Jinko Solar Holding Co., Ltd

ENVIRONMENTAL PRODUCT DECLARATION

Product name:
Mono-crystalline silicon photovoltaic (PV) modules

Site Plants:
Shangrao, Jiangxi Province, China
Haining, Zhejiang Province, China

in compliance with ISO 14025

Program Operator	EPDITALY
Publisher	EPDITALY
Declaration Number	V. 1
Registration Number	EPDITALY0156
Issue Date	16/06/2021
Valid to	16/06/2026

1. GERNERAL INFORMATIONS

EPD OWNER:	Jinko Solar Holding Co., Ltd Add: 1 Jingke Road. Shangrao Economic Development Zone. Jiangxi Province, China
PRODUCT NAME:	Mono-crystalline silicon photovoltaic (PV) modules
PRODUCTION SITE:	Shangrao, Jiangxi Province, P.R.C. and Haining, Zhejiang Province, P.R.C.
FIELD OF APPLICATION:	Electricity generation
PROGRAM OPERATOR:	EPDITALY (www.epditaly.it) Add: via Gaetano De Castillia n° 10 - 20124 Milano, Italy
CPC CODE:	171 “Electrical energy”
COMPANY CONTACT:	Ms. Liu Lifang (llf@jinkosolar.com)
EXTERNAL AUDIT:	This declaration has been developed referring to EPDItaly, following the General Program Instruction; further information and the document itself are available at: www.epditaly.it. Independent verification of the declaration and data, according to EN ISO 14025:2010. ☐ INTERNAL ☒ EXTERNAL Third party verifier: Michele Paleari, ICMQ spa, Via Gaetano De Castillia, 10 202124 MILANO
LCA Consultant	This life cycle assessment was conducted in accordance with ISO 14044 and the reference PCR by: Ecovane Environmental Co., Ltd (www.ecovane.cc) TÜV Rheinland (China)（www.tuv.com）
PRODUCT CATEGORY RULES (PCR):	EPDItaly014: Core PCR for electricity produced by photovoltaic modules (March 2020, Revision REV.1)
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.
LIABILITY:	The owner of the declaration will be responsible for the information and supporting evidence. EPDItaly disclaims any liability regarding the manufacturer's information data.
REFERENCE DOCUMENT:	This declaration is based on the EPDItaly regulation, available on the website www.epditaly.com

2. COMPANY INTRODUCTION

Jinko Solar (NYSE: JKS) is one of the largest and most innovative solar module manufacturers in the world. Jinko Solar distributes its solar products and sells its solutions and services to a diversified international utility, commercial and residential customer. As an industry leader in module efficiency, yield, performance and reliability, Jinko Solar has built a vertically integrated solar product value chain, with an integrated annual capacity of 17.5 GW for mono wafers, 10.6 GW for solar cells, and 16 GW for solar modules, as of March 31, 2020.

JinkoSolar has 9 productions facilities globally, 14 overseas subsidiaries in Japan, South Korea, Vietnam, India, Turkey, Germany, Italy, Switzerland, United States, Mexico, Brazil, Chile and Australia, and global sales teams in China, United Kingdom, France, Spain, Bulgaria, Greece, Ukraine, Jordan, Saudi Arabia, Tunisia, Morocco, Kenya, South Africa, Costa Rica, Colombia, Panama, Kazakhstan, Malaysia, Myanmar, Sri Lanka, Thailand, Vietnam, Poland and Argentina.

3. SCOPE AND TYPE OF EPD

3.1 Scope of EPD

The entire life cycle stages of the product (type of EPD: « cradle-to-grave ») are considered in the LCA study, which include all stages from extraction of raw materials, manufacturing, transportation and installation, maintenance and end-of-life. Table 1 below shows the various stages that are included in this LCA study. The terms of defining life cycle stages from the core PCR, EN15804 and EN50693 are adopted and shown respectively.

Table 1 Life Cycle Stages

Life cycle stages according to EPDItaly PCR	*Life cycle stages according to EN50693*	-	Life cycle stages according to EN15804	
Upstream Module	*Manufacturing Stage*	X	A1	Raw material supply
		X	A2	Transport (to the manufacturer)
Core Module		X	A3	Manufacturing
	Distribution Stage	X	A4	Transport
	Installation Stage	X	A5	Construction – installation process
	Use Stage	X	B1	Use
		X	B2	Maintenance
		X	B3	Repair
		X	B4	Replacement
		X	B5	Refurbishment
		X	B6	Operational energy use
		X	B7	Operational water use
	De-installation Stage	X	C1	De-construction and demolition
Downstream Module	*End of Life Stage*	X	C2	Transport (to waste processing)
		X	C3	Waste processing
		X	C4	Disposal
		X		Voltage drop of electricity distribution to the grid
	Benefits and avoided loads beyond the product system boundary	MND	D	reuse, recovery and/or recycling potentials
Note: X=Declared Module, MND=Module not Declared in this LCA study				

3.2 Type of EPD

This EPD is a product-specific EPD. The declaration covers in total 5 series of PV modules, including JKMXXXM-72H-TV, JKMXXXM-72H-V, JKMXXXM-7RL3-V, JKMXXXM-7RL3-TV and JKMXXXM-78H-V.

3.3 Geographical Validity

The PV modules that are analyzed within this study are manufactured in two factories located in Shangrao, Jiangxi Province and Haining, Zhejiang Province. The reference market is "global".

3.4 Database used

In this study, generic data for materials, energy as well as waste disposal and transportation were taken from the LCI-database Ecoinvent 3.4 with adaptation of regional energy and material data by Ecovane.

3.5 Software

For the modeling and calculation, the LCA-software SimaPro 9.1 was used.

4. DETAILED PRODUCT DESCRIPTION

4.1 Description of the Product

Jinko Solar produces more than a dozen series of mono-crystalline silicon photovoltaic (PV) modules. Within this project, in total there are 5 series of PV modules that were analyzed, including JKMXXXM-72H-TV, JKMXXXM-72H-V, JKMXXXM-7RL3-V, JKMXXXM-7RL3-TV and JKMXXXM-78H-V.

The module series under analysis can generate maximum power output of up to 475Wp (brand model Tiger), and up to 23.7% module efficiency. All the high energy density modules use innovative multi-wire 9BB and TR tiling ribbon technology to reach significantly improved performance with conversion efficiency. In addition to their unparalleled power generation performance and outstanding output temperature coefficient, other advantages of the Tiger Pro module series include lower power attenuation rate (at 2% for the first year) and better open-circuit voltage.

4.2 Technical Data

Table 2 Technical Data

Series (brand name)	Dimensions (inch^3)	Module efficiency (%)	Power output range (W)
JKMXXXM-72H-TV (Swan)	79.96*39.69*1.18	21.8-22.5	385-395
JKMXXXM-72H-V (Cheetah)	79.06*39.45*1.18	22.4-22.7	395-400
JKMXXXM-7RL3-V (Tiger)	85.91*40.51*1.57	22.7-23.3	455-475
JKMXXXM-7RL3-TV (Tiger)	86.81*40.63*1.38	22.5-23.7	450-470
JKMXXXM-78H-V (Cheetah)	85.28*39.45*1.38	21.6-22.7	435-445

Note: H: half-cut series module, V: module with 1500V, TV: SWAN bifacial module

4.3 Material Composition

Table 3 Material Composition

Components	Main substance	CAS No. of main substance	Units	JKMxx xM-72H-V	JKMxxx M-72H-TV	JKMxxx M-7RL3-V	JKMxxx M-7RL3-TV	JKMxx xM-78H-V
Solar cell	Si	7440-21-3	pcs	72	72	78	78	78
Junction box	Cu	7440-50-8	kg	0.2107	0.2107	0.2107	0.2107	0.2107
Bus bar	Cu	7440-50-8	kg	0.1751	0.1706	0.1752	0.1752	0.2051
Aluminum Frame	Al	7429-90-5	kg	2.7368	2.84	2.92	2.96	2.954
Solar glass	$Na_2O{\cdot}nSiO_2$	1344-09-8;106985-35-7	kg	15.65	16.22	17.84	17.93	16.81
Back sheet	$(C_{10}H_8O_4)n$	25038-59-9	kg	0.8984	0.96	0.98	0.99	0.9654
EVA	$(C_2H_4)x.(C_4H_6O_2)y$	24937-78-8	kg	0.0045	0	2.545	2.545	1.9357
Silica gel	SiO_2	112926-00-8	kg	0.2507	0.2892	0.3372	0.3372	0.2892
Solder	Sn	7440-31-5	kg	0.002	0.002	0.002	0.002	0.002
POE	/	/	kg	0	0.8	0	0	0

4.4 Description of The Production Process

The solar module product under study includes five series models (see Table 2). All of the various models are manufactured following the same manufacturing processes.

A flowchart depicting the production process stages of Jinko Solar PV module products is shown in Figure 1 below. For simplification purpose, only main stages of manufacturing are presented, raw material, auxiliary processes considered in the LCA but not shown in the flow chart below include:

- Raw and auxiliary material production and transportation;
- Recycling of waste materials;
- Waste water and off-gas treatment;
- Water recycling and reuse system;
- Supply of natural gas/water/electricity.

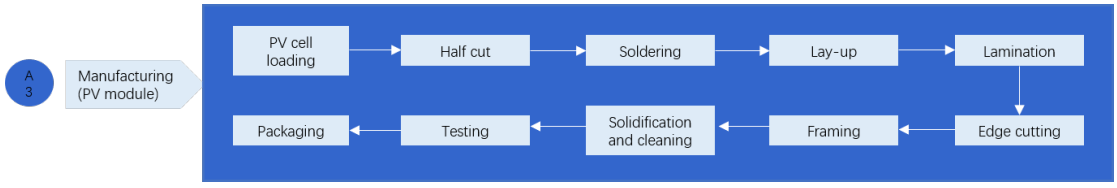

Figure 1 Production Process Flowchart of Jinko Solar PV module products

A brief introduction to the PV module manufacturing process is shown below:

Solar Cells Process

Step 1 Texturing: In this process, a mixture of acidic liquid is applied for silicon etching in order to fabricate a honeycombed surface texture. The texturing process aims to form a pyramid structure to increase the absorption of sunlight.

Step 2 Diffusion: In the diffusion process, $POCl_3$ (Phosphorus Oxychloride) is decomposed under high temperature and generates phosphorus. Then, the phosphorus diffuses on the P-type substrate to form a PN junction, which is solar cells core unit.

Step 3 Etching: In this process, a mixture of HF (Hydrofluoric Acid), HNO_3 (Nitric Acid) and H_2SO_4 (Sulfuric Acid) is applied to etch wafer edge.

Step 4 Thermal oxygen: Oxygen atoms combine with unsaturated silicon atoms on the silicon surface to form a SiO_2 film, thereby reducing the density of dangling bonds on the surface of the silicon wafer, well controlling interface traps and fixed charges, and serving to passivate the surface of the solar cell.

Step 5 PECVD (Plasma Enhanced Chemical Vapor Deposition): PECVD is a batch type reactor using parallel plate boats and low frequency plasma excitation. At low pressure and elevated temperature, a plasma burns directly between the substrates fixed at the plates of the boat. SiH_4 (silane)and NH_3 (ammonia) react to silicon nitride that is deposited on the substrate. The silicon nitride thin film is anti-reflective and serves as surface passivation. It also provides excellent chemical stability and isolation properties from metal ions and humidity.

Step 6 Laser grooving: Using laser grooving to form local back field contact, current collection.

Step 7 Screen printing: Using screen printing process, the corresponding metal electrodes are printed on the upper and lower surfaces of the fabricated p-n junction silicon wafer to collect and conduct the photocurrent generated by illumination.

Step 8 Sintering: Drying the paste on the silicon wafer, burning off the organic components of the paste, forming good ohmic contact between the paste and the silicon wafer, so as to improve the open circuit voltage and short circuit current and making it have strong adhesion and good solderability.

Step 9 Test sorting: Pick out the cells with bad appearance, and classify the cells with similar color together to make the final components have the same color and beautiful appearance.

PV module process

***Step 1 Half-cut*:** to improve the efficiency of the solar module, the loaded PV cell is cut half because the electrical resistance of half-sliced cell modules is smaller than that of uncut cell modules, the cell is cut in half by a spline-machine according to the technical requirements.

***Step 2 soldering*:** Welding machine is used to weld tin-plated belt on the main grid line using multi-point form. Welding heat source is generated from an infrared lamp powered by electricity.

Step 3 Lay-up for Lamination: Solar cell string, glass, EVA and backing (TPO, or POE…) are laid accordingly for preparation of lamination. A layer of primer is pasted on the glass to strengthen bonding strength. Solar cell string, glass and other materials are properly positioned to prepare for lamination process.

Step 4 Lamination: Solar string is laid into the laminating machine. The air between layers will be extracted out by vacuum process. A heating process is applied to melt EVA, cell string and backing so that they are bonded together.

Step 5 Framing: Aluminum frame is installed to the laminated piece to enhance the module strength and form a good sealing. The gap between aluminum frame and glass is filled with silicone glue. A horn button is used to connect frames. A junction box is welded on the back of solar module.

Step 6 High-pressure test: High-pressure test is conducted to test the pressure resistance and insulation strength of module. Standard IV test is also conducted to calibrate the power output rate of module.

Step 7 Packing: The tested modules will be packed into a carton, and put them on the wooden pallet, so that they are convenient for storage and shipment.

4.5 Transportation

In the LCA modelling, the transportation data was collected using the scenario that the PV modules are transported to a real ground-mounted PV plant in Shanxi Province.

4.6 Installation and operation

The materials used for PV plant construction are listed in Table 4. In terms of solar plant, the electricity generation data was taken from a real ground-mounted PV plant in Ruicheng, Shanxi Province, with energy yield capacity at 50MW.

Table 4 components for solar plant installation (per 50MWcapacity)

Components		**Unit**	**Value**
Module required per series	JKMxxxM-72H-V	pcs	1.25E+05
	JKMxxxM-72H-TV	pcs	1.27E+05
	JKMxxxM-7RL3-V	pcs	1.05E+05
	JKMxxxM-7RL3-TV	pcs	1.06E+05
	JKMxxxM-78H-V	pcs	1.12E+05
Inverter, 50kw		pcs	997
Bracket		ton	2806.7974
Cable, 1kv		km	675
Cable, 35kv		km	12
Compact sub-station		kg	149000
Steel		t	654.7
Concrete		m^3	5565.15
Transformer		kg	66260

Note: As for weight of cable, the mass is calculated with density 70kg/km for 1 kV cable, and 2000kg/km for 35kV cable. For concrete, the density is 2360kg/m3.

4.7 Reference Service Life

The reference service life for the PV modules is 30 years.

The total electricity generation from the plant to the grid during RSL is listed in Table 5. A 66.7 tonne booster station is used for the electricity transformation.

In this study, the distribution loss is 0.8% from the station to the grid, which is 21,648,000 kWh per year provided by Jinko Solar, and the electricity consumption for operation and maintenance is 721,600 kWh per year.

Table 5 Electricity generation during RSL

	Units	JKMxxxM-72H-V	JKMxxxM-72H-TV	JKMxxxM-7RL3-V	JKMxxxM-7RL3-TV	JKMxxxM-78H-V
Deg, first year	%	2.5	2.5	2	2	2.5
Deg, rest years	%	0.6	0.55	0.55	0.45	0.6
$E_{operation\ and\ maintenance}$	kWh	21,648,000.0	21,648,000.0	21,648,000.0	21,648,000.0	21,648,000.0
Distribution loss	%	0.8	0.8	0.8	0.8	0.8
$E_{RSL,net}$	kWh	1,702,490,657.5	1,713,881,097.2	1,722,453,201.7	1,745,659,779.1	1,702,490,657.5

4.8 End-of-life

For the end-of-life stage, De-construction (C1) of the PV plant during the disposal stage was assumed to consume mainly electricity, and the electricity consumption was assumed the same as the construction stage (A5). 100km transportation distance from plant site to waste treatment site (C2) was assumed. Electricity used for PV module demolition during waste processing (C3) stage was assumed the same as PV module manufacturing stage (A3). For end-of-life disposal treatment process (C4), the infrastructures of PV plants such as inverters were considered fully reused and following the end of life load and benefit allocation approach, therefore being cut off from the analysis. Since there was lack of existing data of recycling rate for PV module, this study referred 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 (20% landfill and 80% incineration).

5. LCA RESULTS

This LCA follows the requirements of PCR *EPDItaly014: Core-PCR for electricity produced by photovoltaic modules* and uses the recommended impact analysis method for the calculation. Environmental impact indicators follow the characterization factors as stated in EN 15804:2012+A2:2019.

Table 6. LCA Results- Environmental impacts for PV module JKMXXXM-72H-V

Impact Category	Unit	Upstream Module		Core Module												Downstream Module	
		A 1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4
		Raw material Supply	Raw material transportation	Manufacturing	Product transportation	Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-installation	Waste transportation	Waste treatment	Waste disposal
Climate change - Total	kg CO_2 eq.	4.29E-03	1.39E-04	2.25E-03	3.29E-04	3.12E-03	0.00E+00	0.00E+00	0.00E+00	3.72E-05	0.00E+00	0.00E+00	9.55E-08	2.40E-06	6.22E-05	5.90E-09	3.34E-06
Climate change - Fossil	kg CO_2 eq.	5.11E-03	1.39E-04	2.27E-03	3.29E-04	3.14E-03	0.00E+00	0.00E+00	0.00E+00	4.12E-05	0.00E+00	0.00E+00	9.45E-08	2.41E-06	6.23E-05	5.95E-09	3.27E-06
Climate change - Biogenic	kg CO_2 eq.	-8.20E-04	-1.15E-07	-1.76E-05	-2.73E-07	-2.79E-05	0.00E+00	0.00E+00	0.00E+00	-4.12E-06	0.00E+00	0.00E+00	1.02E-09	-1.86E-08	-5.17E-08	-4.58E-11	8.82E-09
Climate change - Land use and Land use change	kg CO_2 eq.	2.76E-06	2.71E-08	2.77E-08	6.40E-08	7.55E-06	0.00E+00	0.00E+00	0.00E+00	6.29E-08	0.00E+00	0.00E+00	1.63E-11	6.32E-11	1.21E-08	1.56E-13	6.48E-08
Ozone depletion	kg CFC-11 eq.	4.31E-10	2.67E-11	2.75E-11	6.32E-11	1.08E-09	0.00E+00	0.00E+00	0.00E+00	5.72E-12	0.00E+00	0.00E+00	7.44E-15	7.80E-15	1.20E-11	1.92E-17	1.69E-12
Acidification	moli di H+ eq.	5.00E-05	7.12E-07	1.24E-05	1.68E-06	7.46E-05	0.00E+00	0.00E+00	0.00E+00	4.59E-07	0.00E+00	0.00E+00	7.28E-10	1.40E-08	3.18E-07	3.46E-11	2.60E-08
Eutrophication	kg PO_4 eq.	1.66E-05	1.11E-07	1.51E-06	2.63E-07	4.06E-05	0.00E+00	0.00E+00	0.00E+00	1.81E-07	0.00E+00	0.00E+00	1.07E-10	1.65E-09	4.97E-08	4.07E-12	4.95E-09
Photochemical ozone formation	kg di NMVOC eq.	2.08E-05	7.66E-07	5.87E-06	1.81E-06	2.17E-05	0.00E+00	0.00E+00	0.00E+00	1.84E-07	0.00E+00	0.00E+00	3.26E-10	6.78E-09	3.43E-07	1.67E-11	2.25E-08
Depletion of abiotic resources – minerals and materials	kg Sb eq.	1.38E-05	9.60E-09	5.10E-09	2.27E-08	1.67E-06	0.00E+00	0.00E+00	0.00E+00	7.23E-08	0.00E+00	0.00E+00	2.54E-11	4.39E-12	4.30E-09	1.08E-14	4.79E-10
Resource use-fossil resources	MJ, net calorific value	5.10E-02	2.12E-03	1.99E-02	5.01E-03	4.71E-02	0.00E+00	0.00E+00	0.00E+00	4.75E-04	0.00E+00	0.00E+00	9.46E-07	1.83E-05	9.47E-04	4.50E-08	8.58E-05
Water resource depletion	m3 eq.	1.17E-04	2.87E-08	1.79E-06	6.78E-08	3.03E-06	0.00E+00	0.00E+00	0.00E+00	5.77E-07	0.00E+00	0.00E+00	1.65E-07	-3.24E-10	1.28E-08	-7.98E-13	1.37E-08

Table 7 LCA Results- Environmental impacts for PV module JKMxxxM-72H-TV

Impact Category	Unit	Upstream Module		Core Module											Downstream Module	
		A 1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4
		Raw material Supply	Raw material transportation	Manufacturing	Product transportation	Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-installation	Waste transportation	Waste treatment	Waste disposal
Climate change - Total	kg CO_2 eq.	4.55E-03	1.48E-04	2.26E-03	3.35E-04	3.10E-03	0.00E+00	0.00E+00	0.00E+00	3.81E-05	0.00E+00	0.00E+00	9.61E-08	2.38E-06	6.25E-05	5.87E-09	3.48E-06
Climate change - Fossil	kg CO_2 eq.	5.33E-03	1.48E-04	2.28E-03	3.36E-04	3.12E-03	0.00E+00	0.00E+00	0.00E+00	4.19E-05	0.00E+00	0.00E+00	9.51E-08	2.40E-06	6.25E-05	5.91E-09	3.40E-06
Climate change - Biogenic	kg CO_2 eq.	-7.79E-04	-1.23E-07	-1.77E-05	-2.78E-07	-2.77E-05	0.00E+00	0.00E+00	0.00E+00	-3.87E-06	0.00E+00	0.00E+00	1.03E-09	-1.85E-08	-5.19E-08	-4.55E-11	9.20E-09
Climate change - Land use and Land use change	kg CO_2 eq.	2.85E-06	2.87E-08	2.78E-08	6.52E-08	7.50E-06	0.00E+00	0.00E+00	0.00E+00	6.29E-08	0.00E+00	0.00E+00	1.64E-11	6.27E-11	1.22E-08	1.55E-13	6.75E-08
Ozone depletion	kg CFC-11 eq.	4.40E-10	2.84E-11	2.77E-11	6.44E-11	1.07E-09	0.00E+00	0.00E+00	0.00E+00	5.73E-12	0.00E+00	0.00E+00	7.49E-15	7.75E-15	1.20E-11	1.91E-17	1.76E-12
Acidification	moli di H+ eq.	5.12E-05	7.56E-07	1.24E-05	1.72E-06	7.42E-05	0.00E+00	0.00E+00	0.00E+00	4.61E-07	0.00E+00	0.00E+00	7.32E-10	1.39E-08	3.20E-07	3.43E-11	2.71E-08
Eutrophication	kg PO_4 eq.	1.67E-05	1.18E-07	1.52E-06	2.68E-07	4.03E-05	0.00E+00	0.00E+00	0.00E+00	1.80E-07	0.00E+00	0.00E+00	1.08E-10	1.64E-09	4.99E-08	4.04E-12	5.16E-09
Photochemical ozone formation	kg di NMVOC eq.	2.18E-05	8.14E-07	5.90E-06	1.85E-06	2.15E-05	0.00E+00	0.00E+00	0.00E+00	1.87E-07	0.00E+00	0.00E+00	3.27E-10	6.74E-09	3.44E-07	1.66E-11	2.34E-08
Depletion of abiotic resources – minerals and materials	kg Sb eq.	1.43E-05	1.02E-08	5.13E-09	2.31E-08	1.66E-06	0.00E+00	0.00E+00	0.00E+00	7.38E-08	0.00E+00	0.00E+00	2.55E-11	4.36E-12	4.31E-09	1.08E-14	4.99E-10
Resource use-fossil resources	MJ, net calorific value	5.64E-02	2.25E-03	2.00E-02	5.10E-03	4.68E-02	0.00E+00	0.00E+00	0.00E+00	4.97E-04	0.00E+00	0.00E+00	9.52E-07	1.81E-05	9.51E-04	4.47E-08	8.95E-05
Water resource depletion	m3 eq.	1.18E-04	3.04E-08	1.80E-06	6.91E-08	3.01E-06	0.00E+00	0.00E+00	0.00E+00	5.75E-07	0.00E+00	0.00E+00	1.66E-07	-3.22E-10	1.29E-08	-7.93E-13	1.42E-08

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Table 8 LCA Results- Environmental impacts for PV module JKMxxxM-7RL3-V

Impact Category	Unit	Upstream Module		Core Module											Downstream Module	
		A 1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4
		Raw material Supply	Raw material transportation	Manufacturing	Product transportation	Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-installation	Waste transportation	Waste treatment	Waste disposal
Climate change - Total	kg CO_2 eq.	4.28E-03	1.37E-04	2.00E-03	3.11E-04	3.08E-03	0.00E+00	0.00E+00	0.00E+00	4.14E-05	0.00E+00	0.00E+00	7.95E-08	2.37E-06	6.04E-05	5.84E-09	3.17E-06
Climate change - Fossil	kg CO_2 eq.	5.00E-03	1.37E-04	2.02E-03	3.11E-04	3.10E-03	0.00E+00	0.00E+00	0.00E+00	4.56E-05	0.00E+00	0.00E+00	7.87E-08	2.39E-06	6.05E-05	5.88E-09	3.10E-06
Climate change - Biogenic	kg CO_2 eq.	-7.18E-04	-1.14E-07	-1.57E-05	-2.58E-07	-2.76E-05	0.00E+00	0.00E+00	0.00E+00	-4.28E-06	0.00E+00	0.00E+00	8.51E-10	-1.84E-08	-5.02E-08	-4.53E-11	8.37E-09
Climate change - Land use and Land use change	kg CO_2 eq.	2.45E-06	2.67E-08	2.46E-08	6.05E-08	7.46E-06	0.00E+00	0.00E+00	0.00E+00	6.32E-08	0.00E+00	0.00E+00	1.36E-11	6.24E-11	1.18E-08	1.54E-13	6.15E-08
Ozone depletion	kg CFC-11 eq.	4.05E-10	2.63E-11	2.44E-11	5.98E-11	1.07E-09	0.00E+00	0.00E+00	0.00E+00	5.99E-12	0.00E+00	0.00E+00	6.20E-15	7.71E-15	1.16E-11	1.90E-17	1.60E-12
Acidification	moli di H+ eq.	4.62E-05	7.01E-07	1.10E-05	1.59E-06	7.38E-05	0.00E+00	0.00E+00	0.00E+00	4.83E-07	0.00E+00	0.00E+00	6.06E-10	1.39E-08	3.09E-07	3.42E-11	2.47E-08
Eutrophication	kg PO_4 eq.	1.48E-05	1.10E-07	1.34E-06	2.49E-07	4.01E-05	0.00E+00	0.00E+00	0.00E+00	1.85E-07	0.00E+00	0.00E+00	8.92E-11	1.63E-09	4.83E-08	4.02E-12	4.70E-09
Photochemical ozone formation	kg di NMVOC eq.	2.01E-05	7.55E-07	5.21E-06	1.71E-06	2.14E-05	0.00E+00	0.00E+00	0.00E+00	2.00E-07	0.00E+00	0.00E+00	2.71E-10	6.70E-09	3.33E-07	1.65E-11	2.13E-08
Depletion of abiotic resources – minerals and materials	kg Sb eq.	1.24E-05	9.46E-09	4.53E-09	2.15E-08	1.65E-06	0.00E+00	0.00E+00	0.00E+00	7.65E-08	0.00E+00	0.00E+00	2.11E-11	4.34E-12	4.17E-09	1.07E-14	4.54E-10
Resource use-fossil resources	MJ, net calorific value	5.06E-02	2.09E-03	1.77E-02	4.73E-03	4.66E-02	0.00E+00	0.00E+00	0.00E+00	5.61E-04	0.00E+00	0.00E+00	7.88E-07	1.80E-05	9.20E-04	4.45E-08	8.14E-05
Water resource depletion	m3 eq.	1.10E-04	2.82E-08	1.60E-06	6.41E-08	2.99E-06	0.00E+00	0.00E+00	0.00E+00	6.41E-07	0.00E+00	0.00E+00	1.37E-07	-3.20E-10	1.25E-08	-7.89E-13	1.30E-08

Table 9 LCA Results- Environmental impacts for PV module JKMxxxM-7RL3-TV

Impact Category	Unit	Upstream Module		Core Module											Downstream Module	
		A 1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4
		Raw material Supply	Raw material transportation	Manufacturing	Product transportation	Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-installation	Waste transportation	Waste treatment	Waste disposal
Climate change - Total	kg CO_2 eq.	4.27E-03	1.38E-04	2.18E-03	3.10E-04	3.04E-03	0.00E+00	0.00E+00	0.00E+00	4.19E-05	0.00E+00	0.00E+00	7.93E-08	2.34E-06	5.99E-05	6.33E-09	3.18E-06
Climate change - Fossil	kg CO_2 eq.	5.00E-03	1.38E-04	2.20E-03	3.10E-04	3.06E-03	0.00E+00	0.00E+00	0.00E+00	4.61E-05	0.00E+00	0.00E+00	7.84E-08	2.35E-06	5.99E-05	6.38E-09	3.11E-06
Climate change - Biogenic	kg CO_2 eq.	-7.24E-04	-1.14E-07	-1.72E-05	-2.58E-07	-2.72E-05	0.00E+00	0.00E+00	0.00E+00	-4.28E-06	0.00E+00	0.00E+00	8.49E-10	-1.81E-08	-4.97E-08	-4.91E-11	8.39E-09
Climate change - Land use and Land use change	kg CO_2 eq.	2.50E-06	2.68E-08	2.68E-08	6.03E-08	7.37E-06	0.00E+00	0.00E+00	0.00E+00	6.26E-08	0.00E+00	0.00E+00	1.35E-11	6.16E-11	1.16E-08	1.67E-13	6.16E-08
Ozone depletion	kg CFC-11 eq.	4.05E-10	2.65E-11	2.54E-11	5.96E-11	1.05E-09	0.00E+00	0.00E+00	0.00E+00	5.92E-12	0.00E+00	0.00E+00	6.18E-15	7.60E-15	1.15E-11	2.06E-17	1.61E-12
Acidification	moli di H+ eq.	4.62E-05	7.06E-07	1.16E-05	1.59E-06	7.28E-05	0.00E+00	0.00E+00	0.00E+00	4.82E-07	0.00E+00	0.00E+00	6.04E-10	1.37E-08	3.06E-07	3.70E-11	2.48E-08
Eutrophication	kg PO_4 eq.	1.47E-05	1.10E-07	1.43E-06	2.48E-07	3.96E-05	0.00E+00	0.00E+00	0.00E+00	1.83E-07	0.00E+00	0.00E+00	8.89E-11	1.61E-09	4.79E-08	4.36E-12	4.71E-09
Photochemical ozone formation	kg di NMVOC eq.	2.01E-05	7.59E-07	5.41E-06	1.71E-06	2.11E-05	0.00E+00	0.00E+00	0.00E+00	1.99E-07	0.00E+00	0.00E+00	2.70E-10	6.61E-09	3.30E-07	1.79E-11	2.14E-08
Depletion of abiotic resources – minerals and materials	kg Sb eq.	1.25E-05	9.52E-09	4.88E-09	2.14E-08	1.63E-06	0.00E+00	0.00E+00	0.00E+00	7.63E-08	0.00E+00	0.00E+00	2.10E-11	4.28E-12	4.13E-09	1.16E-14	4.55E-10
Resource use-fossil resources	MJ, net calorific value	5.71E-02	2.10E-03	1.94E-02	4.72E-03	4.60E-02	0.00E+00	0.00E+00	0.00E+00	5.65E-04	0.00E+00	0.00E+00	7.86E-07	1.78E-05	9.12E-04	4.82E-08	8.16E-05
Water resource depletion	m3 eq.	1.09E-04	2.84E-08	1.81E-06	6.39E-08	2.95E-06	0.00E+00	0.00E+00	0.00E+00	6.34E-07	0.00E+00	0.00E+00	1.37E-07	-3.16E-10	1.23E-08	-8.55E-13	1.30E-08

Table 10 LCA Results- Environmental impacts for PV module JKMxxxM-78H-V

Impact Category	Unit	Upstream Module		Core Module											Downstream Module	
		A 1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4
		Raw material Supply	Raw material transportation	Manufacturing	Product transportation	Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-installation	Waste transportation	Waste treatment	Waste disposal
Climate change - Total	kg CO_2 eq.	4.39E-03	1.41E-04	2.36E-03	3.22E-04	3.12E-03	0.00E+00	0.00E+00	0.00E+00	4.18E-05	0.00E+00	0.00E+00	8.59E-08	2.40E-06	6.17E-05	6.49E-09	3.22E-06
Climate change - Fossil	kg CO_2 eq.	5.19E-03	1.42E-04	2.38E-03	3.23E-04	3.14E-03	0.00E+00	0.00E+00	0.00E+00	4.61E-05	0.00E+00	0.00E+00	8.49E-08	2.41E-06	6.18E-05	6.54E-09	3.15E-06
Climate change - Biogenic	kg CO_2 eq.	-7.95E-04	-1.17E-07	-1.86E-05	-2.68E-07	-2.79E-05	0.00E+00	0.00E+00	0.00E+00	-4.44E-06	0.00E+00	0.00E+00	9.19E-10	-1.86E-08	-5.13E-08	-5.03E-11	8.52E-09
Climate change - Land use and Land use change	kg CO_2 eq.	2.68E-06	2.75E-08	2.91E-08	6.27E-08	7.55E-06	0.00E+00	0.00E+00	0.00E+00	6.41E-08	0.00E+00	0.00E+00	1.47E-11	6.32E-11	1.20E-08	1.71E-13	6.25E-08
Ozone depletion	kg CFC-11 eq.	4.27E-10	2.72E-11	2.75E-11	6.20E-11	1.08E-09	0.00E+00	0.00E+00	0.00E+00	5.99E-12	0.00E+00	0.00E+00	6.69E-15	7.80E-15	1.19E-11	2.11E-17	1.63E-12
Acidification	moli di H+ eq.	4.95E-05	7.24E-07	1.26E-05	1.65E-06	7.46E-05	0.00E+00	0.00E+00	0.00E+00	4.91E-07	0.00E+00	0.00E+00	6.54E-10	1.40E-08	3.16E-07	3.80E-11	2.51E-08
Eutrophication	kg PO_4 eq.	1.64E-05	1.13E-07	1.54E-06	2.58E-07	4.06E-05	0.00E+00	0.00E+00	0.00E+00	1.90E-07	0.00E+00	0.00E+00	9.63E-11	1.65E-09	4.93E-08	4.47E-12	4.78E-09
Photochemical ozone formation	kg di NMVOC eq.	2.10E-05	7.79E-07	5.86E-06	1.78E-06	2.17E-05	0.00E+00	0.00E+00	0.00E+00	2.00E-07	0.00E+00	0.00E+00	2.93E-10	6.78E-09	3.40E-07	1.84E-11	2.17E-08
Depletion of abiotic resources – minerals and materials	kg Sb eq.	1.34E-05	9.77E-09	5.29E-09	2.23E-08	1.67E-06	0.00E+00	0.00E+00	0.00E+00	7.78E-08	0.00E+00	0.00E+00	2.28E-11	4.39E-12	4.26E-09	1.19E-14	4.62E-10
Resource use-fossil resources	MJ, net calorific value	5.76E-02	2.15E-03	2.11E-02	4.91E-03	4.71E-02	0.00E+00	0.00E+00	0.00E+00	5.56E-04	0.00E+00	0.00E+00	8.51E-07	1.83E-05	9.40E-04	4.95E-08	8.29E-05
Water resource depletion	m3 eq.	1.14E-04	2.92E-08	1.96E-06	6.65E-08	3.03E-06	0.00E+00	0.00E+00	0.00E+00	6.27E-07	0.00E+00	0.00E+00	1.48E-07	-3.24E-10	1.27E-08	-8.77E-13	1.32E-08

Table 11. LCA Results - Resource use of JKMxxxM-72H-V

Impact Category	Unit	Upstream Module		Core Module												Downstream Module	
		A 1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4
		Raw material Supply	Raw material transportation	Manufacturing	Product transportation	Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-installation	Waste transportation	Waste treatment	Waste disposal
PENRE	MJ, lower calorific value	6.30E-02	2.05E-03	2.92E-02	4.86E-03	4.47E-02	0.00E+00	0.00E+00	0.00E+00	5.50E-04	0.00E+00	0.00E+00	1.21E-06	2.98E-05	9.19E-04	7.34E-08	6.10E-05
PERE	MJ, lower calorific value	2.81E-02	1.10E-05	2.03E-03	2.61E-05	3.79E-03	0.00E+00	0.00E+00	0.00E+00	1.51E-04	0.00E+00	0.00E+00	9.93E-08	7.78E-07	4.94E-06	1.92E-09	6.22E-06
PENRM	MJ, lower calorific value	3.55E-03	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	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PERM	MJ, lower calorific value	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	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PENRT	MJ, lower calorific value	6.30E-02	2.05E-03	2.92E-02	4.86E-03	4.47E-02	0.00E+00	0.00E+00	0.00E+00	5.50E-04	0.00E+00	0.00E+00	1.21E-06	2.98E-05	9.19E-04	7.34E-08	6.10E-05
PERT	MJ, lower calorific value	2.81E-02	1.10E-05	2.03E-03	2.61E-05	3.79E-03	0.00E+00	0.00E+00	0.00E+00	1.51E-04	0.00E+00	0.00E+00	9.93E-08	7.78E-07	4.94E-06	1.92E-09	6.22E-06
FW	m^3	1.65E-01	1.12E-05	5.62E-05	2.64E-05	1.15E-02	0.00E+00	0.00E+00	0.00E+00	8.25E-04	0.00E+00	0.00E+00	1.11E-06	4.90E-08	5.00E-06	1.21E-10	1.94E-06
SM	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	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RSF	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	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
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	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Caption	PERE = Use of renewable primary energy excluding renewable primary energy resources used as raw materials; PERM = Use of renewable primary energy resources used as raw materials; PERT = Total use of renewable primary energy resources; PENRE = Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials; PENRM = Use of non-renewable primary energy resources used as raw materials; PENRT = Total use of non-renewable primary energy resources; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Use of non-renewable secondary fuels; FW = Use of net fresh water																

Table 12 LCA Results - Resource use of JKMxxxM-72H-TV

Impact Category	Unit	Upstream Module		Core Module												Downstream Module	
		A 1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4
		Raw material Supply	Raw material transportation	Manufacturing	Product transportation	Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-installation	Waste transportation	Waste treatment	Waste disposal
PENRE	MJ, lower calorific value	6.82E-02	2.18E-03	2.93E-02	4.95E-03	4.44E-02	0.00E+00	0.00E+00	0.00E+00	5.70E-04	0.00E+00	0.00E+00	1.22E-06	2.96E-05	9.23E-04	7.29E-08	6.36E-05
PERE	MJ, lower calorific value	2.79E-02	1.17E-05	2.04E-03	2.66E-05	3.77E-03	0.00E+00	0.00E+00	0.00E+00	1.48E-04	0.00E+00	0.00E+00	9.99E-08	7.73E-07	4.96E-06	1.90E-09	6.48E-06
PENRM	MJ, lower calorific value	6.10E-03	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	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PERM	MJ, lower calorific value	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	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PENRT	MJ, lower calorific value	6.82E-02	2.18E-03	2.93E-02	4.95E-03	4.44E-02	0.00E+00	0.00E+00	0.00E+00	5.70E-04	0.00E+00	0.00E+00	1.22E-06	2.96E-05	9.23E-04	7.29E-08	6.36E-05
PERT	MJ, lower calorific value	2.79E-02	1.17E-05	2.04E-03	2.66E-05	3.77E-03	0.00E+00	0.00E+00	0.00E+00	1.48E-04	0.00E+00	0.00E+00	9.99E-08	7.73E-07	4.96E-06	1.90E-09	6.48E-06
FW	m^3	1.66E-01	1.19E-05	5.66E-05	2.69E-05	1.14E-02	0.00E+00	0.00E+00	0.00E+00	8.19E-04	0.00E+00	0.00E+00	1.12E-06	4.86E-08	5.02E-06	1.20E-10	2.02E-06
SM	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	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RSF	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	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
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	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Caption	PERE = Use of renewable primary energy excluding renewable primary energy resources used as raw materials; PERM = Use of renewable primary energy resources used as raw materials; PERT = Total use of renewable primary energy resources; PENRE = Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials; PENRM = Use of non-renewable primary energy resources used as raw materials; PENRT = Total use of non-renewable primary energy resources; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Use of non-renewable secondary fuels; FW = Use of net fresh water																

Table 13 LCA Results - Resource use of JKMXXXM-7RL3-V

Impact Category	Unit	Upstream Module		Core Module												Downstream Module	
		A 1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4
		Raw material Supply	Raw material transportation	Manufacturing	Product transportation	Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-installation	Waste transportation	Waste treatment	Waste disposal
PENRE	MJ, lower calorific value	6.78E-02	2.02E-03	2.59E-02	4.59E-03	4.41E-02	0.00E+00	0.00E+00	0.00E+00	6.39E-04	0.00E+00	0.00E+00	1.01E-06	2.94E-05	8.93E-04	7.26E-08	5.78E-05
PERE	MJ, lower calorific value	2.56E-02	1.09E-05	1.76E-03	2.47E-05	3.75E-03	0.00E+00	0.00E+00	0.00E+00	1.62E-04	0.00E+00	0.00E+00	8.27E-08	7.69E-07	4.80E-06	1.89E-09	5.90E-06
PENRM	MJ, lower calorific value	9.35E-03	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	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PERM	MJ, lower calorific value	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	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PENRT	MJ, lower calorific value	6.78E-02	2.02E-03	2.59E-02	4.59E-03	4.41E-02	0.00E+00	0.00E+00	0.00E+00	6.39E-04	0.00E+00	0.00E+00	1.01E-06	2.94E-05	8.93E-04	7.26E-08	5.78E-05
PERT	MJ, lower calorific value	2.56E-02	1.09E-05	1.76E-03	2.47E-05	3.75E-03	0.00E+00	0.00E+00	0.00E+00	1.62E-04	0.00E+00	0.00E+00	8.27E-08	7.69E-07	4.80E-06	1.89E-09	5.90E-06
FW	m^3	1.53E-01	1.10E-05	5.00E-05	2.50E-05	1.14E-02	0.00E+00	0.00E+00	0.00E+00	9.05E-04	0.00E+00	0.00E+00	9.23E-07	4.84E-08	4.85E-06	1.19E-10	1.84E-06
SM	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	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RSF	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	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
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	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Caption	PERE = Use of renewable primary energy excluding renewable primary energy resources used as raw materials; PERM = Use of renewable primary energy resources used as raw materials; PERT = Total use of renewable primary energy resources; PENRE = Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials; PENRM = Use of non-renewable primary energy resources used as raw materials; PENRT = Total use of non-renewable primary energy resources; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Use of non-renewable secondary fuels; FW = Use of net fresh water																

Table 14 LCA Results - Resource use of JKMXXXM-7RL3-TV

Impact Category	Unit	Upstream Module		Core Module												Downstream Module	
		A 1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4
		Raw material Supply	Raw material transportation	Manufacturing	Product transportation	Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-installation	Waste transportation	Waste treatment	Waste disposal
PENRE	MJ, lower calorific value	6.78E-02	2.04E-03	2.81E-02	4.58E-03	4.35E-02	0.00E+00	0.00E+00	0.00E+00	6.45E-04	0.00E+00	0.00E+00	1.01E-06	2.91E-05	8.84E-04	7.87E-08	5.80E-05
PERE	MJ, lower calorific value	2.57E-02	1.09E-05	1.17E-03	2.46E-05	3.70E-03	0.00E+00	0.00E+00	0.00E+00	1.57E-04	0.00E+00	0.00E+00	8.24E-08	7.58E-07	4.75E-06	2.05E-09	5.91E-06
PENRM	MJ, lower calorific value	9.34E-03	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	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PERM	MJ, lower calorific value	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	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PENRT	MJ, lower calorific value	6.78E-02	2.04E-03	2.81E-02	4.58E-03	4.35E-02	0.00E+00	0.00E+00	0.00E+00	6.45E-04	0.00E+00	0.00E+00	1.01E-06	2.91E-05	8.84E-04	7.87E-08	5.80E-05
PERT	MJ, lower calorific value	2.57E-02	1.09E-05	1.17E-03	2.46E-05	3.70E-03	0.00E+00	0.00E+00	0.00E+00	1.57E-04	0.00E+00	0.00E+00	8.24E-08	7.58E-07	4.75E-06	2.05E-09	5.91E-06
FW	m^3	1.53E-01	1.11E-05	5.30E-05	2.49E-05	1.12E-02	0.00E+00	0.00E+00	0.00E+00	8.93E-04	0.00E+00	0.00E+00	9.20E-07	4.78E-08	4.81E-06	1.29E-10	1.85E-06
SM	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	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RSF	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	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
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	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Caption	PERE = Use of renewable primary energy excluding renewable primary energy resources used as raw materials; PERM = Use of renewable primary energy resources used as raw materials; PERT = Total use of renewable primary energy resources; PENRE = Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials; PENRM = Use of non-renewable primary energy resources used as raw materials; PENRT = Total use of non-renewable primary energy resources; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Use of non-renewable secondary fuels; FW = Use of net fresh water																

Table 15 LCA Results - Resource use of JKMXXXM-78H-V

Impact Category	Unit	Upstream Module		Core Module												Downstream Module	
		A 1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4
		Raw material Supply	Raw material transportation	Manufacturing	Product transportation	Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-installation	Waste transportation	Waste treatment	Waste disposal
PENRE	MJ, lower calorific value	6.90E-02	2.09E-03	3.04E-02	4.76E-03	4.47E-02	0.00E+00	0.00E+00	0.00E+00	6.37E-04	0.00E+00	0.00E+00	1.09E-06	2.98E-05	9.12E-04	8.07E-08	5.89E-05
PERE	MJ, lower calorific value	2.74E-02	1.12E-05	1.27E-03	2.56E-05	3.79E-03	0.00E+00	0.00E+00	0.00E+00	1.59E-04	0.00E+00	0.00E+00	8.93E-08	7.78E-07	4.90E-06	2.11E-09	6.00E-06
PENRM	MJ, lower calorific value	8.36E-03	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	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PERM	MJ, lower calorific value	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	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PENRT	MJ, lower calorific value	6.90E-02	2.09E-03	3.04E-02	4.76E-03	4.47E-02	0.00E+00	0.00E+00	0.00E+00	6.37E-04	0.00E+00	0.00E+00	1.09E-06	2.98E-05	9.12E-04	8.07E-08	5.89E-05
PERT	MJ, lower calorific value	2.74E-02	1.12E-05	1.27E-03	2.56E-05	3.79E-03	0.00E+00	0.00E+00	0.00E+00	1.59E-04	0.00E+00	0.00E+00	8.93E-08	7.78E-07	4.90E-06	2.11E-09	6.00E-06
FW	m^3	1.61E-01	1.14E-05	5.74E-05	2.59E-05	1.15E-02	0.00E+00	0.00E+00	0.00E+00	8.91E-04	0.00E+00	0.00E+00	9.96E-07	4.90E-08	4.96E-06	1.33E-10	1.87E-06
SM	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	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RSF	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	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
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	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Caption	PERE = Use of renewable primary energy excluding renewable primary energy resources used as raw materials; PERM = Use of renewable primary energy resources used as raw materials; PERT = Total use of renewable primary energy resources; PENRE = Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials; PENRM = Use of non-renewable primary energy resources used as raw materials; PENRT = Total use of non-renewable primary energy resources; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Use of non-renewable secondary fuels; FW = Use of net fresh water																

Table 16 LCA Results - Output flows and waste categories of JKMXXXM-72H-V

Impact Category	Unit	Upstream Module		Core Module												Downstream Module	
		A 1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4
		Raw material Supply	Raw material transportation	Manufacturing	Product transportation	Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-installation	Waste transportation	Waste treatment	Waste disposal
HWD	kg	2.79E-03	0.00E+00	5.17E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.36E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NHWD	kg	2.88E-11	0.00E+00	1.44E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.38E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.42E-04
RWD	kg	1.19E-15	2.39E-11	2.98E-11	5.64E-11	1.67E-10	0.00E+00	0.00E+00	0.00E+00	2.05E-12	0.00E+00	0.00E+00	3.67E-15	2.50E-15	1.07E-11	6.17E-18	4.50E-16
MFR	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	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MER	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	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.03E-04	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	3.73E-03
ETE	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	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EEE	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	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
Caption	HWD = Hazardous waste disposed; NHWD = Non-hazardous waste disposed; RWD = Radioactive waste disposed; MFR = Materials for recycling; MER = Materials for energy recovery; CRU = Components for re-use; ETE = Exported thermal energy; EEE = Exported electrical energy																

Table 17 LCA Results - Output flows and waste categories of JKMxxxM-72H-TV

Impact Category	Unit	Upstream Module		Core Module												Downstream Module	
		A 1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4
		Raw material Supply	Raw material transportation	Manufacturing	Product transportation	Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-installation	Waste transportation	Waste treatment	Waste disposal
HWD	kg	3.11E-06	0.00E+00	5.20E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.35E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NHWD	kg	2.57E-11	0.00E+00	6.86E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.37E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.19E-04	2.19E-04
RWD	kg	1.07E-15	2.53E-11	3.00E-11	5.75E-11	1.66E-10	0.00E+00	0.00E+00	0.00E+00	2.07E-12	0.00E+00	0.00E+00	3.69E-15	2.49E-15	1.07E-11	6.13E-18	4.69E-16
MFR	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	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MER	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	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.82E-05	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	3,59E-03
ETE	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	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EEE	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	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
Caption	HWD = Hazardous waste disposed; NHWD = Non-hazardous waste disposed; RWD = Radioactive waste disposed; MFR = Materials for recycling; MER = Materials for energy recovery; CRU = Components for re-use; ETE = Exported thermal energy; EEE = Exported electrical energy																

Table 18 LCA Results - Output flows and waste categories of JKMXXXM-7RL3-V

Impact Category	Unit	Upstream Module		Core Module												Downstream Module	
		A 1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4
		Raw material Supply	Raw material transportation	Manufacturing	Product transportation	Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-installation	Waste transportation	Waste treatment	Waste disposal
HWD	kg	2.80E-03	0.00E+00	4.66E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.46E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NHWD	kg	2.89E-11	0.00E+00	1.99E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.36E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.76E-04
RWD	kg	1.20E-15	2.35E-11	2.65E-11	5.34E-11	1.65E-10	0.00E+00	0.00E+00	0.00E+00	2.21E-12	0.00E+00	0.00E+00	3.06E-15	2.48E-15	1.04E-11	6.10E-18	4.27E-16
MFR	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	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MER	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	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.05E-04	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	3,89E-03
ETE	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	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EEE	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	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
Caption	HWD = Hazardous waste disposed; NHWD = Non-hazardous waste disposed; RWD = Radioactive waste disposed; MFR = Materials for recycling; MER = Materials for energy recovery; CRU = Components for re-use; ETE = Exported thermal energy; EEE = Exported electrical energy																

Table 19 LCA Results - Output flows and waste categories of JKMXXXM-7RL3-TV

Impact Category	Unit	Upstream Module		Core Module											Downstream Module	
		A 1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4
		Raw material Supply	Raw material transportation	Manufacturing	Product transportation	Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-installation	Waste transportation	Waste treatment	Waste disposal
HWD	kg	2.51E-03	0.00E+00	4.65E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.44E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NHWD	kg	2.39E-11	0.00E+00	5.86E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.35E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.26E-04
RWD	kg	9.92E-16	2.37E-11	2.98E-11	5.32E-11	1.63E-10	0.00E+00	0.00E+00	0.00E+00	2.21E-12	0.00E+00	0.00E+00	3.05E-15	2.44E-15	1.03E-11	6.62E-18	4.28E-16
MFR	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	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MER	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	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.06E-05	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	3,58E-03
ETE	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	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EEE	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	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
Caption	HWD = Hazardous waste disposed; NHWD = Non-hazardous waste disposed; RWD = Radioactive waste disposed; MFR = Materials for recycling; MER = Materials for energy recovery; CRU = Components for re-use; ETE = Exported thermal energy; EEE = Exported electrical energy																

Table 20 LCA Results - Output flows and waste categories of JKMXXXM-78H-V

Impact Category	Unit	Upstream Module		Core Module											Downstream Module	
		A 1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4
		Raw material Supply	Raw material transportation	Manufacturing	Product transportation	Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-installation	Waste transportation	Waste treatment	Waste disposal
HWD	kg	2.71E-03	0.00E+00	5.03E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.48E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NHWD	kg	2.59E-11	0.00E+00	1.09E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.38E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.25E-04
RWD	kg	1.07E-15	2.43E-11	3.23E-11	5.53E-11	1.67E-10	0.00E+00	0.00E+00	0.00E+00	2.20E-12	0.00E+00	0.00E+00	3.30E-15	2.50E-15	1.06E-11	6.78E-18	4.34E-16
MFR	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	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MER	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	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.40E-05	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	3,63E-03
ETE	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	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EEE	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	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
Caption	HWD = Hazardous waste disposed; NHWD = Non-hazardous waste disposed; RWD = Radioactive waste disposed; MFR = Materials for recycling; MER = Materials for energy recovery; CRU = Components for re-use; ETE = Exported thermal energy; EEE = Exported electrical energy																

The contribution analysis of the PV module products on various impact categories reveals that production stage of the PV module including raw components and PV plant construction stage are the main contributions to environmental impact categories. In terms of production stage, electricity consumption for ingot, wafer, cell and PV module and supply of solar glass are two key impact factors. And for the PV plant construction stage, cable used for PV plant infrastructure is the key impact factor.

6. CALCULATION RULES

6.1 Functional Unit

In this study the functional unit is 1 kWh of electricity generated as output from the solar PV plant. The environmental impact from this study was calculated and reported per functional unit.

In order to report the environmental impacts generated by the Jinko Solar PV modules during its life cycle per functional unit, the total energy produced by the solar PV plant during the reference service life needs to be calculated. Once total energy has been calculated, the overall environmental impacts generated throughout the entire life cycle are divided by this value to return the results in the individual kWh produced. The total energy produced by the plant will therefore be equal to

$$E_{tot}[kWh] = E_{year} * RSL$$

Where:
E_{tot} represents the total energy produced by the plant (or, in an extreme case, by the individual module) during its entire life cycle;

E_{year} represents the energy produced annually by the plant. In the case of already installed plants, this figure can be calculated from the actual measurement of the energy produced. In the case of plants under construction but not yet operational, an estimate can be provided of the annual production of the plant, which will be a function of various parameters (average irradiation, exposure, temperature, optical factors, performance ratio / coefficient for losses, degradation rate and etc.) however known at the design stage. In this study, the study adopts a calculation method using the following approach from *Design specification for photovoltaic power station (GB-50797-2012)*.

Energy production in the first year of operation:

$$E_1 = H_A \times P / E_s \times K$$

E_1 = Energy produced in the first year of operation, kWh/year
H_A = Site specific annual average solar radiation on module (shadings not included), kWh/m². The annual radiation must take into consideration the specific inclination (slope, tilt) and orientation.
P = Installed capacity of the plant, 50,000kW
E_s= radiation at standard testing condition (STC), kWh/m²; STC: The ratio is given for standard test conditions: radiation 1000 W/m², cell temperature 25 °C, wind speed 1 m/s, AM 1.5.
K = Overall efficiency coefficient, 81.4% in this study as provided by Jinko Solar;

Energy production over reference service life of module, assuming linear annual degradation:

$$E_{RSL} = E_1 * (1 + \sum_{n=1}^{RSL-1}(1 - \mathrm{deg})^n)$$

n = year of operation, here 0<n<30
deg = yearly degradation rate.
RSL = Reference service life, 30 years according to PCR.
Please see Table 5 for the total electricity generation during RSL.

Table 21 Parameters per functional unit

Parameters	**Value**		**Source**
	Amount	**Unit**	
Peak power of the plant	50	MW	Jinko
Plant latitude and longitude	34°35'~34°51'N, 110°16'~ 111°58' E	°	Jinko
Plant altitude	26	m	Jinko
Nominal solar irradiance	1580000	Wh/m²/year	Jinko

6.2 Period under review

The study used primary data collected from August 1st, 2019 to August 1st, 2020.

6.3 System boundaries

This LCA study includes life cycle information from cradle-to-grave (see Table 1 for reference). According to the PCR, the life cycle stages must refer to segmentation in the following three modules:

1. *Upstream module* which includes all the processes upstream of the production of the photovoltaic module and/or solar park. In this study the upstream ends at the beginning of PV modules manufacturing, including extraction and processing of raw materials including silicon, ingot block, wafer, PV cell with packaging (A1), and the transportation of the raw material to the factory (A2) and etc.;

2. *Core module* which includes all the relevant processes managed by the Organization proposing the EPD. The core module in this study includes manufacturing of the solar cells and PV modules (A3) with the supply of the raw material, energy and auxiliary material input, and treatment and emission of off gas, wastewater and solid wastes during the PV module manufacturing; considering that the functional unit is energy generated by solar plant utilizing the PV modules, the core module is extended to include the transportation of PV modules to solar plant (A4), the 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). However, considering that the installation and operation is beyond the control of Jinko Solar, for simplification purpose, assumption was made on the life cycle inventory (LCI) data during the modeling of core modules;

3. *Downstream module* which includes all the relevant processes that take place outside of the control of the Organization proposing the EPD. In this study, the downstream module includes waste processing (C3) and disposal (C4). According to the PCR, the benefit and avoided loads beyond the product system boundary were not reported in module D separately within this study, neither were the benefit and loads be reported in other stages by following a cut off allocation approach. Due to the fact that it will take 30 years to enter the end of life stage for the PV modules, scenarios have to be developed for end of life treatment. For simplification purpose, assumption was made during the modeling of downstream modules.

Figure 2 below illustrates the system boundaries of the LCA study for the Jinko solar PV modules, including raw material production and transportation, manufacture, delivery, solar plant installation, and waste disposal.

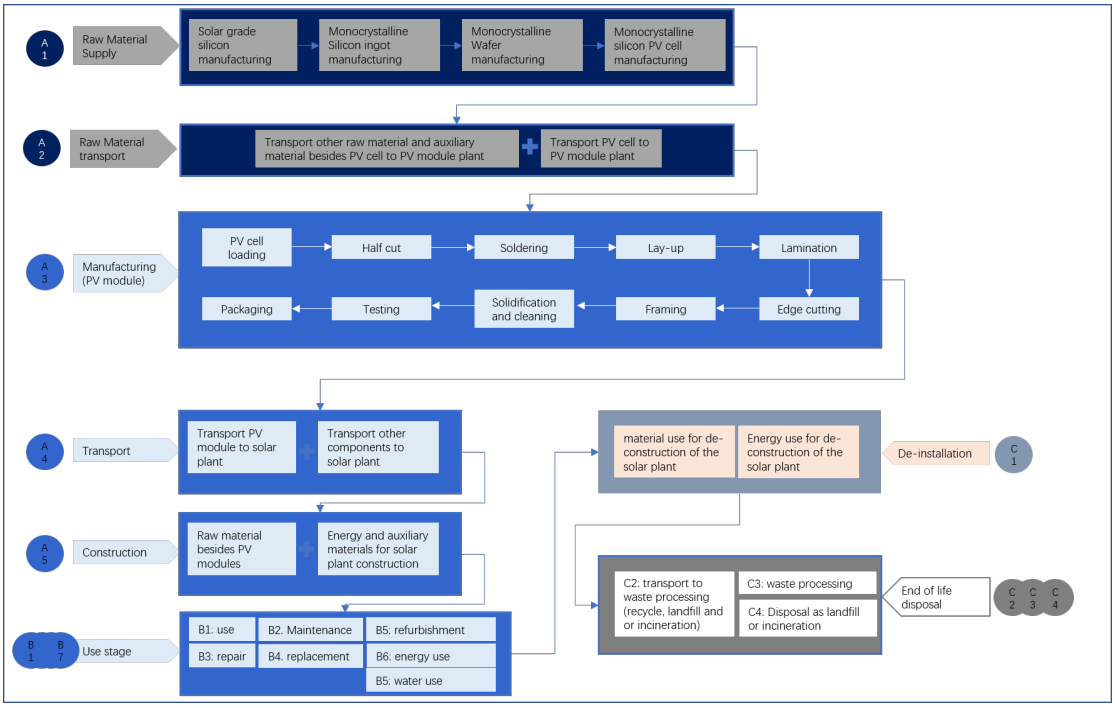

Figure 2 System boundary of the LCA study

6.4 Assumptions

The key assumptions of this LCA study are as follows：

- For missing background data, substitution of missing data using similar background data approach was taken to shorten the gap. A sensitivity analysis was conducted;
- During development of the raw material LCI data, the production of silicon ingot and silicon wafer was based on the inventory from Sichuan factory, while the electricity used the electricity data of Sichuan and Xinjiang respectively;
- The purchased solar cells from the market adopted the same production data (materials use) from Jinko's manufacturing data of solar cell, while the electricity data was replaced by the China grid average mix;
- Besides transportation of PV module, transportation of other infrastructures for the installation of the solar plant used assumed distance (100km) and transportation vehicles (Euro 4 truck) for simplification purpose. A sensitivity analysis was conducted;
- The number of PV module employed in PV plant construction (A5) was calculated by dividing the total power capacity of the PV plant (50MW) by the peak power output of each PV module;
- The electricity consumption during PV plant construction stage was 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 was assumed to be powered by the plant itself, water used for cleaning the PV panels was assumed to be 0.23L (source: www.polywater.com) per module per time and two times per year;
- Replacements: PV modules: 20 pcs/year, inverter: 1 pcs/2years;
- The electricity consumption during deconstruction of PV plant (C1) was assumed the same as the electricity consumption of construction stage (A5), and electricity consumption for PV module demolition at waste processing stage (C3) was assumed the same as the electricity consumption of PV module manufacturing stage (A3);
- During the end-of-life stage, the transportation distance 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.

6.5 Excluded processes

The following main steps/stages were not included in the system boundary due to the reason that the elements below were considered irrelevant or not within the boundary of the LCA study of PV module relevant products：

- Production and disposal of the infrastructure and capital equipment (buildings, machines, transport media, roads, etc.) and their maintenance during PV module manufacturing, installation, and maintenance;
- The load and benefit of recycling waste solar module as well as waste equipment from solar plant was excluded from the analysis (see Section 6.8 allocation for further explanation);
- The packaging for ingot, wafer and solar cell is reused internally and its impact was excluded from the system;
- Storage phases and sales of PV products;
- Product losses due to abnormal damage such as natural disaster or fire accident. These losses would mostly be accidental;
- Recycling process of defective products;
- Handling operations at the distribution center and retail outlet.

Table 22 Life cycle inventories that are included and excluded

Included	Excluded
Upstream(A1-A2)	
• Raw material, energy and fuels • Capital goods for PV module production (implemented in generic LCI-data) • Silicone production • Wafer production • Solar cell fabrication • production of components (inverters, mounting and cable). • Transports of components	• Labor • Transport of personnel • Occupation of land in production • The packaging for ingot, wafer and solar cell
Core (A3-C2)	
• PV module fabrication • Mounting and installation • Electricity consumption • Transports of component to solar plant, installation and electricity generation services. • Occupation of land in use • De-construction and demolition of the solar plant • Transport to waste processing	• Labour • Transport of personnel • Occupation of land in production • Handling operations at the distribution center and retail outlet. • Storage phases of PV products. • Capital goods for solar plant installation, operation and de-construction
Downstream (C3-C4)	
• Waste processing, and • Disposal including landfill and incineration	• Labour • Transport of personnel • Occupation of land in production • Capital goods for solar plant de-construction and waste processing • Load and benefit from recycling and waste to energy treatment

6.6 Cut-off rules

The following procedures were followed for the exclusion of inputs and outputs:

- All inputs and outputs to a (unit) process were included in the calculation where data was available. Data gaps were filled by conservative assumptions with average or generic data. Any assumptions for such choices were documented;
- In case of insufficient input data or data gaps for a unit process, according to the PCR requirement, the cut-off criteria chosen was 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 total neglected input flows of the cradle-to-grave stage, e.g. per module A1-A3, A4-A5, B1-B7, C1-C4 shall be a maximum of 2% of energy usage and mass, in this study, the neglected flow is demonstrated in table below.

Table 23 Cut-off flows

Flow name	**Process stage**	**Reason for cut-off**	**Total cut off mass % estimated**
Packaging material for raw material e.g. wafer, cell and etc	A1	Used repeatedly inside the plant	<0.1%
Raw materials (Bom) trace elements	A1	Mass <2%	0%-0.4%
Transportation and storage within the plant	A3	Energy<2%	0%-0.7%
Inspection during operation of solar plant	B	Cut off due to small impact according to PCR	<0.1%
Packaging material for waste transportation	C4	<2%	<1%
Total			**<2%**

Material and energy flows known to have the potential to cause significant emissions into air, water or soil related to the environmental indicators of this study were included in the assessment. After reviewing the Material Safety Data Sheets and relevant physical, chemical, and other information of the flows listed in table above, no significant negative emission to the environment from above listed flows was identified.

6.7 Data quality

The data quality requirements for this study were as follows:

- 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, e.g. electricity and transportation data from China were utilized;
- The scenarios represented the average technologies at the time of data collection.

In the study, the key parameters for producer-specific foreground data were based on yearly production amounts and extrapolations of measurements on specific machines and plants. The specific production data referred to an average of 12 months from August 2019 to July 2020 for PV modules including raw materials such as ingot, wafer and cells, and the input data of raw material and transportation referred to an average of production scenario using data from bill of material (BOM) sheet. For the data regarding the solar plant installation, operation, maintenance and disposal, scenarios based on representative data and situation were developed. Most of the necessary life cycle inventories for the basic materials were available in the SimaPro database

using generic data. The last update of the database was in 2020 by Ecovane Environmental. Further LCIs for materials of the supply chain of the basic materials were approximated with LCIs of similar materials or estimated by the combination of available LCIs.

6.8 Allocations

Multi-input processes

For data sets in this study, the allocation of the inputs from coupled processes was generally carried out via the mass. The consumption and transportation of raw materials was allocated by mass ratio. For PV module production, the total consumption of energy and water during manufacturing was equally allocated to per unit watt of energy yield capacity. No other approach was taken for the allocation of energy and water consumption for each model of PV module product.

Multi-output processes

Multi-output allocation is based on a quantitative calculation of the resource consumption and the emissions for example in relation to the distribution of functions, physical properties or economic aspects. Physical properties, such as mass, net calorific values, etc., shall be preferred, otherwise economic aspects, such as man-hours, operating hours or manufacturing cost may be used.

In this study, there were no by-products from the PV module production line, hence, there was quite little occasion that required allocation for multi-output processes. One allocation occurred on the environmental emissions allocation, especially in the area of waste treatment. The environmental emissions of PV module product were allocated by energy yield capacity (watt) to each unit module product.

Allocation for recovery processes

For the allocation of residuals, the model “allocation cut-off by classification” according to ISO standard (called “Allocation Recycled 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 was 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. was also allocated to the next life cycle of substituted products, but not the primary producers of PV modules, hence no burden or benefit was allocated to the primary producer of the PV module or solar plant

7 LCA SCENARIOS

The processes included in modules A1-A3 are described in Section 4.

7.1 Transport (A4)

Table 24 Scenario and additional technical information of transport to the operation site

Name	Value	Unit
	Road	
Fuel type	Diesel	
Consumption of fuel	31.11	l/100km
Vehicle type	Lorry (20t)	/
Transport distance	1300	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	-

7.2 Installation (A5)

Table 25 Scenario and additional technical information of installation

Name	Value	Unit
Ancillary materials	1.70E+07	kg
Net freshwater consumption specified by water source and fate (amount evaporated, amount disposed to sewer)	0	m^3
Other resources	0	kg
Electricity consumption	3,160	kWh
Other energy carriers	0	MJ
Product loss per functional unit	N/A	kg
Waste materials at the construction site before waste processing, generated by product installation	N/A	kg
Output materials resulting from on-site waste processing (specified by route; e.g. for recycling, energy recovery and/or disposal)	N/A	kg
Direct emissions to ambient air, soil and water	0	kg

7.3 Use Stage

Table 26 Scenarios and additional technical information of use stage

Scenario Information	Unit	Value
B1-Use		
Electricity use	kWh/day	N/A
B2-Maintenance		
Maintenance process	/	Cleaning Panels
Maintenance cycle	Number per RSL or year	twice per year
Ancillary materials for maintenance, e.g. cleaning agent, specify materials	kg/cycle	0
Waste material resulting from maintenance (specify materials)	kg	0
Net fresh water consumption during maintenance	m^3	1730
Energy input during maintenance, e.g. vacuum cleaning, energy carrier type, e.g. electricity, and amount, if applicable and relevant	kWh/year	1977
B3-Repair	N/A	
B4-Replacement	Inverter, pcs	0.5pcs/year
B5-Refurbishment	Module, pcs	20pcs/year
B6-Operational energy use	N/A	
B7-Operational water use	Same as *B2: Maintenance*	

7.4 End-of-life

Table 27 End-of-life scenarios

Process	Unit (expressed per functional unit or per declared unit of components products or materials and by type of material)	Value
Collection process specified by type	kg collected separately	0
	kg collected with mixed construction waste	N/A
Recovery system specified by type	kg for re-use	3.73E-03
	kg for recycling	1.18E-03
	kg for energy recovery	0
Disposal specified by type	kg product or material for final deposition	1.75E-04
Assumptions for scenario development, e.g. transportation	units as appropriate	100 km for the road transportation (C2) required from an installation site to an MSW treatment site

8 OTHER ADDITIONAL ENVIRONMENTAL INFORMATION

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 in Table 29.

The calculation of RoE is done using the following formula:

$$\text{RoE [years]} = E_{invested} / E_{produced,annual}$$

where:

$E_{invested}$ = PENRT+PERT

$E_{produced,annual}$= total amount of electricity generated in a year by the solar park

Table 28 RoE results of Trina Solar PV modules

Modules	JKMXXXM-72H-V	JKMXXXM-72H-TV	JKMXXXM-7RL3-V	JKMXXXM-7RL3-TV	JKMXXXM-78H-V
RoE	1.46	1.50	1.44	1.45	1.50

9 Reference

EPDItaly

Regulations of the EPDItaly Programme, version 5 (01/07/2020)

EPDItaly014: Core-PCR for electricity produced by photovoltaic modules (March 2020, Revision REV.1)

SUSTAINABILITY REPORTING STANDARDS

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

European Standards. (2019). EN 50693:2019 Product category rules for life cycle assessments of electronic and electrical products and systems

ISO. (2006). ISO 14044: Environmental management - Life cycle assessment - Requirements and guidelines.

ISO. (2009). ISO 14040: Environmental management - Life cycle assessment - principles and frameworks.

ISO. (2011). ISO 14025: Environmental labels and declarations - Type III environmental declarations - principles and procedures.

LCA report

LCA report for photovoltaic modules (report number: PJ-JINKO-20001), by Ecovane Environmental Co., Ltd& TÜV Rheinland (China), June 2021

10 Contact Information

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