following the PCR's recommendation on end of life scenario. Along with the benefit, the load from waste treatment for recycling purpose such as de-pollution and crushing etc., is also allocated to the next life cycle of substituted products, but not the primary producers of PV module, hence no burden or benefit will be allocated to the primary producer of the PV module or solar PV plant (cut off approach).

1.15. Period under Review

The study used primary data collected from July 2020 - June 2021.

1.16. Comparability and Benchmarking

No comparisons or benchmarking are included in this EPD. LCA results across EPDs can be calculated with different background databases, modeling assumptions, geographic scope and time periods, all of which are valid and acceptable according to the Product Category Rules (PCR) and ISO standards. The user of the EPD should take care when comparing EPDs from different companies. Assumptions, data sources, and assessment tools may all impact the uncertainty of the final results and make comparisons misleading.

1.17. Electricity power mix

In this EPD, different electricity mix data is taken where the process takes place based on grid mixes of China. The electricity inventory is based on the year 2015 for Chinese electricity generation (China Energy Statistics Yearbook 2016). All products selection electricity (based on the data from Ecoinvent 3.6 database value, select medium electricity of electricity country mix) and transportation data from China.

1.18. Units

SI units are used for all LCA results of LONGi Solar's products.

2. Life Cycle Assessment Scenarios

2.1. Manufacturing

- The PV module products under study includes 8 models (see Table 1). All the products share similar manufacturing processes and life cycle stages, which have a defective rate of about 10%. Therefore, Model inputs 110% of materials. A flowchart depicting the production process stages of LONGi Solar PV module products is shown in Figure 3 below. For simplification purpose, only main stages of manufacturing are presented, raw material, auxiliary processes considered in the LCA but not shown in the flowcharts, which include:
- -Raw and auxiliary material production and transportation
- -Recycling of waste materials;
- -Waste water treatment;
- -Supply of electricity

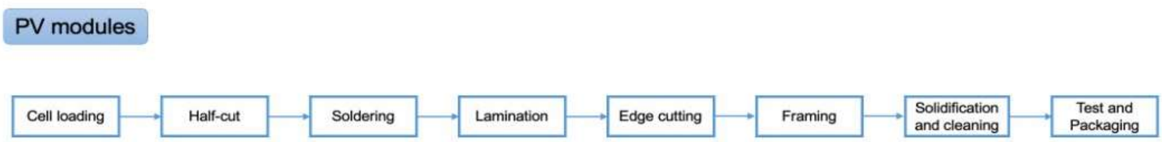


Figure 3 PV module production process

2.2. Packaging

There are three main kinds of packaging materials: Paper board/Paper (corner protector, box, top cover, bottom cover, module label (namplate, barcode, color lable), packaging label); PET (Wrap film, strip); Wood (Pallet).

2.3. Transportation

According to LONGi, the production site is in Lot CN-03 Factory E12, Van Trung Industrial park, Van Trung commune, Viet Yen District,Bac Giang Province, Viet Nam. The raw materials are mainly sourced from Yunnan Province in China, Vietnam, Malaysia and delivered by lorry. As it was not possible to define specific distances, justified estimates and web map service according to the suppliers' locations provided by LONGi were used. For all transportation vehicles, since it was not specified, unspecified EURO 4 lorry was used for LCA modelling for simplification purpose.

Table 5. Transport to the building site (A4)

NAME	VALUE	UNIT
Fuel type	Diesel	
Liters of fuel	31.11	l/100km
Vehicle type	Lorry	
Transport distance	1900	km
Capacity utilization (including empty runs mass based)	100	%
Gross density of products transported	N/A	kg/m^3
Capacity utilization volume factor (factor: =1 or <1 or ≥1 for compressed or nested packaging products)	=1	-

2.4. Product Installation

After the PV modules are manufactured, the PV modules and other materials, such as brackets, cables, and inverters, are transported to the installation site. During the construction process, construction materials such as concrete and tape are used, and electricity is mainly consumed during the construction process. Since, the construction of PV parks is already very mature, the emissions involved in the construction can be borrowed from background data. Therefore, all installation data concerning the solar PV plant are based on data from the Ecoinvent 3.6 database values, and the assumed installation sites provide only nominal solar irradiance data, as well as the installed capacity, with the installation site assumed to be San Francisco, California, USA. The detailed information about the PV plant is listed in Table 6.

Table 6. PV plant information

PARAMETERS	VALUE		SOURCE
	Amount	**Unit**	
Peak power of the plant	100000	kW	LONGi
Plant latitude and longitude	N37°48' 0'' W122°25'0''	°	LONGi
Plant altitude	2990	m	LONGi
Nominal solar irradiance	1721000	$Wh/m^2/year$	LONGi

2.5. Disposal

For the end-of-life stage, De-construction (C1) of the PV plant during the disposal stage is assumed mainly consumes electricity, and the electricity consumption is as sumed the same as the construction stage (A5), 100km transportation distance from plant site to waste treatment site (C2) is assumed, electricity used for PV module demolition during waste processing stage is assumed the same as PV module manufacturing stage (A3). For end of life disposal treatment process (C4), the disposal of other components including inverters is regarded as 100% recyclable and following the end of life load and benefit allocation approach, is then cut off from the analysis. Since there is lack of existing data of recycling rate for PV module, this study refers to legal requirements issued by Waste Electrical and Electronic Equipment (WEEE). In 2012/19/EU-Article 11 & ANNEX V, the required recycling rate for waste PV module is 85%. Therefore, 15% of waste PV module end up with waste disposal, waste management scenario of 20% landfill and 80% incineration was adopted.

3. Life Cycle Assessment Results

Table 7. Description of the system boundary modules

	PRODUCT STAGE			CONSTRUCT-ION PROCESS STAGE		USE STAGE							END OF LIFE STAGE				BENEFITS AND LOADS BEYOND THE SYSTEM BOUNDARY
	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
EPD Type: cradle-to grave	Raw material supply	Transport	Manufacturing	Transport from gate to site	Assembly/Install	Use	Maintenance	Repair	Replacement	Refurbishment	Building Operational Energy Use During Product Use	Building Operational Water Use During Product Use	Deconstruction	Transport	Waste processing	Disposal	Reuse, Recovery, Recycling Potential
	X	X	X	X	X	x	x	x	x	x	x	x	X	X	X	X	MND

3.1. Life Cycle Impact Assessment Results

This EPD follows the PCR EPDItaly014 ± Photovoltaic modules guideline and use the recommended impact method for the analysis, the EN 15804+A2:2019 (version 1.00) method was used in this report. The EN 15804 standard covers Environmental Product Declarations (EPDs) of construction products. The A2:2019 revision of this standard has aligned their methodology with the Environmental Footprint (EF) 3.0 method, except for their approach on biogenic carbon. According to the EN 15804, biogenic carbon emissions cause the same amount of Climate Change as fossil carbon, but can be neutralized by removing this carbon from the atmosphere again.

Based on the model of PV module products, the EN 15804 result is calculated and the tables below shows the results. Note that impact results are calculated based on 1 kWh electricity generated by the PV plant. The results have been demonstrated through different processes according to the PCR, namely upstream, core, and downstream processes.

Table 8. Life Cycle Impact Assessment Results- LR4-72HBD(Vina)

IMPACT CATEGORY	UNIT	UPSTREAM	CORE STREAM	DOWNSTREAM	TOTAL
Climate change - total	kg CO_2 eq	1.67E-02	8.05E-04	8.44E-04	1.83E-02
Climate change - fossil	kg CO_2 eq	1.66E-02	8.05E-04	6.99E-04	1.81E-02
Climate change - biogenic	kg CO_2 eq	7.29E-05	1.98E-07	-1.49E-04	-7.55E-05
Climate change - land use and change in land use	kg CO_2 eq	3.50E-05	2.48E-07	7.15E-08	3.54E-05
Ozone Depletion	kg CFC-11 eq	2.08E-09	7.33E-11	4.81E-12	2.16E-09
Acidification	mol H^+ eq	9.84E-05	1.54E-05	3.25E-06	1.17E-04
Eutrophication of water	kg PO_4 eq	1.05E-05	2.52E-06	1.20E-07	1.32E-05
Photochemical ozone formation	kg NMVOC eq	6.82E-05	4.58E-06	1.95E-06	7.47E-05

Consumption of abiotic resources - minerals and materials	kg Sb eq	5.41E-07	5.35E-08	1.22E-10	5.95E-07
Consumption of abiotic resources - fossil resources	MJ, calculated using lower calorific values	2.08E-01	1.10E-02	5.51E-03	2.24E-01
Water consumption	m³ eq	1.24E-02	2.82E-04	7.13E-05	1.28E-02

Table 9. Life Cycle Impact Assessment Results- LR5-72HBD(Vina)

Impact category	Unit	Upstream	Core stream	Downstream	Total
Climate change - total	kg CO_2 eq	1.63E-02	7.88E-04	8.26E-04	1.79E-02
Climate change - fossil	kg CO_2 eq	1.62E-02	7.88E-04	6.84E-04	1.77E-02
Climate change - biogenic	kg CO_2 eq	7.14E-05	1.94E-07	-1.45E-04	-7.39E-05
Climate change - land use and change in land use	kg CO_2 eq	3.43E-05	2.43E-07	7.00E-08	3.46E-05
Ozone Depletion	kg CFC-11 eq	2.04E-09	7.18E-11	4.71E-12	2.12E-09
Acidification	mol H^+ eq	9.63E-05	1.51E-05	3.19E-06	1.15E-04
Eutrophication of water	kg PO_4 eq	1.03E-05	2.47E-06	1.18E-07	1.29E-05
Photochemical ozone formation	kg NMVOC eq	6.67E-05	4.48E-06	1.91E-06	7.31E-05
Consumption of abiotic resources - minerals and materials	kg Sb eq	5.30E-07	5.23E-08	1.20E-10	5.82E-07
Consumption of abiotic resources - fossil resources	MJ, calculated using lower calorific values	2.03E-01	1.07E-02	5.39E-03	2.19E-01
Water consumption	m³ eq	1.21E-02	2.76E-04	6.98E-05	1.25E-02

Table 10. Life Cycle Impact Assessment Results- LR5-72HPH(Vina)

Impact category	Unit	Upstream	Core stream	Downstream	Total
Climate change - total	kg CO_2 eq	1.36E-02	6.59E-04	6.91E-04	1.50E-02
Climate change - fossil	kg CO_2 eq	1.35E-02	6.58E-04	5.72E-04	1.48E-02
Climate change - biogenic	kg CO_2 eq	5.97E-05	1.62E-07	-1.22E-04	-6.18E-05
Climate change - land use and change in land use	kg CO_2 eq	2.87E-05	2.03E-07	5.85E-08	2.89E-05
Ozone Depletion	kg CFC-11 eq	1.71E-09	6.00E-11	3.93E-12	1.77E-09
Acidification	mol H^+ eq	8.05E-05	1.26E-05	2.66E-06	9.58E-05
Eutrophication of water	kg PO_4 eq	8.62E-06	2.06E-06	9.82E-08	1.08E-05
Photochemical ozone formation	kg NMVOC eq	5.58E-05	3.74E-06	1.60E-06	6.11E-05
Consumption of abiotic resources - minerals and materials	kg Sb eq	4.43E-07	4.38E-08	1.00E-10	4.87E-07
Consumption of abiotic resources - fossil resources	MJ, calculated using lower calorific values	1.70E-01	8.98E-03	4.50E-03	1.83E-01
Water consumption	m³ eq	1.01E-02	2.30E-04	5.83E-05	1.04E-02

Table 11. Life Cycle Impact Assessment Results- LR5-72HIBD(Vina)

Impact category	Unit	Upstream	Core stream	Downstream	Total
Climate change - total	kg CO_2 eq	1.65E-02	7.96E-04	8.34E-04	1.81E-02
Climate change - fossil	kg CO_2 eq	1.64E-02	7.95E-04	6.90E-04	1.78E-02

Climate change - biogenic	kg CO_2 eq	7.20E-05	1.95E-07	-1.47E-04	-7.46E-05
Climate change - land use and change in land use	kg CO_2 eq	3.46E-05	2.45E-07	7.06E-08	3.49E-05
Ozone Depletion	kg CFC-11 eq	2.06E-09	7.25E-11	4.75E-12	2.14E-09
Acidification	mol H^+ eq	9.72E-05	1.53E-05	3.22E-06	1.16E-04
Eutrophication of water	kg PO_4 eq	1.04E-05	2.49E-06	1.19E-07	1.30E-05
Photochemical ozone formation	kg NMVOC eq	6.73E-05	4.52E-06	1.93E-06	7.38E-05
Consumption of abiotic resources - minerals and materials	kg Sb eq	5.35E-07	5.28E-08	1.21E-10	5.88E-07
Consumption of abiotic resources - fossil resources	MJ, calculated using lower calorific values	2.05E-01	1.08E-02	5.44E-03	2.21E-01
Water consumption	m^3 eq	1.23E-02	2.78E-04	7.04E-05	1.26E-02

Table 12. Life Cycle Impact Assessment Results- LR5-72HIH(Vina)

Impact category	Unit	Upstream	Core stream	Downstream	Total
Climate change - total	kg CO_2 eq	1.37E-02	6.64E-04	6.96E-04	1.51E-02
Climate change - fossil	kg CO_2 eq	1.36E-02	6.63E-04	5.76E-04	1.49E-02
Climate change - biogenic	kg CO_2 eq	6.01E-05	1.63E-07	-1.23E-04	-6.22E-05
Climate change - land use and change in land use	kg CO_2 eq	2.89E-05	2.04E-07	5.89E-08	2.91E-05
Ozone Depletion	kg CFC-11 eq	1.72E-09	6.05E-11	3.96E-12	1.78E-09
Acidification	mol H^+ eq	8.11E-05	1.27E-05	2.68E-06	9.65E-05
Eutrophication of water	kg PO_4 eq	8.68E-06	2.08E-06	9.89E-08	1.09E-05
Photochemical ozone formation	kg NMVOC eq	5.62E-05	3.77E-06	1.61E-06	6.16E-05
Consumption of abiotic resources - minerals and materials	kg Sb eq	4.46E-07	4.41E-08	1.01E-10	4.90E-07
Consumption of abiotic resources - fossil resources	MJ, calculated using lower calorific values	1.71E-01	9.05E-03	4.54E-03	1.85E-01
Water consumption	m^3 eq	1.02E-02	2.32E-04	5.87E-05	1.05E-02

Table 13. Life Cycle Impact Assessment Results- LR5-54HPH(Vina)

Impact category	Unit	Upstream	Core stream	Downstream	Total
Climate change - total	kg CO_2 eq	1.37E-02	6.60E-04	6.92E-04	1.50E-02
Climate change - fossil	kg CO_2 eq	1.36E-02	6.60E-04	5.73E-04	1.48E-02
Climate change - biogenic	kg CO_2 eq	5.98E-05	1.62E-07	-1.22E-04	-6.19E-05
Climate change - land use and change in land use	kg CO_2 eq	2.87E-05	2.03E-07	5.86E-08	2.90E-05
Ozone Depletion	kg CFC-11 eq	1.71E-09	6.02E-11	3.94E-12	1.77E-09
Acidification	mol H^+ eq	8.07E-05	1.27E-05	2.67E-06	9.61E-05
Eutrophication of water	kg PO_4 eq	8.64E-06	2.07E-06	9.85E-08	1.08E-05
Photochemical ozone formation	kg NMVOC eq	5.59E-05	3.75E-06	1.60E-06	6.12E-05
Consumption of abiotic resources - minerals and materials	kg Sb eq	4.44E-07	4.39E-08	1.00E-10	4.88E-07
Consumption of abiotic resources - fossil resources	MJ, calculated using lower calorific values	1.70E-01	9.00E-03	4.52E-03	1.84E-01

Water consumption	m^3 eq	1.02E-02	2.31E-04	5.84E-05	1.05E-02

Table 14. Life Cycle Impact Assessment Results- LR5-54HIH(Vina)

Impact category	Unit	Upstream	Core stream	Downstream	Total
Climate change - total	kg CO_2 eq	1.38E-02	6.68E-04	7.01E-04	1.52E-02
Climate change - fossil	kg CO_2 eq	1.37E-02	6.68E-04	5.80E-04	1.50E-02
Climate change - biogenic	kg CO_2 eq	6.05E-05	1.64E-07	-1.23E-04	-6.27E-05
Climate change - land use and change in land use	kg CO_2 eq	2.91E-05	2.06E-07	5.93E-08	2.94E-05
Ozone Depletion	kg CFC-11 eq	1.73E-09	6.09E-11	3.99E-12	1.80E-09
Acidification	mol H^+ eq	8.17E-05	1.28E-05	2.70E-06	9.72E-05
Eutrophication of water	kg PO_4 eq	8.75E-06	2.09E-06	9.97E-08	1.09E-05
Photochemical ozone formation	kg NMVOC eq	5.66E-05	3.80E-06	1.62E-06	6.20E-05
Consumption of abiotic resources - minerals and materials	kg Sb eq	4.49E-07	4.44E-08	1.02E-10	4.94E-07
Consumption of abiotic resources - fossil resources	MJ, calculated using lower calorific values	1.72E-01	9.11E-03	4.57E-03	1.86E-01
Water consumption	m^3 eq	1.03E-02	2.34E-04	5.92E-05	1.06E-02

Table 15. Life Cycle Impact Assessment Results- LR5-54HIB(Vina)

Impact category	Unit	Upstream	Core stream	Downstream	Total
Climate change - total	kg CO_2 eq	1.40E-02	6.77E-04	7.09E-04	1.54E-02
Climate change - fossil	kg CO_2 eq	1.39E-02	6.76E-04	5.87E-04	1.52E-02
Climate change - biogenic	kg CO_2 eq	6.13E-05	1.66E-07	-1.25E-04	-6.35E-05
Climate change - land use and change in land use	kg CO_2 eq	2.94E-05	2.08E-07	6.01E-08	2.97E-05
Ozone Depletion	kg CFC-11 eq	1.75E-09	6.16E-11	4.04E-12	1.82E-09
Acidification	mol H^+ eq	8.27E-05	1.30E-05	2.74E-06	9.84E-05
Eutrophication of water	kg PO_4 eq	8.85E-06	2.12E-06	1.01E-07	1.11E-05
Photochemical ozone formation	kg NMVOC eq	5.73E-05	3.84E-06	1.64E-06	6.28E-05
Consumption of abiotic resources - minerals and materials	kg Sb eq	4.55E-07	4.49E-08	1.03E-10	5.00E-07
Consumption of abiotic resources - fossil resources	MJ, calculated using lower calorific values	1.74E-01	9.22E-03	4.63E-03	1.88E-01
Water consumption	m^3 eq	1.04E-02	2.37E-04	5.99E-05	1.07E-02

Table 16. TRACI Result- LR4-72HBD(Vina)

Impact category	Unit	Upstream	Core stream	Downstream	Total
Ozone depletion	kg CFC-11 eq	2.49E-09	8.01E-11	8.00E-12	2.58E-09
Global warming	kg CO2 eq	1.61E-02	7.87E-04	5.54E-04	1.75E-02
Smog	kg O3 eq	9.58E-04	7.64E-05	3.38E-05	1.07E-03
Acidification	kg SO2 eq	8.20E-05	1.22E-05	2.23E-06	9.65E-05
Eutrophication	kg N eq	8.52E-05	1.91E-05	1.11E-06	1.05E-04

Carcinogenics	CTUh	1.29E-09	1.78E-10	2.78E-11	1.50E-09
Non carcinogenics	CTUh	1.08E-08	4.67E-09	2.71E-10	1.57E-08
Respiratory effects	kg PM2.5 eq	2.25E-05	1.54E-06	3.82E-07	2.44E-05
Ecotoxicity	CTUe	2.32E-01	9.45E-01	1.90E-02	1.20E+00
Fossil fuel depletion	MJ surplus	1.46E-02	1.24E-03	9.11E-05	1.60E-02

Table 17. TRACI Result- LR5-72HBD(Vina)

Impact category	Unit	Upstream	Core stream	Downstream	Total
Ozone depletion	kg CFC-11 eq	2.44E-09	7.84E-11	7.83E-12	2.52E-09
Global warming	kg CO2 eq	1.58E-02	7.71E-04	5.42E-04	1.71E-02
Smog	kg O3 eq	9.37E-04	7.48E-05	3.31E-05	1.05E-03
Acidification	kg SO2 eq	8.03E-05	1.20E-05	2.18E-06	9.45E-05
Eutrophication	kg N eq	8.34E-05	1.87E-05	1.09E-06	1.03E-04
Carcinogenics	CTUh	1.26E-09	1.74E-10	2.72E-11	1.46E-09
Non carcinogenics	CTUh	1.06E-08	4.57E-09	2.65E-10	1.54E-08
Respiratory effects	kg PM2.5 eq	2.20E-05	1.50E-06	3.74E-07	2.39E-05
Ecotoxicity	CTUe	2.27E-01	9.25E-01	1.86E-02	1.17E+00
Fossil fuel depletion	MJ surplus	1.43E-02	1.22E-03	8.92E-05	1.56E-02

Table 18. TRACI Result- LR5-72HPH(Vina)

IMPACT CATEGORY	UNIT	UPSTREAM	CORE STREAM	DOWNSTREAM	TOTAL
Ozone depletion	kg CFC-11 eq	2.04E-09	6.55E-11	6.54E-12	2.11E-09
Global warming	kg CO2 eq	1.32E-02	6.44E-04	4.53E-04	1.43E-02
Smog	kg O3 eq	7.83E-04	6.25E-05	2.76E-05	8.74E-04
Acidification	kg SO2 eq	6.71E-05	1.00E-05	1.82E-06	7.90E-05
Eutrophication	kg N eq	6.97E-05	1.56E-05	9.08E-07	8.63E-05
Carcinogenics	CTUh	1.06E-09	1.45E-10	2.28E-11	1.22E-09
Non carcinogenics	CTUh	8.83E-09	3.82E-09	2.21E-10	1.29E-08
Respiratory effects	kg PM2.5 eq	1.84E-05	1.26E-06	3.12E-07	1.99E-05
Ecotoxicity	CTUe	1.90E-01	7.73E-01	1.55E-02	9.78E-01
Fossil fuel depletion	MJ surplus	1.20E-02	1.02E-03	7.46E-05	1.31E-02

Table 19. TRACI Result- LR5-72HIBD(Vina)

Impact category	Unit	Upstream	Core stream	Downstream	Total
Ozone depletion	kg CFC-11 eq	2.46E-09	7.91E-11	7.90E-12	2.55E-09
Global warming	kg CO2 eq	1.59E-02	7.78E-04	5.47E-04	1.73E-02
Smog	kg O3 eq	9.46E-04	7.55E-05	3.34E-05	1.05E-03

Acidification	kg SO2 eq	8.10E-05	1.21E-05	2.20E-06	9.53E-05
Eutrophication	kg N eq	8.42E-05	1.89E-05	1.10E-06	1.04E-04
Carcinogenics	CTUh	1.27E-09	1.76E-10	2.75E-11	1.48E-09
Non carcinogenics	CTUh	1.07E-08	4.61E-09	2.67E-10	1.55E-08
Respiratory effects	kg PM2.5 eq	2.22E-05	1.52E-06	3.77E-07	2.41E-05
Ecotoxicity	CTUe	2.29E-01	9.33E-01	1.88E-02	1.18E+00
Fossil fuel depletion	MJ surplus	1.44E-02	1.23E-03	9.00E-05	1.58E-02

Table 20. TRACI Result- LR5-72HIH(Vina)

Impact category	Unit	Upstream	Core stream	Downstream	Total
Ozone depletion	kg CFC-11 eq	2.05E-09	6.60E-11	6.59E-12	2.13E-09
Global warming	kg CO2 eq	1.33E-02	6.49E-04	4.57E-04	1.44E-02
Smog	kg O3 eq	7.89E-04	6.30E-05	2.79E-05	8.80E-04
Acidification	kg SO2 eq	6.76E-05	1.01E-05	1.84E-06	7.95E-05
Eutrophication	kg N eq	7.02E-05	1.58E-05	9.15E-07	8.69E-05
Carcinogenics	CTUh	1.06E-09	1.46E-10	2.29E-11	1.23E-09
Non carcinogenics	CTUh	8.90E-09	3.85E-09	2.23E-10	1.30E-08
Respiratory effects	kg PM2.5 eq	1.85E-05	1.27E-06	3.15E-07	2.01E-05
Ecotoxicity	CTUe	1.91E-01	7.79E-01	1.57E-02	9.86E-01
Fossil fuel depletion	MJ surplus	1.20E-02	1.03E-03	7.51E-05	1.31E-02

Table 21. TRACI Result- LR5-54HPH(Vina)

Impact category	Unit	Upstream	Core stream	Downstream	Total
Ozone depletion	kg CFC-11 eq	2.04E-09	6.57E-11	6.56E-12	2.12E-09
Global warming	kg CO2 eq	1.32E-02	6.46E-04	4.54E-04	1.43E-02
Smog	kg O3 eq	7.85E-04	6.27E-05	2.77E-05	8.76E-04
Acidification	kg SO2 eq	6.73E-05	1.00E-05	1.83E-06	7.91E-05
Eutrophication	kg N eq	6.99E-05	1.57E-05	9.11E-07	8.65E-05
Carcinogenics	CTUh	1.06E-09	1.46E-10	2.28E-11	1.23E-09
Non carcinogenics	CTUh	8.85E-09	3.83E-09	2.22E-10	1.29E-08
Respiratory effects	kg PM2.5 eq	1.84E-05	1.26E-06	3.13E-07	2.00E-05
Ecotoxicity	CTUe	1.91E-01	7.75E-01	1.56E-02	9.81E-01
Fossil fuel depletion	MJ surplus	1.20E-02	1.02E-03	7.48E-05	1.31E-02

Table 22. TRACI Result- LR5-54HIH(Vina)

Impact category	Unit	Upstream	Core stream	Downstream	Total
Ozone depletion	kg CFC-11 eq	2.07E-09	6.65E-11	6.64E-12	2.14E-09

Global warming	kg CO2 eq	1.34E-02	6.54E-04	4.60E-04	1.45E-02
Smog	kg O3 eq	7.95E-04	6.35E-05	2.81E-05	8.86E-04
Acidification	kg SO2 eq	6.81E-05	1.02E-05	1.85E-06	8.01E-05
Eutrophication	kg N eq	7.08E-05	1.59E-05	9.22E-07	8.75E-05
Carcinogenics	CTUh	1.07E-09	1.48E-10	2.31E-11	1.24E-09
Non carcinogenics	CTUh	8.96E-09	3.87E-09	2.25E-10	1.31E-08
Respiratory effects	kg PM2.5 eq	1.86E-05	1.28E-06	3.17E-07	2.02E-05
Ecotoxicity	CTUe	1.93E-01	7.84E-01	1.58E-02	9.93E-01
Fossil fuel depletion	MJ surplus	1.21E-02	1.03E-03	7.57E-05	1.32E-02

Table 23. TRACI Result- LR5-54HIB(Vina)

IMPACT CATEGORY	UNIT	UPSTREAM	CORE STREAM	DOWNSTREAM	TOTAL
Ozone depletion	kg CFC-11 eq	2.09E-09	6.73E-11	6.72E-12	2.17E-09
Global warming	kg CO2 eq	1.36E-02	6.62E-04	4.66E-04	1.47E-02
Smog	kg O3 eq	8.05E-04	6.42E-05	2.84E-05	8.97E-04
Acidification	kg SO2 eq	6.89E-05	1.03E-05	1.87E-06	8.11E-05
Eutrophication	kg N eq	7.16E-05	1.61E-05	9.33E-07	8.86E-05
Carcinogenics	CTUh	1.08E-09	1.49E-10	2.34E-11	1.26E-09
Non carcinogenics	CTUh	9.07E-09	3.92E-09	2.27E-10	1.32E-08
Respiratory effects	kg PM2.5 eq	1.89E-05	1.29E-06	3.21E-07	2.05E-05
Ecotoxicity	CTUe	1.95E-01	7.94E-01	1.60E-02	1.01E+00
Fossil fuel depletion	MJ surplus	1.23E-02	1.05E-03	7.66E-05	1.34E-02

4.2. Resource Consumption and Waste Generation Results

The resource consumption and waste generation results are demonstrated in tables below.

Table 24. Resource Use- LR4-72HBD(Vina)

PARAMETER	UNIT	UPSTREAM	CORE STREAM	DOWNSTREAM	TOTAL
PENRE: Non-renewable primary resources used as an energy carrier (fuel)	MJ	2.08E-01	1.10E-02	5.51E-03	2.24E-01
PERE:Renewable primary energy used as energy carrier (fuel)	MJ	3.95E-02	1.47E-03	5.32E-04	4.15E-02
PENRM:Non-renewable primary resources with energy content used as material	MJ	2.46E-02	0.00E+00	0.00E+00	2.46E-02
PERM:Renewable primary resources with energy content used as material	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PENRT:Total use of non-renewable primary energy resources	MJ	2.32E-01	1.10E-02	3.82E-03	2.32E-01
PERT:Total use of renewable primary energy resources	MJ	3.95E-02	1.47E-03	3.68E-04	3.76E-02
FW:Use of net fresh water	m3	4.36E-06	2.08E-07	6.31E-09	4.57E-06

MS: Use of secondary raw materials	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RSF:Use of renewable secondary fuels	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NRSF:Use of none renewable secondary fuels	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 25. Output Flows and Waste Categories- LR4-72HBD(Vina)

PARAMETER	UNIT	UPSTREAM	CORE STREAM	DOWNSTREAM	TOTAL
HWD:Hazardous waste disposed	kg	4.66E-06	4.39E-07	7.19E-09	5.11E-06
NHWD:Non-hazardous waste disposed	kg	1.37E-03	3.99E-04	8.98E-05	1.86E-03
RWD:Radioactive waste disposed	kg	5.78E-07	3.13E-08	2.70E-09	6.12E-07
MRF:Materials for recycling	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CRU:Components for re-use	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETE: Exported thermal energy	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EEE: Exported electricity energy	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 26. Resource Use- LR5-72HBD(Vina)

PARAMETER	UNIT	UPSTREAM	CORE STREAM	DOWNSTREAM	TOTAL
PENRE: Non-renewable primary resources used as an energy carrier (fuel)	MJ	2.03E-01	1.07E-02	5.39E-03	2.19E-01
PERE:Renewable primary energy used as energy carrier (fuel)	MJ	3.87E-02	1.44E-03	5.21E-04	4.06E-02
PENRM:Non-renewable primary resources with energy content used as material	MJ	2.41E-02	0.00E+00	0.00E+00	2.41E-02
PERM:Renewable primary resources with energy content used as material	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PENRT:Total use of non-renewable primary energy resources	MJ	2.27E-01	1.07E-02	3.74E-03	2.27E-01
PERT:Total use of renewable primary energy resources	MJ	3.87E-02	1.44E-03	3.60E-04	3.68E-02
FW:Use of net fresh water	m3	4.26E-06	2.03E-07	6.18E-09	4.47E-06
MS: Use of secondary raw materials	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RSF:Use of renewable secondary fuels	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NRSF:Use of none renewable secondary fuels	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 27. Output Flows and Waste Categories- LR5-72HBD(Vina)

PARAMETER	UNIT	UPSTREAM	CORE STREAM	DOWNSTREAM	TOTAL
HWD:Hazardous waste disposed	kg	4.56E-06	4.30E-07	7.04E-09	5.00E-06
NHWD:Non-hazardous waste disposed	kg	1.35E-03	3.90E-04	8.79E-05	1.82E-03
RWD:Radioactive waste disposed	kg	5.65E-07	3.06E-08	2.65E-09	5.99E-07
MRF:Materials for recycling	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CRU:Components for re-use	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETE: Exported thermal energy	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EEE: Exported electricity energy	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 28. Resource Use- LR5-72HPH(Vina)

PARAMETER	UNIT	UPSTREAM	CORE STREAM	DOWNSTREAM	TOTAL
PENRE: Non-renewable primary resources used as an energy carrier (fuel)	MJ	1.70E-01	8.98E-03	4.50E-03	1.83E-01
PERE:Renewable primary energy used as energy carrier (fuel)	MJ	3.23E-02	1.20E-03	4.36E-04	3.40E-02
PENRM:Non-renewable primary resources with energy content used as material	MJ	2.02E-02	0.00E+00	0.00E+00	2.02E-02
PERM:Renewable primary resources with energy content used as material	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PENRT:Total use of non-renewable primary energy resources	MJ	1.90E-01	8.98E-03	3.12E-03	1.90E-01
PERT:Total use of renewable primary energy resources	MJ	3.23E-02	1.20E-03	3.01E-04	3.08E-02
FW:Use of net fresh water	m3	3.56E-06	1.70E-07	5.17E-09	3.74E-06
MS: Use of secondary raw materials	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RSF:Use of renewable secondary fuels	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NRSF:Use of none renewable secondary fuels	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 29. Output Flows and Waste Categories- LR5-72HPH(Vina)

PARAMETER	UNIT	UPSTREAM	CORE STREAM	DOWNSTREAM	TOTAL
HWD:Hazardous waste disposed	kg	3.81E-06	3.59E-07	5.88E-09	4.18E-06
NHWD:Non-hazardous waste disposed	kg	1.12E-03	3.26E-04	7.35E-05	1.52E-03
RWD:Radioactive waste disposed	kg	4.73E-07	2.56E-08	2.21E-09	5.00E-07
MRF:Materials for recycling	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CRU:Components for re-use	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETE: Exported thermal energy	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EEE: Exported electricity energy	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 30. Resource Use- LR5-72HIBD(Vina)

PARAMETER	UNIT	UPSTREAM	CORE STREAM	DOWNSTREAM	TOTAL
PENRE: Non-renewable primary resources used as an energy carrier (fuel)	MJ	2.05E-01	1.08E-02	5.44E-03	2.21E-01
PERE:Renewable primary energy used as energy carrier (fuel)	MJ	3.90E-02	1.45E-03	5.26E-04	4.10E-02
PENRM:Non-renewable primary resources with energy content used as material	MJ	2.43E-02	0.00E+00	0.00E+00	2.43E-02
PERM:Renewable primary resources with energy content used as material	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PENRT:Total use of non-renewable primary energy resources	MJ	2.29E-01	1.08E-02	3.77E-03	2.29E-01
PERT:Total use of renewable primary energy resources	MJ	3.90E-02	1.45E-03	3.63E-04	3.72E-02
FW:Use of net fresh water	m3	4.30E-06	2.05E-07	6.24E-09	4.51E-06
MS: Use of secondary raw materials	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RSF:Use of renewable secondary fuels	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NRSF:Use of none renewable secondary fuels	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 31. Output Flows and Waste

PARAMETER	UNIT	UPSTREAM	CORE STREAM	DOWNSTREAM	TOTAL

HWD:Hazardous waste disposed	kg	4.60E-06	4.34E-07	7.10E-09	5.05E-06
NHWD:Non-hazardous waste disposed	kg	1.36E-03	3.94E-04	8.87E-05	1.84E-03
RWD:Radioactive waste disposed	kg	5.71E-07	3.09E-08	2.67E-09	6.04E-07
MRF:Materials for recycling	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CRU:Components for re-use	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETE: Exported thermal energy	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EEE: Exported electricity energy	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 32. Resource Use- LR5-72HIH(Vina)

PARAMETER	UNIT	UPSTREAM	CORE STREAM	DOWNSTREAM	TOTAL
PENRE: Non-renewable primary resources used as an energy carrier (fuel)	MJ	1.71E-01	9.05E-03	4.54E-03	1.85E-01
PERE:Renewable primary energy used as energy carrier (fuel)	MJ	3.26E-02	1.21E-03	4.39E-04	3.42E-02
PENRM:Non-renewable primary resources with energy content used as material	MJ	2.03E-02	0.00E+00	0.00E+00	2.03E-02
PERM:Renewable primary resources with energy content used as material	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PENRT:Total use of non-renewable primary energy resources	MJ	1.91E-01	9.05E-03	3.15E-03	1.91E-01
PERT:Total use of renewable primary energy resources	MJ	3.26E-02	1.21E-03	3.03E-04	3.10E-02
FW:Use of net fresh water	m3	3.59E-06	1.71E-07	5.20E-09	3.77E-06
MS: Use of secondary raw materials	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RSF:Use of renewable secondary fuels	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NRSF:Use of none renewable secondary fuels	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 33. Output Flows and Waste Categories- LR5-72HIH(Vina)

PARAMETER	UNIT	UPSTREAM	CORE STREAM	DOWNSTREAM	TOTAL
HWD:Hazardous waste disposed	kg	3.84E-06	3.62E-07	5.93E-09	4.21E-06
NHWD:Non-hazardous waste disposed	kg	1.13E-03	3.29E-04	7.40E-05	1.54E-03
RWD:Radioactive waste disposed	kg	4.76E-07	2.58E-08	2.23E-09	5.04E-07
MRF:Materials for recycling	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CRU:Components for re-use	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETE: Exported thermal energy	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EEE: Exported electricity energy	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 34. Resource Use- LR5-54HPH(Vina)

PARAMETER	UNIT	UPSTREAM	CORE STREAM	DOWNSTREAM	TOTAL
PENRE: Non-renewable primary resources used as an energy carrier (fuel)	MJ	1.70E-01	9.00E-03	4.52E-03	1.84E-01
PERE:Renewable primary energy used as energy carrier (fuel)	MJ	3.24E-02	1.21E-03	4.37E-04	3.40E-02
PENRM:Non-renewable primary resources with energy content used as material	MJ	2.02E-02	0.00E+00	0.00E+00	2.02E-02
PERM:Renewable primary resources with energy content used as material	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00

PENRT:Total use of non-renewable primary energy resources	MJ	1.90E-01	9.00E-03	3.13E-03	1.90E-01
PERT:Total use of renewable primary energy resources	MJ	3.24E-02	1.21E-03	3.02E-04	3.09E-02
FW:Use of net fresh water	m3	3.57E-06	1.70E-07	5.18E-09	3.75E-06
MS: Use of secondary raw materials	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RSF:Use of renewable secondary fuels	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NRSF:Use of none renewable secondary fuels	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 35. Output Flows and Waste Categories- LR5-54HPH(Vina)

Parameter	Unit	Upstream	Core stream	Downstream	Total
HWD:Hazardous waste disposed	kg	3.82E-06	3.60E-07	5.90E-09	4.19E-06
NHWD:Non-hazardous waste disposed	kg	1.13E-03	3.27E-04	7.36E-05	1.53E-03
RWD:Radioactive waste disposed	kg	4.74E-07	2.57E-08	2.22E-09	5.02E-07
MRF:Materials for recycling	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CRU:Components for re-use	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETE: Exported thermal energy	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EEE: Exported electricity energy	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 36. Resource Use- LR5-54HIH(Vina)

Parameter	Unit	Upstream	Core stream	Downstream	Total
PENRE: Non-renewable primary resources used as an energy carrier (fuel)	MJ	1.72E-01	9.11E-03	4.57E-03	1.86E-01
PERE:Renewable primary energy used as energy carrier (fuel)	MJ	3.28E-02	1.22E-03	4.42E-04	3.45E-02
PENRM:Non-renewable primary resources with energy content used as material	MJ	2.04E-02	0.00E+00	0.00E+00	2.04E-02
PERM:Renewable primary resources with energy content used as material	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PENRT:Total use of non-renewable primary energy resources	MJ	1.93E-01	9.11E-03	3.17E-03	1.93E-01
PERT:Total use of renewable primary energy resources	MJ	3.28E-02	1.22E-03	3.05E-04	3.12E-02
FW:Use of net fresh water	m3	3.62E-06	1.72E-07	5.24E-09	3.79E-06
MS: Use of secondary raw materials	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RSF:Use of renewable secondary fuels	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NRSF:Use of none renewable secondary fuels	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 37. Output Flows and Waste Categories- LR5-54HIH(Vina)

Parameter	Unit	Upstream	Core stream	Downstream	Total
HWD:Hazardous waste disposed	kg	3.87E-06	3.65E-07	5.97E-09	4.24E-06
NHWD:Non-hazardous waste disposed	kg	1.14E-03	3.31E-04	7.45E-05	1.55E-03
RWD:Radioactive waste disposed	kg	4.79E-07	2.60E-08	2.24E-09	5.08E-07
MRF:Materials for recycling	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CRU:Components for re-use	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETE: Exported thermal energy	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EEE: Exported electricity energy	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 38. Resource Use- LR5-54HIB(Vina)

PARAMETER	UNIT	UPSTREAM	CORE STREAM	DOWNSTREAM	TOTAL
PENRE: Non-renewable primary resources used as an energy carrier (fuel)	MJ	1.74E-01	9.22E-03	4.63E-03	1.88E-01
PERE:Renewable primary energy used as energy carrier (fuel)	MJ	3.32E-02	1.24E-03	4.47E-04	3.49E-02
PENRM:Non-renewable primary resources with energy content used as material	MJ	2.07E-02	0.00E+00	0.00E+00	2.07E-02
PERM:Renewable primary resources with energy content used as material	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PENRT:Total use of non-renewable primary energy resources	MJ	1.95E-01	9.22E-03	3.21E-03	1.95E-01
PERT:Total use of renewable primary energy resources	MJ	3.32E-02	1.24E-03	3.09E-04	3.16E-02
FW:Use of net fresh water	m3	3.66E-06	1.74E-07	5.31E-09	3.84E-06
MS: Use of secondary raw materials	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RSF:Use of renewable secondary fuels	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NRSF:Use of none renewable secondary fuels	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 39. Output Flows and Waste Categories- LR5-54HIB(Vina)

PARAMETER	UNIT	UPSTREAM	CORE STREAM	DOWNSTREAM	TOTAL
HWD: Hazardous waste disposed	kg	3.92E-06	3.69E-07	6.04E-09	4.29E-06
NHWD: Non-hazardous waste disposed	kg	1.16E-03	3.35E-04	7.55E-05	1.57E-03
RWD: Radioactive waste disposed	kg	4.85E-07	2.63E-08	2.27E-09	5.14E-07
MRF: Materials for recycling	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CRU: Components for re-use	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETE: Exported thermal energy	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EEE: Exported electricity energy	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00

5. LCA Interpretation

The interpretation phase conforms to ISO 14044 with further guidance from the ILCD General Guide for Life Cycle Assessment. The interpretation included the use of evaluation and sensitivity checks to steer the iterative process during the assessment, and a final evaluationat the end of the study.

The contribution analysis of the PV module products on various impact categories reveals that core stream contributes more than 70% of the environmental impact in the life cycle of photovoltaic power generation. PV module including raw components production stage(A1,A3), and PV plant construction stage(A5) are the main contributions to environmental impact categories.

In terms of production stage, material consumption for ingot, wafer, cell and PV module and supply of solar glass are key impact components, and for the PV plant construction stage, cable and bracket used for PV plant infrastructure are the two key impact components. This also brings us enlightenment about the necessity of building production bases near photovoltaic parks.

From the above conclusions, it can be seen that PV module including raw components production stage(A1,A3), and PV plant construction stage(A5) have the greatest impact on the environment during the entire life cycle. Therefore, it is recommended to start from the above stages to reduce the impact of products on the environment. (1) For A1 and A3 stage, reduce the waste of raw materials, optimize the industrial structure, and select raw materials with less impact on the environment. (2) For A5 stage, choose building materials with less environmental impact.

The LCA study has been carried out based on available information, regional and global database and experience to achieve more accuracy, completeness and representative of the results.The production stage data in this study are derived from the most recent ERP data, and due to the allocation principle, the LCA results can represent the company's average level of similar products.

Since wood and cardboard are all recycled, some sequestration occurs for the duration of the 100-year time frame of the Climate change - biogenic impact category, resulting in biomass carbon being a negative impact.

The wastewater generated from the used water is divided into two parts, one part needs to be discharged after WWT wastewater treatment, and the other part is directly discharged into the municipal wastewater system,therefore this part is not included in the inventory.

Most of the gases used in the processing of all products are directly released (such as: oxygen and nitrogen, etc.), so these are not included in the inventory, and the rest are recycled. In addition, most of the chemical reagents are discharged into the wastewater after use, and then discharged after being treated by the wastewater treatment system, which is the main reason for the quatity imbalance.

6. Additional Environmental Information

6.1. Additional Environmental Indicators

An additional indicator is the Return On Energy (RoE). This parameter gives an estimate of the efficiency of the photovoltaic park's solar energy production. The results are shown on Table 46.

The calculation of RoE is done using the following formula:

$$RoE[years] = \frac{E_{invested}}{E_{product,annual}}$$

Where: $E_{invested} = PENRT + PERT$, $E_{product,annual}$= total amount of electricity generated in a year by the solar Park.

Table 46. RoE results of LONGi Solar PV modules

MODULE	LR4-72HBD (VINA)	LR5-72HBD (VINA)	LR5-72HPH (VINA)	LR5-72HIBD (VINA)	LR5-72HIH (VINA)	LR5-54HPH (VINA)	LR5-54HIH (VINA)	LR5-54HIB (VINA)
RoE	2.25E+00	2.20E+00	1.84E+00	2.22E+00	1.85E+00	1.84E+00	1.87E+00	1.89E+00

In order to report the environmental impacts generated by the product during its life cycle in the declared unit, the total energy produced by the plant during the reference service life needs to be calculated. The total energy produced by the plant will therefore be equal to:

Etot [kWh] = Eyear * RSL

Where:

- Etot represents the total energy produced by the plant (or, in an extreme case, by the individual module) during its entire life cycle;

- Eyear represents the energy produced annually by the plant.

- RSL represents the reference service life of the module or plant. In order to ensure that EPDs based on this PCR can be compared, a constant fixed reference service life of 30 years is assumed.

The The assumption of system loss is detailed in 1.6. The loss is 20% and use to estimate Eyear.

Table 47. RoE results of LONGi Solar PV modules

MODULE	LR4-72HBD (VINA)	LR5-72HBD (VINA)	LR5-72HPH (VINA)	LR5-72HIBD (VINA)	LR5-72HIH (VINA)	LR5-54HPH (VINA)	LR5-54HIH (VINA)	LR5-54HIB (VINA)
Etot(kWh)	3.80E+09	3.80E+09	3.80E+09	3.80E+09	3.80E+09	3.80E+09	3.80E+09	3.80E+09

6.2. Environmental Activities and Certifications

Clean Solar Energy

LONGi Solar is committed to continuously exploring and applying technologies that increase PV product efficiency and help reduce CO_2 emissions. We strive to use the clean solar energy to promote energy transformation. We are committed to systematically addressing the issues of economic development, environmental protection and energy security and providing the clean solar energy to the public. We not only conduct our operation in a responsible manner, but also contribute to meet the rising demand for clean energy by establishing Product Stewardship Policy, technological innovations, efficiency improvement, so as to actively respond to global climate change.

Sustainable Use of Water Resource

LONGi Solar regards protecting water resource as one of its important tasks, and strives to reduce the consumption of water resource per MW module production through sustainable use of water resource. Solar module production consumes a lot of water. To carry out water conservation management, we setup water saving goals for each workshops and implemented various of water saving projects, such as reuse of RO (Reverse Osmosis) rejected water, treat and reuse of wastewater, collection of condensate water from air conditioning system etc. We setup a strict maintenance scheme to clean RO membrane to increase DI(De-ionized) water yield. With business expanding, total amount of water consumption is in increasing trend. But as we continue to develop and implement water conservation projects, our water use efficiency continues to increase.

Certifications

Plants of LONGi Solar comply with the following standards:

- ISO 9001-Quality Management System
- ISO 14001- Environmental Management System
- ISO 50001- Energy Management System
- ISO14064 - Organization Level for Quantification and Reporting of Greenhouse Gas Emission and Removals - ISO45001: Occupational Health and Safety Management System

7. Supporting Documentation

Additional information about LONGi Solar's products can be found on the website: https://www.longi.com

8. References

PCR EPDItaly014: Electricity Produced by Photovoltaic Modules.

PCR EPDItaly007: Electronic and Electrical Products and Systems.

EN 15804:2012+A2:2019, Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products.

ISO 14040: 2006 Environmental Management – Life cycle assessment – Principles and Framework.

ISO 14044: 2006 Environmental Management – Life cycle assessment – Requirements and Guidelines.

ISO 14025: ISO14025:2011-10, Environmental labels and declarations - Type III environmental declarations - Principles and procedures.

www.polywater.com: Water Consumption in PV Panel Cleaning.

LCA Report - LCA Report for photovoltaic modules (LR4-72HBD(Vina), LR5-72HBD(Vina), LR5-72HPH(Vina), LR5-72HIBD(Vina), LR5-72HIH(Vina), LR5-54HPH(Vina), LR5-54HIH(Vina), LR5-54HIB(Vina)) by Maojun Zou, SRF testing and certification (Changzhou) Co., Ltd, July 15. 2022.

T/CESA 1074—2020 T/CPIA 0021—2022 Technical specification for green-design product assessment - photovoltaic silicon wafer.

9. Contact Information

9.1. EPD Owner

LONGi Green Energy Technology Co., Ltd.
EMAIL：market@longi.com
Website: https://www.longi.com

9.2. LCA practitioner

SRF testing and certification (Changzhou) Co., Ltd.
EMAIL：sales@srf-cn.com
Website: http://www.srf-cn.com