DAS SOLAR CO., LTD.

ENVIRONMENTAL PRODUCT DECLARATION

CRYSTALLINE SILICON PHOTOVOLTAIC (PV) MODULES:

DAS-DH144NA-xxx
DAS-DH108NA-xxx
DAS-DH144PA-xxx
DAS-WH144PA-xxx
DAS-LOJP-xxx

SITE: Quzhou, Zhejiang Province, China

In accordance with ISO 14025

Program Operator	EPDItaly
Publisher	EPDItaly

Declaration Number	DAS Solar_EPD01
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Valid to	2028/10/14

GENERAL INFORMATION

EPD OWNER

Name of the company	DAS SOLAR CO., LTD.
Registered office	No. 43, South of Bailing Rd, 324022 Quzhou City, Zhejiang Province, PEOPLE'S REPUBLIC OF CHINA
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PROGRAM OPERATOR	
EPDItaly	Via Gaetano De Castillia n° 10 - 20124 Milano, Italy

INFORMATION ON THE EPD	
Product name (s)	Crystalline Silicon Photovoltaic (PV) Modules
Site (s)	No. 43, South of Bailing Rd, 324022 Quzhou City, Zhejiang Province, PEOPLE'S REPUBLIC OF CHINA
Short description and technical information of the product (s)	High efficiency mono crystalline silicon photovoltaic modules
Field of application of the product (s)	Electricity generation
Product (s) reference standards (if any)	IEC 61215: 2016 & IEC 61730: 2016
CPC Code (number)	171 “Electrical energy”

VERIFICATION INFORMATION	
PCR (title, version, date of publication or update)	PCR EPDItaly014: Electricity Produced by Photovoltaic Modules, Rev 1.1, 08/02/2022
EPDItaly Regulation (version, date of publication or update)	Regulations of the EPDItaly Program, Rev 5.2, 16/02/2022
Project Report LCA	The LCA report is written by TÜV SÜD Certification and Testing (China) Co., Ltd. Shanghai Branch (www.tuvsud.cn)
Independent Verification Statement	The PCR review was performed by Ing. Daniele Pace, Arch. Michele Paleari, Ing. Sara Toniolo - info@epditaly.it. Independent verification of the declaration and data, carried out according to ISO 14025: 2010. ☐ Internal ☑ External Third party verification carried out by: ICMQ S.p.A., via Gaetano De Castillia n ° 10 - 20124 Milan, Italy. Accredited by Accredia.
Comparability Statement	Environmental statements published within the same product category, but from different programs, may not be comparable. In particular, EPDs of construction products may not be comparable if they do not comply with EN 15804: 2012 + A2: 2019.
Liability Statement	The EPD Owner releases EPDItaly from any non-compliance with environmental legislation. The holder of the declaration will be responsible for the information and supporting evidence. EPDItaly disclaims any responsibility for the information, data and results provided by the EPD Owner for life cycle assessment.

1. COMPANY INTRODUCTION

Founded in August 2018, DAS SOLAR CO., LTD. is a national high-tech enterprise that specializes in the research and development, manufacturing, and sales of high-efficiency solar cells, photovoltaic modules, and system applications. Additionally, DAS Solar is involved in the investment, construction, and operation of power stations, which meet the "Photovoltaic Manufacturing Industry Specification Conditions" of the Ministry of Industry and Information Technology and recognize as a "Future Factory" and a "Specialized, Refined, Unique, and Innovative" enterprise in Zhejiang Province. DAS Solar is also a strategic investment enterprise of state-owned companies.

DAS Solar emphasizes R&D investment and industry-university-research cooperation. R&D and professional technical personnel occupy 20% of the total employees, and the annual research and investment accounts for approximately 5% of the sales revenue. Additionally, DAS Solar has possessed and applied for over 150 patents. As a leader in N-type photovoltaic technology, DAS Solar boasts two key products (N-type modules and lightweight modules) and three series of full-scenario PV system solutions (ecological PV, urban PV, and offshore PV), which have successively been brought under the procurement directory of a number of large state-owned companies. It has also established a comprehensive sales network at home and abroad, which has introduced exported products to more than 60 countries and regions. With a production capacity of 30GW for high-efficiency cells and 30GW for high-efficiency modules set for 2023, DAS Solar has become a leading top-tier brand in the photovoltaic market.

Plants of DAS Solar comply with the following standards:

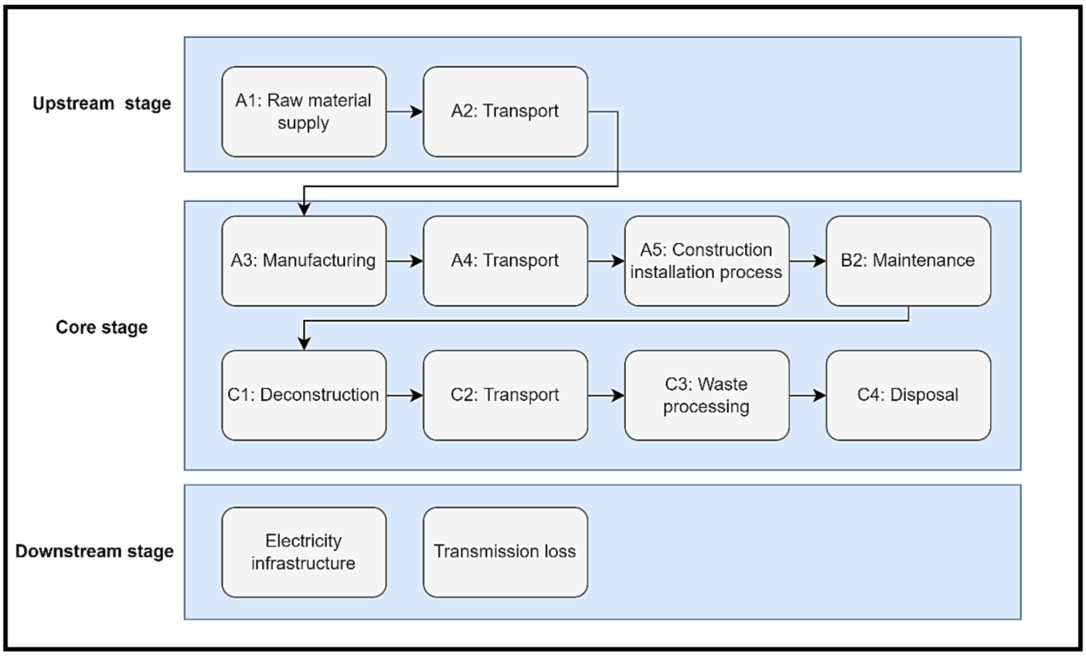
- ISO 9001-Quality Management System
- ISO 14001- Environmental Management System
- ISO45001: Occupational Health and Safety Management System

2. SCOPE AND TYPE OF EPD

2.1. Scope of EPD

The study is a cradle to grave analysis from the extraction of raw materials up to the decommission of the product. Figure 2-1 illustrates the system boundaries for DAS Solar’s PV module products, including raw materials acquisition, transportation, manufacturing, delivery, installation, maintenance, waste disposal for end-of-life, electricity infrastructure and transmission loss.

Figure 2-1 System boundaries diagram



According to the PCR, the life cycle stages must refer to segmentation in the follow three modules:

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

Core module: which includes manufacturing of solar cells and PV modules (A3) with the supply of energy and water, and emissions; and distribution of PV modules to solar PV plant (A4); the construction of the solar PV plant (A5), the maintenance (B2) during the RSL (30 years) period; de-construction and demolition of the solar PV plant (C1); transportation to waste processing (C2); waste processing (C3) and disposal (C4). 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.

Downstream module: which includes infrastructure of distributing electricity, and dissipation related to voltage drop operations before feeding electricity into the grid.

The following steps/stages are not included in the system boundary due to the reason that the elements below are considered irrelevant or not within the boundary to the LCA study：

- Production and disposal of the infrastructure and capital equipment (buildings, machines, transport media, roads, etc.) and their maintenance during PV module manufacturing and solar plant construction and maintenance.
- The load and benefit of recycling waste solar modules as well as waste equipment from solar plant are excluded.
- The packaging for solar cells is reused internally and its impact is excluded from the system.
- Storage phases and sales of products.
- Personnel activities and transport of personnel.
- Emissions during the solar PV plant construction and operation due to no obvious emission observable.

2.1. Type of EPD

The present EPD is a product specific EPD. The following 5 series of mono crystalline silicon photovoltaic (PV) modules covered by the declaration:

- DAS-DH144NA-xxx, xxx=555-580, in step of 5
- DAS-DH108NA-xxx, xxx=420-430, in step of 5
- DAS-DH144PA-xxx, xxx=540-555, in step of 5
- DAS-WH144PA-xxx, xxx=540-555, in step of 5
- DAS-LOJP-xxx, xxx=420-430, in step of 5

2.2. Geographical scope

All products are produced by DAS Solar in Quzhou factory in China. Most of the parts are manufactured in China. Photovoltaic cells are manufactured in Quzhou factory in China. The present EPD study is based on the scenario that the PV power plant is installed in the city of Kunyun, Xinjiang province in China.

2.3. Time representativeness

The input and output data of solar cells and PV modules is based on the inventory of production of DAS Solar from 2022-03-01 to 2023-02-28.

2.4. Database and LCA software used

Generic data for raw materials for PV module manufacturing and packaging; natural resources, such as water, energy, waste disposal and transport were taken from the LCI-database Ecoinvent 3.8, allocation, Cut-off by classification -unit is adopted. LCA software SimaPro 9.3 was used for the modeling and calculation.

3. DETAILED PRODUCT DESCRIPTION

3.1. Declared or functional unit

The functional unit is used as a reference unit to quantify performance of a product system. To assess the environment impact of different products, the functional units of these products must be equivalent so that the results may be interpreted clearly.

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

3.2. Reference Service Life

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.

3.3. Description of the Product

DAS Solar produces series of crystalline silicon photovoltaic (PV) modules. In this study, 5 types of modules are included.

3.4. Technical parameters

Table 3-1 List of module types under analysis

Module type	Cell number	Dimension(mm)	Weight(kg)	Power output (W)
DAS-DH144NA-xxx	144	2278×1134	31.3	555-580
DAS-DH108NA-xxx	108	1722×1134	23.7	420-430
DAS-DH144PA-xxx	144	2278×1134	31.4	540-555
DAS-WH144PA-xxx	144	2278×1134	27.3	540-555
DAS-LOJP-xxx	86.3	1985×1165	9.9	420-430

Note: DAS: DAS Solar; D: double glass module; W: single glass module; H: half- cell; 144/108: Number of cells; NA: N type 182mm solar cells; PA: P type 182mm solar cells; XXX: power rating at STC; L: light weight module; O: Shingled module; J: 86.3 pieces of cell; P: P type 158.75mm solar cells.

3.5. Materials compositions

The materials compositions of 1 piece of modules listed as Table 3-2.

Table 3-3 Materials compositions

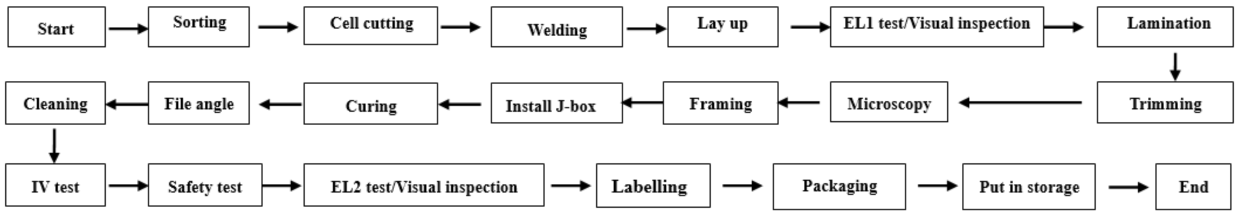
Components	Main substance	CAS No. of main substance	DAS-DH144NA-xxx	DAS-DH108NA-xxx	DAS-DH144PA-xxx	DAS-WH144PA-xxx	DAS-LOJP-xxx	Unit
Frame	Aluminum	7429-90-5	2.63E+00	2.20E+00	2.63E+00	2.63E+00	0.00E+00	kg
Glass	Na2O·nSiO2	1344-09-8; 106985-35-7	2.58E+01	1.95E+01	2.58E+01	2.07E+01	0.00E+00	kg
Cell	Si	7440-21-3	7.20E-01	5.40E-01	7.92E-01	7.92E-01	8.64E-01	kg
Cell connector	Copper	7440-50-8	1.81E-01	1.36E-01	1.81E-01	1.81E-01	1.26E-01	kg
String connector	Copper	7440-50-8	4.51E-02	2.25E-02	2.25E-02	2.25E-02	0.00E+00	kg
POE	POE	/	1.94E+00	1.46E+00	0.00E+00	0.00E+00	4.47E+00	kg
Junction box	Fibre glass reinforced plastic	/	1.69E-01	1.69E-01	1.69E-01	1.69E-01	1.69E-01	kg
Potting silicone	Silicone	112926- 00-8	2.91E-02	2.91E-02	2.70E-02	2.70E-02	1.75E-02	kg
Adhesive	Silicone	112926- 00-8	3.13E-01	2.69E-01	3.13E-01	3.01E-01	1.10E-02	kg
Backsheet	PET	25038-59- 9	0.00E+00	0.00E+00	0.00E+00	1.14E+00	3.09E+00	kg
Insulation sheet	EPE	24937-78- 8	0.00E+00	0.00E+00	0.00E+00	1.54E-03	0.00E+00	kg
EVA	EVA	24937-78- 8	0.00E+00	0.00E+00	5.42E-01	2.08E+00	0.00E+00	kg
EPE	EVA&POE	24937-78- 8	0.00E+00	0.00E+00	5.42E-01	0.00E+00	0.00E+00	kg
Aluminum foil	Aluminum	7429-90-5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.22E+00	kg
Conductive adhesive	Epoxy resin	/	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.84E-03	kg

Note : EVA: Ethylene vinyl acetate; POE: Polyolefin elastomer; EPE: EVA-POE-EVA; PET: Polyethylene terephthalate.

3.6. Description of the production process

The PV module products under study includes 5 models (see Table 3-1). All the products share similar manufacturing processes and life cycle stages. A flowchart depicting the production process stages of DAS Solar PV module products shown in Figure 4-1 below. The LCI data of manufacturing process including input and output of energy, emissions and waste disposal. All the data are provided by DAS solar basing on product inventory. All the wastes generated during manufacturing process are entrusted to outsourcing companies for disposal and recycling.

Figure 3-1 Manufacturing process of PV modules



- **Sorting:** sort the solar cells which meet the requirements of the order and check whether they conform to the standards. Prepare for welding procedure.
- **Cell cutting:** the full cell is cut into the appropriate size according to the BOM size.
- **Welding:** solder the positive and negative electrodes of the single solar cells together to get cell strings and prepare for the lamination process.
- **Lay up:** connect the soldered cell strings with string connector, and lay up the glass, EVA film, backsheet or back glass.
- **EL1 test/Visual inspection:** inspect the appearance of laid components before lamination and EL test to find the unqualified points.
- **Lamination:** the lamination process is to melt EVA and solidify the laminate at a certain temperature.
- **Trimming:** trim the edge of laminate.
- **Microscopy:** inspect the laminate.
- **Framing:** assemble the frame and mount the J-box on the back of laminate with silicone adhesive.
- **Install J-box:** solder the welding point of J-box with string connector, then fill the J-box with potting adhesive.
- **Curing:** curing the adhesive.
- **File angle:** polish the edge of the frame.
- **Cleaning:** clean the surface of PV modules.
- **IV test:** test the electrical parameters of PV modules and determine the power rating.
- **Safety test:** insulation test, dielectric withstanding test and grounding continuity test.
- **EL2 test/Visual inspection:** test to find the hidden cracking of cells and determine the EL level.
- **Labelling:** label the PV modules according to the power rating.
- **Packaging:** package the products ready for distribution.
- **Put in storage:** put the packaged products into warehouse.

4. LCA RESULTS

The present LCA study is made by following the requirements of PCR EPDItaly014 and based on the recommended impact analysis method for the calculation. Environmental impact indicators have been calculated by following the characterization factors included in EN 15804:2012+A2:2019. Results are showed by environmental impact indicators, resource use indicators and output flows and waste categories indicators. Due to the characteristics of PV module products, a PV module product usually has several different power ratings in a specific design, structure and process. The impact results are calculated basing on the highest rating of the module type and expressed per kwh electricity generated during the RSL.

4.1. Environmental impacts

Table 4-1 Environmental impacts- DAS-DH144NA-xxx

Results per functional unit					
Indicator	**Unit**	**Upstream**	**Core stream**	**Downstream**	**Total**
GWP-total	kg CO2 eq	1.09E-02	4.27E-03	1.56E-04	1.53E-02
GWP-fossil	kg CO2 eq	1.08E-02	4.14E-03	1.54E-04	1.51E-02
GWP-biogenic	kg CO2 eq	1.58E-05	1.20E-04	1.46E-06	1.37E-04
GWP-luluc	kg CO2 eq	1.48E-05	7.50E-06	2.29E-07	2.25E-05
ODP	kg CFC11 eq	6.05E-10	2.13E-10	8.55E-12	8.27E-10
AP	mol H+ eq	6.15E-05	2.76E-05	1.10E-06	9.02E-05
EP-freshwater	kg P eq	4.66E-07	1.47E-07	7.06E-09	6.20E-07
POCP	kg NMVOC eq	3.27E-05	1.51E-05	5.23E-07	4.84E-05
ADP minerals & metals	kg Sb eq	2.73E-07	1.44E-07	9.17E-09	4.26E-07
ADP-fossil	MJ	1.34E-01	4.32E-02	1.83E-03	1.79E-01
WDP	m3 depriv.	9.30E-03	8.11E-04	1.05E-04	1.02E-02
Abbreviations: GWP-total=Global Warming Potential total; GWP-fossil=Global Warming Potential fossil; GWP-biogenic=Global Warming Potential biogenic; GWP-luluc=Global Warming Potential land use and land use change; ODP=Depletion potential of the stratospheric ozone layer; AP=Acidification potential, Accumulated Exceedance; EP-freshwater=Eutrophication potential, fraction of nutrients reaching freshwater end compartment; POCP=Formation potential of tropospheric ozone; ADP-minerals & metals=Abiotic Depletion for non-fossil resources potential; ADP-fossil=Abiotic Depletion for non-fossil resources potential; WDP= Water deprivation potential, deprivation, weighted water consumption.					

Table 4-2 Environmental impacts- DAS-DH108NA-xxx

Results per functional unit					
Indicator	**Unit**	**Upstream**	**Core stream**	**Downstream**	**Total**
GWP-total	kg CO2 eq	1.11E-02	4.27E-03	1.58E-04	1.55E-02
GWP-fossil	kg CO2 eq	1.10E-02	4.14E-03	1.56E-04	1.53E-02
GWP-biogenic	kg CO2 eq	1.73E-05	1.24E-04	1.51E-06	1.42E-04
GWP-luluc	kg CO2 eq	1.52E-05	7.49E-06	2.33E-07	2.29E-05
ODP	kg CFC11 eq	6.16E-10	2.14E-10	8.67E-12	8.38E-10
AP	mol H+ eq	6.26E-05	2.76E-05	1.11E-06	9.12E-05
EP-freshwater	kg P eq	4.73E-07	1.47E-07	7.13E-09	6.27E-07
POCP	kg NMVOC eq	3.33E-05	1.52E-05	5.29E-07	4.90E-05
ADP minerals & metals	kg Sb eq	2.73E-07	1.44E-07	9.16E-09	4.26E-07
ADP-fossil	MJ	1.37E-01	4.32E-02	1.85E-03	1.82E-01

WDP	m3 depriv.	9.44E-03	8.19E-04	1.06E-04	1.04E-02
Abbreviations: GWP-total=Global Warming Potential total; GWP-fossil=Global Warming Potential fossil; GWP-biogenic=Global Warming Potential biogenic; GWP-luluc=Global Warming Potential land use and land use change; ODP=Depletion potential of the stratospheric ozone layer; AP=Acidification potential, Accumulated Exceedance; EP-freshwater=Eutrophication potential, fraction of nutrients reaching freshwater end compartment; POCP=Formation potential of tropospheric ozone; ADP-minerals & metals=Abiotic Depletion for non-fossil resources potential; ADP-fossil=Abiotic Depletion for non-fossil resources potential; WDP= Water deprivation potential, deprivation, weighted water consumption.					

Table 4-3 Environmental impacts- DAS-DH144PA-xxx

Results per functional unit					
Indicator	**Unit**	**Upstream**	**Core stream**	**Downstream**	**Total**
GWP-total	kg CO2 eq	1.24E-02	4.52E-03	1.73E-04	1.70E-02
GWP-fossil	kg CO2 eq	1.23E-02	4.37E-03	1.71E-04	1.69E-02
GWP-biogenic	kg CO2 eq	1.89E-05	1.33E-04	1.62E-06	1.53E-04
GWP-luluc	kg CO2 eq	1.72E-05	7.90E-06	2.58E-07	2.54E-05
ODP	kg CFC11 eq	6.90E-10	2.27E-10	9.56E-12	9.27E-10
AP	mol H+ eq	6.92E-05	2.91E-05	1.21E-06	9.95E-05
EP-freshwater	kg P eq	5.30E-07	1.55E-07	7.83E-09	6.93E-07
POCP	kg NMVOC eq	3.71E-05	1.60E-05	5.77E-07	5.36E-05
ADP minerals & metals	kg Sb eq	2.44E-07	1.52E-07	9.20E-09	4.05E-07
ADP-fossil	MJ	1.55E-01	4.57E-02	2.06E-03	2.03E-01
WDP	m3 depriv.	1.02E-02	8.55E-04	1.15E-04	1.12E-02
Abbreviations: GWP-total=Global Warming Potential total; GWP-fossil=Global Warming Potential fossil; GWP-biogenic=Global Warming Potential biogenic; GWP-luluc=Global Warming Potential land use and land use change; ODP=Depletion potential of the stratospheric ozone layer; AP=Acidification potential, Accumulated Exceedance; EP-freshwater=Eutrophication potential, fraction of nutrients reaching freshwater end compartment; POCP=Formation potential of tropospheric ozone; ADP-minerals & metals=Abiotic Depletion for non-fossil resources potential; ADP-fossil=Abiotic Depletion for non-fossil resources potential; WDP= Water deprivation potential, deprivation, weighted water consumption.					

Table 4-4 Environmental impacts- DAS-WH144PA-xxx

Results per functional unit					
Indicator	**Unit**	**Upstream**	**Core stream**	**Downstream**	**Total**
GWP-total	kg CO2 eq	1.31E-02	4.69E-03	1.82E-04	1.79E-02
GWP-fossil	kg CO2 eq	1.30E-02	4.55E-03	1.80E-04	1.78E-02
GWP-biogenic	kg CO2 eq	9.52E-06	1.22E-04	1.43E-06	1.33E-04
GWP-luluc	kg CO2 eq	1.82E-05	8.29E-06	2.72E-07	2.67E-05
ODP	kg CFC11 eq	1.38E-09	2.31E-10	1.65E-11	1.62E-09
AP	mol H+ eq	7.19E-05	3.04E-05	1.26E-06	1.04E-04
EP-freshwater	kg P eq	5.59E-07	1.63E-07	8.25E-09	7.30E-07
POCP	kg NMVOC eq	3.89E-05	1.66E-05	6.05E-07	5.62E-05
ADP minerals & metals	kg Sb eq	2.57E-07	1.59E-07	9.68E-09	4.26E-07
ADP-fossil	MJ	1.66E-01	4.75E-02	2.19E-03	2.15E-01
WDP	m3 depriv.	1.08E-02	8.97E-04	1.21E-04	1.18E-02
Abbreviations: GWP-total=Global Warming Potential total; GWP-fossil=Global Warming Potential fossil; GWP-biogenic=Global Warming Potential biogenic; GWP-luluc=Global Warming Potential land use and land use change; ODP=Depletion potential of the stratospheric ozone layer; AP=Acidification potential, Accumulated Exceedance; EP-freshwater=Eutrophication potential, fraction of nutrients reaching freshwater end compartment; POCP=Formation potential of tropospheric ozone; ADP-minerals & metals=Abiotic Depletion for non-fossil resources potential; ADP-					

fossil=Abiotic Depletion for non-fossil resources potential; WDP= Water deprivation potential, deprivation, weighted water consumption.

Table 4-5 Environmental impacts- DAS-LOJP-xxx

Results per functional unit					
Indicator	**Unit**	**Upstream**	**Core stream**	**Downstream**	**Total**
GWP-total	kg CO2 eq	1.82E-02	4.44E-03	2.31E-04	2.28E-02
GWP-fossil	kg CO2 eq	1.81E-02	4.37E-03	2.29E-04	2.27E-02
GWP-biogenic	kg CO2 eq	4.36E-05	5.66E-05	1.11E-06	1.01E-04
GWP-luluc	kg CO2 eq	2.26E-05	8.23E-06	3.16E-07	3.12E-05
ODP	kg CFC11 eq	3.06E-09	1.98E-10	3.30E-11	3.29E-09
AP	mol H+ eq	9.39E-05	2.96E-05	1.47E-06	1.25E-04
EP-freshwater	kg P eq	7.94E-07	1.62E-07	1.06E-08	9.66E-07
POCP	kg NMVOC eq	5.20E-05	1.59E-05	7.28E-07	6.87E-05
ADP minerals & metals	kg Sb eq	4.64E-07	1.59E-07	1.18E-08	6.35E-07
ADP-fossil	MJ	2.34E-01	4.53E-02	2.85E-03	2.83E-01
WDP	m3 depriv.	1.54E-02	8.95E-04	1.67E-04	1.64E-02
Abbreviations: GWP-total=Global Warming Potential total; GWP-fossil=Global Warming Potential fossil; GWP-biogenic=Global Warming Potential biogenic; GWP-luluc=Global Warming Potential land use and land use change; ODP=Depletion potential of the stratospheric ozone layer; AP=Acidification potential, Accumulated Exceedance; EP-freshwater=Eutrophication potential, fraction of nutrients reaching freshwater end compartment; POCP=Formation potential of tropospheric ozone; ADP-minerals & metals=Abiotic Depletion for non-fossil resources potential; ADP-fossil=Abiotic Depletion for non-fossil resources potential; WDP= Water deprivation potential, deprivation, weighted water consumption.					

4.2. Resources uses

Table 4-6 Resource use- DAS-DH144NA-xxx

Results per functional unit					
Indicator	**Unit**	**Upstream**	**Core stream**	**Downstream**	**Total**
PENRE	MJ	1.31E-01	4.32E-02	1.79E-03	1.76E-01
PERE	MJ	2.23E-02	3.99E-03	2.76E-04	2.66E-02
PENRM	MJ	2.70E-03	0.00E+00	2.70E-05	2.73E-03
PERM	MJ	7.21E-04	0.00E+00	7.21E-06	7.28E-04
PENRT	MJ	1.34E-01	4.32E-02	1.82E-03	1.79E-01
PERT	MJ	2.30E-02	3.99E-03	2.83E-04	2.73E-02
FW	M^3	3.09E-04	2.64E-05	3.45E-06	3.39E-04
MS	kg	3.20E-04	7.37E-04	1.06E-05	1.07E-03
RSF	MJ	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
Abbreviations: PENRE=Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw material ; PERE=Use of renewable primary energy excluding renewable primary energy resources used as raw material; PENRM=Use of non-renewable primary energy resources used as raw material; PERM=Use of renewable primary energy resources used as raw material; PENRT =Total use of non-renewable primary energy resources (primary energy and primary energy resources used as raw materials); PERT=Total use of renewable primary energy resources (primary energy and primary energy resources used as raw materials); FW=Net use of fresh water; MS=Use of secondary raw materials; RSF=Use of renewable secondary fuels; NRSF=Use of non-renewable secondary fuels					

Table 4-7 Resource use- DAS-DH108NA-xxx

Results per functional unit					
Indicator	**Unit**	**Upstream**	**Core stream**	**Downstream**	**Total**
PENRE	MJ	1.33E-01	4.32E-02	1.82E-03	1.78E-01
PERE	MJ	2.26E-02	3.99E-03	2.79E-04	2.69E-02
PENRM	MJ	2.75E-03	0.00E+00	2.75E-05	2.78E-03
PERM	MJ	7.31E-04	0.00E+00	7.31E-06	7.38E-04
PENRT	MJ	1.36E-01	4.32E-02	1.84E-03	1.81E-01
PERT	MJ	2.33E-02	3.99E-03	2.86E-04	2.76E-02
FW	M^3	3.14E-04	2.64E-05	3.49E-06	3.44E-04
MS	kg	3.42E-04	7.33E-04	1.08E-05	1.09E-03
RSF	MJ	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
Abbreviations: PENRE=Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw material ; PERE=Use of renewable primary energy excluding renewable primary energy resources used as raw material; PENRM=Use of non-renewable primary energy resources used as raw material; PERM=Use of renewable primary energy resources used as raw material; PENRT =Total use of non-renewable primary energy resources (primary energy and primary energy resources used as raw materials); PERT=Total use of renewable primary energy resources (primary energy and primary energy resources used as raw materials); FW=Net use of fresh water; MS=Use of secondary raw materials; RSF=Use of renewable secondary fuels; NRSF=Use of non-renewable secondary fuels					

Table 4-8 Resource use- DAS-DH144PA-xxx

Results per functional unit					
Indicator	**Unit**	**Upstream**	**Core stream**	**Downstream**	**Total**
PENRE	MJ	1.51E-01	4.57E-02	1.97E-03	1.99E-01
PERE	MJ	2.62E-02	4.20E-03	3.04E-04	3.07E-02
PENRM	MJ	3.31E-03	0.00E+00	3.31E-05	3.35E-03
PERM	MJ	7.92E-04	0.00E+00	7.92E-06	8.00E-04
PENRT	MJ	1.54E-01	4.57E-02	2.05E-03	2.02E-01
PERT	MJ	2.70E-02	4.20E-03	3.26E-04	3.16E-02
FW	M^3	3.50E-04	2.78E-05	3.87E-06	3.81E-04
MS	kg	3.62E-04	7.75E-04	1.14E-05	1.15E-03
RSF	MJ	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
Abbreviations: PENRE=Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw material ; PERE=Use of renewable primary energy excluding renewable primary energy resources used as raw material; PENRM=Use of non-renewable primary energy resources used as raw material; PERM=Use of renewable primary energy resources used as raw material; PENRT =Total use of non-renewable primary energy resources (primary energy and primary energy resources used as raw materials); PERT=Total use of renewable primary energy resources (primary energy and primary energy resources used as raw materials); FW=Net use of fresh water; MS=Use of secondary raw materials; RSF=Use of renewable secondary fuels; NRSF=Use of non-renewable secondary fuels					

Table 4-9 Resource use- DAS-WH144PA-xxx

Results per functional unit					
Indicator	**Unit**	**Upstream**	**Core stream**	**Downstream**	**Total**
PENRE	MJ	1.62E-01	4.75E-02	2.15E-03	2.11E-01
PERE	MJ	2.77E-02	4.41E-03	3.36E-04	3.25E-02

PENRM	MJ	3.49E-03	0.00E+00	3.49E-05	3.52E-03
PERM	MJ	9.67E-04	0.00E+00	9.67E-06	9.77E-04
PENRT	MJ	1.65E-01	4.75E-02	2.18E-03	2.15E-01
PERT	MJ	2.87E-02	4.41E-03	3.46E-04	3.35E-02
FW	M^3	3.69E-04	2.92E-05	4.08E-06	4.02E-04
MS	kg	3.84E-04	8.15E-04	1.20E-05	1.21E-03
RSF	MJ	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
Abbreviations: PENRE=Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw material ; PERE=Use of renewable primary energy excluding renewable primary energy resources used as raw material; PENRM=Use of non-renewable primary energy resources used as raw material; PERM=Use of renewable primary energy resources used as raw material; PENRT =Total use of non-renewable primary energy resources (primary energy and primary energy resources used as raw materials); PERT=Total use of renewable primary energy resources (primary energy and primary energy resources used as raw materials); FW=Net use of fresh water; MS=Use of secondary raw materials; RSF=Use of renewable secondary fuels; NRSF=Use of non-renewable secondary fuels					

Table 4-10 Resource use- DAS- LOJP-xxx

Results per functional unit					
Indicator	**Unit**	**Upstream**	**Core stream**	**Downstream**	**Total**
PENRE	MJ	2.20E-01	4.53E-02	2.71E-03	2.68E-01
PERE	MJ	3.76E-02	4.39E-03	4.34E-04	4.24E-02
PENRM	MJ	1.25E-02	0.00E+00	1.25E-04	1.27E-02
PERM	MJ	5.16E-04	0.00E+00	5.16E-06	5.21E-04
PENRT	MJ	2.32E-01	4.53E-02	2.83E-03	2.80E-01
PERT	MJ	3.81E-02	4.39E-03	4.39E-04	4.29E-02
FW	M^3	5.17E-04	2.89E-05	5.56E-06	5.52E-04
MS	kg	2.89E-04	8.11E-04	1.10E-05	1.11E-03
RSF	MJ	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
Abbreviations: PENRE=Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw material ; PERE=Use of renewable primary energy excluding renewable primary energy resources used as raw material; PENRM=Use of non-renewable primary energy resources used as raw material; PERM=Use of renewable primary energy resources used as raw material; PENRT =Total use of non-renewable primary energy resources (primary energy and primary energy resources used as raw materials); PERT=Total use of renewable primary energy resources (primary energy and primary energy resources used as raw materials); FW=Net use of fresh water; MS=Use of secondary raw materials; RSF=Use of renewable secondary fuels; NRSF=Use of non-renewable secondary fuels					

4.3. Waste and Output flows

Table 4-11 Waste and output flows- DAS-DH144NA-xxx

Results per functional unit					
Indicator	**Unit**	**Upstream**	**Core stream**	**Downstream**	**Total**
HWD	kg	4.51E-06	1.08E-06	5.61E-08	5.65E-06
NHWD	kg	1.41E-03	8.52E-04	2.47E-05	2.29E-03
RWD	kg	3.24E-07	9.98E-08	4.39E-09	4.28E-07
MER	kg	0.00E+00	1.26E-04	1.26E-06	1.27E-04
MFR	kg	0.00E+00	1.36E-03	1.36E-05	1.38E-03
CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETE	MJ	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
Abbreviations: HWD=Hazardous landfill waste; NHWD=Non-hazardous waste disposed; RWD=Radioactive waste disposed; MER=Materials for energy recovery; MFR=Material for recycling; CRU =Components for reuse; ETE=Exported thermal energy; EEE=Exported electricity energy					

Table 4-12 Waste and output flows - DAS-DH108NA-xxx

Results per functional unit					
Indicator	**Unit**	**Upstream**	**Core stream**	**Downstream**	**Total**
HWD	kg	4.58E-06	1.08E-06	5.67E-08	5.72E-06
NHWD	kg	1.43E-03	8.56E-04	2.50E-05	2.31E-03
RWD	kg	3.28E-07	1.00E-07	4.44E-09	4.33E-07
MER	kg	0.00E+00	1.30E-04	1.30E-06	1.31E-04
MFR	kg	0.00E+00	1.39E-03	1.39E-05	1.40E-03
CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETE	MJ	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
Abbreviations: HWD=Hazardous landfill waste; NHWD=Non-hazardous waste disposed; RWD=Radioactive waste disposed; MER=Materials for energy recovery; MFR=Material for recycling; CRU =Components for reuse; ETE=Exported thermal energy; EEE=Exported electricity energy					

Table 4-13 Waste and output flows - DAS-DH144PA-xxx

Results per functional unit					
Indicator	**Unit**	**Upstream**	**Core stream**	**Downstream**	**Total**
HWD	kg	5.40E-06	1.13E-06	6.55E-08	6.60E-06
NHWD	kg	1.53E-03	9.08E-04	2.66E-05	2.47E-03
RWD	kg	3.72E-07	1.06E-07	4.94E-09	4.83E-07
MER	kg	0.00E+00	1.39E-04	1.39E-06	1.41E-04
MFR	kg	0.00E+00	1.48E-03	1.48E-05	1.50E-03
CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETE	MJ	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
Abbreviations: HWD=Hazardous landfill waste; NHWD=Non-hazardous waste disposed; RWD=Radioactive waste disposed; MER=Materials for energy recovery; MFR=Material for recycling; CRU =Components for reuse; ETE=Exported thermal energy; EEE=Exported electricity energy					

Table 4-14 Waste and output flows- DAS-WH144PA-xxx

Results per functional unit					
Indicator	**Unit**	**Upstream**	**Core stream**	**Downstream**	**Total**
HWD	kg	5.69E-06	1.19E-06	6.90E-08	6.95E-06
NHWD	kg	1.70E-03	9.23E-04	2.85E-05	2.65E-03
RWD	kg	4.00E-07	1.08E-07	5.25E-09	5.14E-07
MER	kg	0.00E+00	1.28E-04	1.28E-06	1.30E-04
MFR	kg	0.00E+00	1.44E-03	1.44E-05	1.46E-03
CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETE	MJ	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
Abbreviations: HWD=Hazardous landfill waste; NHWD=Non-hazardous waste disposed; RWD=Radioactive waste disposed; MER=Materials for energy recovery; MFR=Material for recycling; CRU =Components for reuse; ETE=Exported thermal energy; EEE=Exported electricity energy					

Table 4-15 Waste and output flows- DAS- LOJP-xxx

Results per functional unit					
Indicator	**Unit**	**Upstream**	**Core stream**	**Downstream**	**Total**
HWD	kg	7.98E-06	1.19E-06	9.19E-08	9.26E-06
NHWD	kg	2.23E-03	7.97E-04	3.25E-05	3.06E-03
RWD	kg	5.02E-07	9.41E-08	6.13E-09	6.03E-07
MER	kg	0.00E+00	1.05E-04	1.05E-06	1.06E-04
MFR	kg	0.00E+00	9.38E-04	9.38E-06	9.47E-04
CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETE	MJ	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
Abbreviations: HWD=Hazardous landfill waste; NHWD=Non-hazardous waste disposed; RWD=Radioactive waste disposed; MER=Materials for energy recovery; MFR=Material for recycling; CRU =Components for reuse; ETE=Exported thermal energy; EEE=Exported electricity energy					

5. Calculation rules

5.1. Assumptions

- 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.
- The diesel consumption during PV plant construction stage is scaled up based on the data from Ecoinvent database value (7673 MJ/570kWp) according to the power capacity.
- For the distribution stage (A4), the transportation distance from the storage site to PV plant site is assumed as 500km.
- De-construction (C1) is assumed mainly energy use for onsite dismantling and the energy use is assumed the same as the construction stage (A5). Transport distance of 100 km is assumed for transporting to waste processing site (C2). The electricity consumption for demolition of PV modules and sorting of waste (C3) is assumed the same as the manufacture stage (A3) of PV modules.
- For end-of-life disposal treatment process (C4), the disposal of other components excluding inverters, concrete and PV modules is regarded as 100% recyclable. The disposal of concrete is regarded as 100% landfilling. Since there is lack of existing data of recycling rate for PV module and inverter, 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 is 85%. Therefore, 15% of waste PV module end up with waste disposal, waste management scenario of 20% landfill and 80% incineration was adopted.
- Since the lorries for transportation are unspecified, it is assumed that the lorries are EURO5, 16-32 metric ton for LCA modelling. And the ship for transportation to oversea market is assumed as container ship.
- During the maintenance stage, water used for cleaning is assumed 0.3L per module per time (source: www.polywater.com) and cleaning frequency is two time per year. And it assumed small manual systems with handheld that spray water onto panels are used, no electricity consumption during the cleaning process.
- For waste disposal, recycling during the installation stage, the transportation distance from waste generation site to waste disposal site is assumed as 100 km.
- The distribution distance of electricity generated by the solar plant is assumed as 5 km, and the transmission loss of network is assumed as 1%.

5.2. Cut-off rules

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 total of neglected input flows per module, e.g., per module A1-A3, A4-A5, B2, C1-C4 is maximum 2% of energy usage and mass.

Table 5-1 Cut off flows

Flow	Process stage	Mass %	Criteria to cut off
Trimethyl aluminum (TMA)	A1	<0.1	<1%

5.3. Data quality

The inventory is based on the collection of measured data in the manufacturer plant. A high accuracy and quality are expected for specific data. Missing data are completed by data from secondary database. Consistency checks are performed. Data quality of the main contributors are improved when possible.

Data	Description	Quality
Time related coverage	The data collected represents the average production of DAS Solar from 2022-03-01 to 2023-02-28. Very recent data.	Good
Geographical coverage	The specific data are collected from manufacturer in China. Other secondary data represent the level of rest of world (Row) unless otherwise specified.	Good
Technology coverage	The technology is from DAS Solar, and the data collected represent the current technology.	Good
Precision	All the data were collected through direct measurement and calculation.	Good
Completeness	The unit process data received are checked for completeness. Materials coming into the factory need to go out in the product, to external waste treatment or as emission to the environment. All the flows were included with less than 1% cut off.	Good
Representativeness	See time related, geographical and technology coverage as above.	Good
Consistency	The methodology is applied uniformly and consist with the goal and scope of the study.	Good
Reproducibility	The results can be reproduced basing on the same methodology	Good
Sources of the data	The raw materials consumption, transport, energy consumption including PV module and solar cell manufacturing are from specific data. The life cycle impacts of output and input flows are from secondary database ecoinvent 3.8.	Good
Uncertainty of the information	All the data were confirmed with evidence provided.	Good

5.4. Allocations

In this study, raw materials as well as packaging materials of different solar cells and PV modules are based on the BOM from DAS Solar, no allocation is used at the stage. For input and output flows during manufacturing processes such as electricity, auxiliary consumption, emissions and waste, the allocation is based on the amounts for solar cells and power rating for PV modules.

5.5. Electricity mix

In this study, the manufacturing stage takes place in China, electricity mix of manufacturing stage is used based on grid mixes of China, market for electricity, medium voltage from Ecoinvent 3.8 database. And for installation, maintenance and end-of-life stages, the data for counting the environmental impact is basing on solar plant in China, electricity mix used for these stages is grid mixes of China, market for electricity, low voltage from Ecoinvent 3.8 database.

6. LCA calculation scenarios

6.1. Distribution

According to DAS Solar's inventory, the target markets of PV modules include both domestic and oversea market. Therefore, a weighted transportation mode and distance is used basing on the sales proportion of each market. Since the inventory of DAS Solar only includes the transportation from the factory to storage site, the distance from the storage site to PV plant site is assumed as 500km for modelling the distribution of PV modules.

6.2. Installation

The specific data regarding solar PV plant installation was taken from a real PV plant in Kunyu, Xinjiang in China, with an energy yield capacity of 480MW. The detailed information about the plant is listed as Table 6-1.

Considering that the installation and operation is beyond the control of DAS Solar. The electricity consumption and diesel consumption during PV plant construction stage is scaled up based on the data from Ecoinvent database value (36.03 kWh/570kWp and 7673 MJ/570kWp respectively) according to the power capacity.

Table 6-1 PV plant information

Parameter	Value	Unit
Peak power of the plant	480000	kW
Plant latitude and longitude	37.09 °N, 79.06°E	°
Plant altitude	2046	m
Nominal solar irradiance	2137600	Wh/m²/year

In terms of electricity generation during RSL, as provided by DAS Solar, the electricity generated during the first year is simulated by PVsyst V7.3.4. And the electricity generation during RSL by each type of PV module is calculated by the formula below.

Energy production over reference service life of module：

$E_{RSL}=E1*(1+\sum_{n=1}^{RSL-1}(1-\mathrm{deg})^{n})$

- deg = yearly degradation.
- RSL = Reference service life for energy-producing unit, assumed as 30 years according to the PCR.

6.3. Use & Maintenance

For Life cycle modules B1-B7, the consumption only occurs in maintenance stage (B2). During the maintenance stage, water used for cleaning is assumed 0.3L per module per time (source: www.polywater.com) and cleaning frequency is two time per year. And it assumed small manual systems with handheld that spray water onto panels are used, no electricity consumption during the cleaning process. No activities contained during life cycle modules B1, B3-B7.

6.4. End-of-life

For the end-of-life stage, de-construction (C1) is assumed mainly energy use for onsite dismantling and the energy use is assumed the same as the construction stage (A5). Transport distance of 100 km is assumed for transporting to waste processing site (C2). The electricity consumption for demolition of PV modules and sorting of waste (C3) is assumed the same as the manufacture stage (A3) of PV modules. For end-of-life disposal treatment process (C4), the disposal of other components excluding inverters, concrete and PV modules is regarded as 100% recyclable. The disposal of concrete is regarded as 100% landfilling. Since there is lack of existing data of recycling rate for PV module and inverter, 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 is 85%. Therefore, 15% of waste PV module end up with waste disposal, waste management scenario of 20% landfill and 80% incineration was adopted. 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.

7. REFERENCES

- ISO 14040:2006 Environmental management – Life cycle assessment – Principles and framework
- ISO 14044:2006 Environmental management – Life cycle assessment – Requirements and guidelines
- EN 15804:2012+A2:2019 Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products
- ISO 14025: Environmental labels and declarations - Type III environmental declarations - principles and procedures.
- REGULATIONS OF THE EPDItaly PROGRAMME, Rev 5.2. (2022/02/16)
- PCR EPDItaly014: Electricity Produced by Photovoltaic Modules
- Ecoinvent database 3.8, http://www.ecoinvent.org.
- WEEE Directive 2012/19/EU Article 4,11&15
- Life Cycle Assessment (LCA) of Photovoltaic Modules, report 704062305405-00, Ver. 2, 2023.10.07