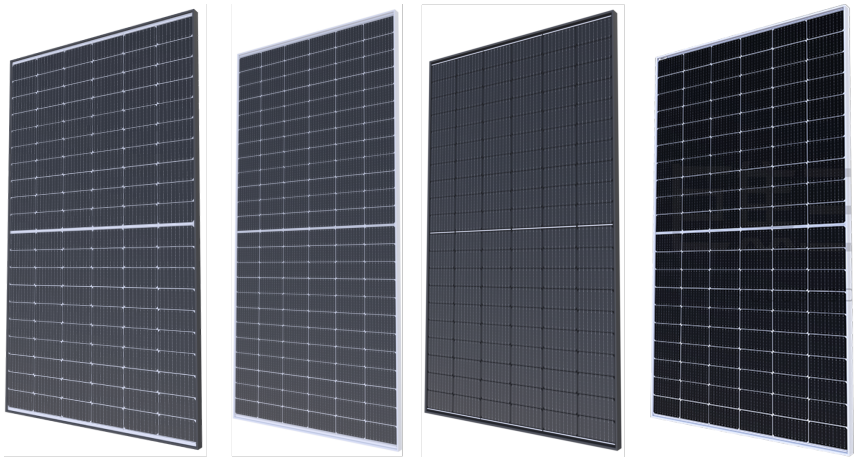
Boviet Solar Technology Co., Ltd.

ENVIRONMENTAL PRODUCT DECLARATION

Product Name: **Boviet Monocrystalline Photovoltaic Module (PERC and TOPCon cells)**

Site Plant: **Bac Giang City, Bac Giang Province, Vietnam**

in accordance with ISO 14025



Program Operator	EPDItaly
Publisher	EPDItaly
Declaration Number	*BOVIET001*
Registration Number	EPDITALY0800
Issue Date	30/08/2024
Valid to	30/08/2029

1. GENERAL INFORMATION

EPD Owner:	Boviet Solar Technology Co., Ltd. Address: B5-B6, Song Khe-Noi Hoang Industrial Zone, Song Khe District, 21000, Bac Giang City, Bac Giang Province, Vietnam
Product Name:	Boviet Monocrystalline Photovoltaic Module (PERC and TOPCon cells)
Production site:	B5-B6, Song Khe-Noi Hoang Industrial Zone, Song Khe District, 21000, Bac Giang City, Bac Giang Province, Vietnam
Product technical description of application:	Monocrystalline photovoltaic modules are widely used for electricity generation on rooftop and ground solar farms.
Program Operator:	EPDITALY (www.epditaly.it) Add: via Gaetano De Castillia n° 10 - 20124 Milano, Italy
CPC Code:	171 “Electrical energy”
Company Contact:	Name: Jianbo Hu Email: Jianbo.hu@bowayalloy.com
External Audit:	This declaration has been developed referring to EPDItaly, following the General Program Instruction; further information and the document itself are available at: www.epditaly.it. Independent verification of the declaration and data, according to EN ISO 14025:2010. ☐ INTERNAL ☒ EXTERNAL Third party verifier: ICMQ SpA - Via Gaetano De Castillia, 10 - 20124 – Milano/Italy
LCA Consultant:	This life cycle assessment was conducted in accordance with ISO 14044 and the reference PCR by: Tian Hongyu, TÜV SÜD (www.tuvsud.cn)
LCA report	LCA report of Boviet Solar Photovoltaic Modules for Environmental Product Declaration (EPD), Rev1, 202408.
Reference PCR and version number:	EPDItaly 014: PCR for PV Panel – rel. 1.1 (PRODUCED BY PHOTOVOLTAIC MODULES, 08/02/2022)
Other reference documents:	Regulations of the EPDItaly Program rev. 6.0.
Comparability:	EPDs relating to the same category of products but belonging to different programmes may not be comparable. Full conformance with a PCR allows EPD comparability only when all stages of a life cycle have been considered. However, variations and deviations are possible. Example of variations: Different LCA software and background LCI datasets may lead to differences results for upstream or downstream of the life cycle stages declared.
Liability:	The owner of the declaration will be responsible for the information and supporting evidence. EPDItaly disclaims any liability regarding the manufacturer's information data.
Reference document:	This declaration is based on the EPDItaly regulation, available on the website www.epditaly.com

2. COMPANY INTRODUCTION

Founded in 2013 in Vietnam, Boviet Solar, is a Tier 1 solar technology company that specializes in the manufacturing of Monocrystalline PERC, TOPCon PV cells and Gamma Series™ Monofacial, Vega Series™ Bifacial PV modules, as well as solar project development. The company offers business, financial stability, technological know-how, manufacturing excellence, top-performing PV modules, supply chain transparency and strong environmental, social, corporate governance protocol and client relations based on mutual partnership. As of January 2024, Boviet Solar's annual PV cell and PV module manufacturing capacity is 3.0 GW, it has delivered a total of 6.2 GW since inception and mainly focuses on U.S.A market.

The company works with EPCs, developers, installers, and contractors to deliver top-performing PV modules for utility-scale, commercial, industrial, and residential solar projects. With a proven track record of successfully working with many of the industry's leading players, Boviet Solar has maintained its position as a BloombergNEF Tier 1 solar module manufacturer since 2017. Boviet Solar's PV Modules are known for their power, performance, and quality and have been rated as top performers on Kiwa PVEL's PV Module Reliability Scorecard since 2019. Black & Veatch successfully completed an independent assessment of Boviet Solar's manufacturing facilities in 2022. Boviet Solar's manufacturing facilities located in Vietnam, USA and has offices in the United States, Germany, and China, with its global headquarters in Vietnam.

3. SCOPE AND TYPE OF EPD

3.1. Scope of EPD

The system boundary of this study on PV module encompasses the entire life cycle of the product, from cradle to grave, including the manufacturing, distribution, installation, use, and end-of-life stage. All the life cycle stages are divided based on the segmentation as defined in the PCR, namely upstream module, core module (core infrastructure and core process), and downstream module.

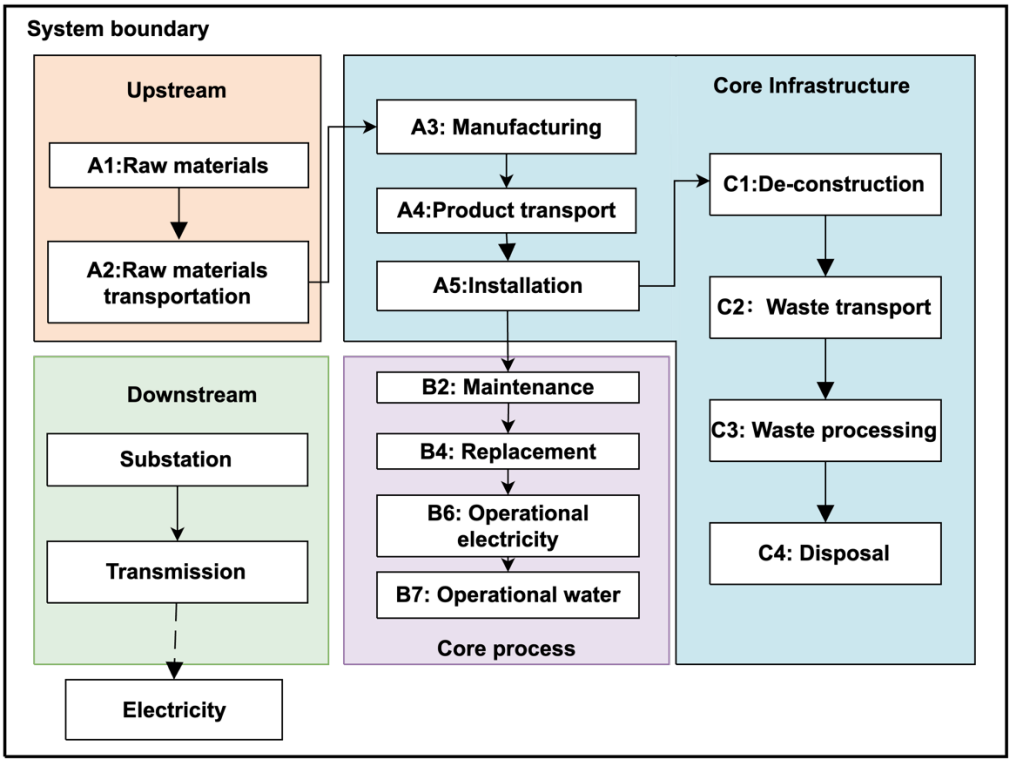


Figure 3-1 System boundary

3.2. Type of EPD

This EPD is a product-specific EPD. The declaration covers 7 products:

(1) (PERC) BVM7612M-xxx-H-HC-BF-DG (510-555W)

(2) (PERC) BVM7612M-xxx-H-HC-BF (510-555W)

(3) (TOPCon) BVM7612M-xxx-H-HC (550-590W)

(4) (TOPCon) BVM7612M-xxx-H-HC-BF-DG (550-590W)

(5) (TOPCon) BVM7612M-xxx-H-HC-BF (3.2/4.0mm glass) (550-590W)

(6) (TOPCon) BVM7610M-xxx-H-HC-BF (all black/silver frame) (450-490W)

(7) (TOPCon) BVM7609M-xxx-H-HC-BF (all black) (400-440W)

3.3. Geographical scope

The upstream production of silicon ingot and silicon wafer take place in mainland China. The production of solar cells and PV modules occurs in Vietnam. During the reference period, the product is sold globally. To model the electricity generation by the PV plant using the declared product, a specific PV plant needs to be selected. In this study, the installation, operation, maintenance, and end-of-life processes of the PV plant is taken place in Vietnam.

3.4. Time representativeness

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

3.5. Database and LCA software used

In this study, generic data for materials, energy as well as waste disposal and transportation were taken from the database Ecoinvent 3.10. LCA-software SimaPro 9.6 was used for the modeling and calculation.

4. DETAILED PRODUCT DESCRIPTION

4.1. Description of the Product

Boviet Solar's photovoltaic (PV) modules, including the Mono-Monofacial Gamma Series™ and Mono-Bifacial Vega Series™, are designed for exceptional performance and durability. By incorporating advanced technologies such as PERC and TOPCon cells, half-cut designs, multi-busbar layouts, and large cell configurations, these modules are engineered to capture more photons, generate more energy, and ensure reliable system performance under various installation requirements and environmental conditions. Boviet Solar's PV modules are made from high-purity monocrystalline wafers and robust components, manufactured under stringent quality controls and high-tech processes. This results in modules that deliver more power per unit, reduce project risks, lower the balance of system (BOS) costs, and decrease the levelized cost of electricity (LCOE). These features ensure a high return on investment (ROI) and long-term reliable energy generation for residential, commercial, industrial, and utility-scale projects. Boviet Solar is committed to utilizing best-in-class solar module technology, ensuring that their products continue to provide exceptional value and performance, making them the ideal choice for EPCs, installers, contractors, and project developers.

4.2. Technical parameters

Table 4-1 technical parameters of different PV modules

Brand	Power Rating (Wp)	Dimensions(mm^3)	Area (m^2)	Weight (kg)	Module efficiency (%) at STC	First year degradation (%)	Annual degradation (%)
(PERC) BVM7612M-xxx-H-HC-BF-DG	510-555	2296*1134*35mm	2.604	33.5	20.50-21.30	2.0	0.45
(PERC) BVM7612M-xxx-H-HC-BF	510-555	2296*1134*35mm	2.604	29	20.50-21.30	2.0	0.45
(TOPCon) BVM7612M-xxx-H-HC	550-590	2278*1134*35mm	2.583	28	21.68-22.45	1.0	0.40
(TOPCon) BVM7612M-xxx-H-HC-BF-DG	550-590	2278*1134*35mm	2.583	32	21.68-22.45	1.0	0.40
(TOPCon) BVM7612M-xxx-H-HC-BF (3.2/4.0mm glass)	550-590	2278*1134*35mm	2.583	28/32	21.68-22.45	1.0	0.40
(TOPCon) BVM7610M-xxx-H-HC-BF (all black/silver frame)	450-490	1903*1134*30mm	2.158	23	21.78-22.70	1.0	0.40
(TOPCon) BVM7609M-xxx-H-HC-BF (all black)	400-440	1722*1134*30mm	1.953	20	21.51-22.28	1.0	0.40

*Note: BVM: BOVIET Module; 7: 182 solar cells; 612/610/609: number of cells (6*24/6*20/6*18); M: mono-crystalline cell; HC: halved cell, BF: Bifacial module and could only use transparent backsheet; DG: double glass. STC: AM1.5 Irradiance 1000W/m2, 25° C*

4.3. Materials compositions

Table 4-2 Materials compositions (Mass ratio)

Materials classes	**Main substances**	**CAS No. of main substances**	(PERC) BVM7612M-xxx-H-HC-BF-DG	(PERC) BVM7612M-xxx-H-HC-BF	(TOPCon) BVM7612M-xxx-H-HC-BF-DG	(TOPCon) BVM7612M-xxx-H-HC-BF (3.2/4.0mm glass)	(TOPCon) BVM7612M-xxx-H-HC	(TOPCon) BVM7610M-xxx-H-HC-BF (all black/silver frame)	(TOPCon) BVM7609M-xxx-H-HC-BF (all black)
Glass	$Na_2O{\cdot}nSiO_2$	1344-09-8; 106985-35-7	74.2%	70.8%	74.4%	73.3%	71.1%	67.0%	66.4%
Backsheet	$(C_{10}H_8O_4)_n$	25038-59-9	0.0%	0.0%	0.0%	0.0%	0.0%	3.6%	3.6%
POE	$(CH2CHR)_n$	308070-21-5	7.9%	4.5%	3.9%	4.1%	4.5%	4.5%	4.4%
EVA	$(C_2H_4)_x(C_4H_6O_2)_y$	24937-78-8	0.0%	4.5%	3.9%	4.1%	4.5%	4.5%	4.4%
Frame	Al	7429-90-5	10.2%	11.6%	10.0%	10.4%	11.3%	10.9%	11.2%
Solder	Sn	7440-31-5	0.6%	0.7%	0.8%	0.8%	0.9%	0.9%	0.9%
Cells	Si	7440-21-3	2.3%	2.6%	2.1%	2.2%	2.4%	2.4%	2.3%
Junction Box	Cu	7440-50-8	2.9%	3.3%	0.0%	0.0%	0.0%	0.0%	0.0%
Flux	C_3H_8O	67-63-0	0.0%	0.0%	2.9%	3.0%	3.3%	3.9%	4.3%
Silicone	SiO_2	112926-00-8	0.6%	0.7%	0.7%	0.7%	0.8%	0.9%	1.0%

4.4. Description of the production process

All the products share similar manufacturing processes. Figure 4-1 describes the production processes.

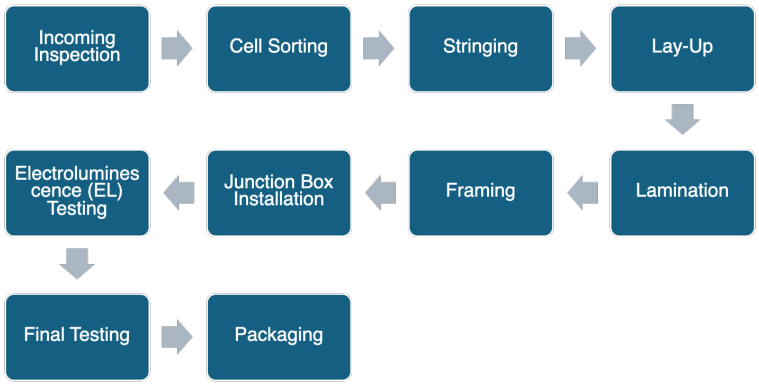


Figure 4-1 Manufacturing process flow diagram of PV module

Step 1 : **Incoming Inspection**

Inspect incoming raw materials for quality and specifications.

Step 2: **Cell Sorting**

Sort solar cells based on their electrical characteristics and quality.

Step 3: **Stringing**

Connect solar cells in series using soldering to form a cell string.

Step 4: **Lay-Up**

Place the cell strings onto a sheet of encapsulant material in a specific pattern.

Step 5: **Lamination**

Encapsulate the cell strings between layers of protective materials and laminate them to form a solid module.

Step 6: **Framing**

Attach a metal frame around the laminated module to provide structural support and protection.

Step 7: **Junction Box Installation**

Install a junction box on the back of the module for electrical connections and output.

Step 8: **Electroluminescence (EL) Testing**

Conduct EL testing to check for defects or cracks in the solar cells that are not visible to the naked eye.

Step 9: **Final Testing**

Perform various tests, including electrical performance and visual inspection, to ensure the module meets quality standards.

Step 10: **Packaging**

Package the finished modules for shipment and delivery.

5. LCA RESULTS

The LCA results show the environmental impacts and resource input and output flows calculated according to EN 15804:2012+A2:2019/AC:2021.

5.1. Environmental impacts

Table 5-1 Environmental impacts – (PERC) BVM7612M-xxx-H-HC-BF-DG

Category	Unit	Upstream	Core-infrastructure	Core-process	Downstream	Total
GWP-total	kg CO_2 eq	1.17E-02	5.07E-03	2.03E-03	4.80E-04	1.92E-02
GWP-fossil	kg CO_2 eq	1.16E-02	5.05E-03	2.03E-03	4.78E-04	1.92E-02
GWP-biogenic	kg CO_2 eq	4.48E-05	1.19E-05	7.05E-07	4.37E-07	5.78E-05
GWP-luluc	kg CO_2 eq	7.39E-06	3.29E-06	2.93E-07	1.03E-06	1.20E-05
ODP	kg CFC11 eq	1.22E-10	3.59E-11	1.40E-11	3.54E-12	1.75E-10
AP	mol H+ eq	7.16E-05	8.66E-05	1.86E-05	4.59E-06	1.81E-04
EP-Freshwater	kg P eq	3.24E-07	4.64E-07	9.10E-08	2.38E-08	9.03E-07
EP-Marine	kg N eq	1.44E-05	6.64E-06	2.40E-06	5.79E-07	2.40E-05
EP-Terrestrial	mol N eq	1.51E-04	8.48E-05	2.66E-05	6.83E-06	2.70E-04
POCP	kg NMVOC eq	4.41E-05	2.73E-05	7.77E-06	2.24E-06	8.14E-05
ADP- M&M*	kg Sb eq	7.52E-02	2.92E-02	1.58E-02	2.81E-03	1.23E-01
ADP-fossil*	MJ	3.85E-07	9.06E-07	9.71E-09	3.15E-08	1.33E-06
WDP	m^3 depriv.	1.37E-02	1.87E-03	7.64E-04	1.26E-04	1.65E-02

* The results of this environmental impact indicator shall be used with care as the uncertainties of these results are high or as there is limited experience with the indicator.

Table 5-2 Environmental impacts –(PERC) BVM7612M-xxx-H-HC-BF

Category	Unit	Upstream	Core-infrastructure	Core-process	Downstream	Total
GWP-total	kg CO_2 eq	1.18E-02	5.15E-03	2.08E-03	4.93E-04	1.95E-02
GWP-fossil	kg CO_2 eq	1.17E-02	5.14E-03	2.08E-03	4.92E-04	1.94E-02
GWP-biogenic	kg CO_2 eq	4.46E-05	1.23E-05	7.11E-07	4.49E-07	5.81E-05
GWP-luluc	kg CO_2 eq	7.56E-06	3.37E-06	3.01E-07	1.06E-06	1.23E-05
ODP	kg CFC11 eq	1.23E-10	3.65E-11	1.44E-11	3.64E-12	1.77E-10
AP	mol H+ eq	7.16E-05	8.86E-05	1.91E-05	4.72E-06	1.84E-04
EP-Freshwater	kg P eq	3.30E-07	4.75E-07	9.35E-08	2.45E-08	9.24E-07
EP-Marine	kg N eq	1.45E-05	6.75E-06	2.46E-06	5.95E-07	2.43E-05
EP-Terrestrial	mol N eq	1.52E-04	8.64E-05	2.73E-05	7.02E-06	2.72E-04
POCP	kg NMVOC eq	4.42E-05	2.78E-05	7.98E-06	2.31E-06	8.22E-05
ADP- M&M*	kg Sb eq	7.70E-02	2.97E-02	1.62E-02	2.89E-03	1.26E-01
ADP-fossil*	MJ	3.95E-07	9.31E-07	9.96E-09	3.23E-08	1.37E-06
WDP	m^3 depriv.	1.41E-02	1.93E-03	7.85E-04	1.30E-04	1.69E-02

* The results of this environmental impact indicator shall be used with care as the uncertainties of these results are high or as there is limited experience with the indicator.

Table 5-3 Environmental impacts – (TOPCon) BVM7612M-xxx-H-HC-BF-DG

Category	Unit	Upstream	Core-infrastructure	Core-process	Downstream	Total
GWP-total	kg CO_2 eq	1.04E-02	5.01E-03	2.02E-03	4.79E-04	1.79E-02
GWP-fossil	kg CO_2 eq	1.04E-02	5.00E-03	2.02E-03	4.78E-04	1.79E-02
GWP-biogenic	kg CO_2 eq	4.23E-05	1.19E-05	7.00E-07	4.37E-07	5.54E-05
GWP-luluc	kg CO_2 eq	6.80E-06	3.28E-06	2.90E-07	1.03E-06	1.14E-05
ODP	kg CFC11 eq	1.15E-10	3.56E-11	1.40E-11	3.54E-12	1.68E-10
AP	mol H+ eq	6.60E-05	8.62E-05	1.86E-05	4.59E-06	1.75E-04
EP-Freshwater	kg P eq	3.20E-07	4.63E-07	9.10E-08	2.38E-08	8.97E-07
EP-Marine	kg N eq	1.30E-05	6.58E-06	2.38E-06	5.78E-07	2.25E-05
EP-Terrestrial	mol N eq	1.38E-04	8.42E-05	2.65E-05	6.82E-06	2.56E-04
POCP	kg NMVOC eq	4.03E-05	2.71E-05	7.75E-06	2.24E-06	7.74E-05
ADP- M&M*	kg Sb eq	6.58E-02	2.90E-02	1.57E-02	2.80E-03	1.13E-01
ADP-fossil*	MJ	5.70E-07	9.05E-07	1.18E-08	3.14E-08	1.52E-06
WDP	m^3 depriv.	1.13E-02	1.87E-03	7.45E-04	1.26E-04	1.41E-02

* The results of this environmental impact indicator shall be used with care as the uncertainties of these results are high or as there is limited experience with the indicator.

Table 5-4 Environmental impacts- (TOPCon) BVM7612M-xxx-H-HC-BF (3.2 /4.0mm glass)

Category	Unit	Upstream	Core-infrastructure	Core-process	Downstream	Total
GWP-total	kg CO_2 eq	1.07E-02	5.10E-03	2.05E-03	4.88E-04	1.83E-02
GWP-fossil	kg CO_2 eq	1.07E-02	5.08E-03	2.05E-03	4.86E-04	1.83E-02
GWP-biogenic	kg CO_2 eq	4.33E-05	1.21E-05	7.07E-07	4.44E-07	5.66E-05
GWP-luluc	kg CO_2 eq	7.02E-06	3.33E-06	2.95E-07	1.05E-06	1.17E-05
ODP	kg CFC11 eq	1.17E-10	3.61E-11	1.42E-11	3.60E-12	1.71E-10
AP	mol H+ eq	6.76E-05	8.77E-05	1.89E-05	4.67E-06	1.79E-04
EP-Freshwater	kg P eq	3.30E-07	4.71E-07	9.26E-08	2.42E-08	9.17E-07
EP-Marine	kg N eq	1.33E-05	6.68E-06	2.43E-06	5.88E-07	2.30E-05
EP-Terrestrial	mol N eq	1.42E-04	8.55E-05	2.70E-05	6.94E-06	2.61E-04
POCP	kg NMVOC eq	4.13E-05	2.75E-05	7.88E-06	2.28E-06	7.90E-05
ADP- M&M*	kg Sb eq	6.80E-02	2.95E-02	1.60E-02	2.85E-03	1.16E-01
ADP-fossil*	MJ	5.90E-07	9.21E-07	1.20E-08	3.20E-08	1.56E-06
WDP	m^3 depriv.	1.17E-02	1.90E-03	7.58E-04	1.28E-04	1.45E-02

* The results of this environmental impact indicator shall be used with care as the uncertainties of these results are high or as there is limited experience with the indicator.

Table 5-5 Environmental impacts- (TOPCon) BVM7612M-xxx-H-HC

Category	Unit	Upstream	Core-infrastructure	Core-process	Downstream	Total
GWP-total	kg CO_2 eq	1.10E-02	5.26E-03	2.13E-03	5.06E-04	1.89E-02
GWP-fossil	kg CO_2 eq	1.09E-02	5.25E-03	2.13E-03	5.04E-04	1.88E-02

GWP-biogenic	kg CO_2 eq	4.39E-05	1.26E-05	7.23E-07	4.61E-07	5.77E-05
GWP-luluc	kg CO_2 eq	7.24E-06	3.45E-06	3.05E-07	1.09E-06	1.21E-05
ODP	kg CFC11 eq	1.18E-10	3.73E-11	1.47E-11	3.73E-12	1.73E-10
AP	mol H+ eq	6.88E-05	9.07E-05	1.96E-05	4.84E-06	1.84E-04
EP-Freshwater	kg P eq	3.40E-07	4.87E-07	9.60E-08	2.51E-08	9.48E-07
EP-Marine	kg N eq	1.36E-05	6.90E-06	2.51E-06	6.10E-07	2.36E-05
EP-Terrestrial	mol N eq	1.44E-04	8.83E-05	2.80E-05	7.20E-06	2.68E-04
POCP	kg NMVOC eq	4.21E-05	2.84E-05	8.16E-06	2.37E-06	8.11E-05
ADP- M&M*	kg Sb eq	7.02E-02	3.04E-02	1.65E-02	2.96E-03	1.20E-01
ADP-fossil*	MJ	6.11E-07	9.55E-07	1.24E-08	3.32E-08	1.61E-06
WDP	m^3 depriv.	1.21E-02	1.98E-03	7.85E-04	1.33E-04	1.50E-02

* The results of this environmental impact indicator shall be used with care as the uncertainties of these results are high or as there is limited experience with the indicator.

Table 5-6 Environmental impacts- (TOPCon) BVM7610M-xxx-H-HC-BF (all black/silver frame)

Category	Unit	Upstream	Core-infrastructure	Core-process	Downstream	Total
GWP-total	kg CO_2 eq	1.07E-02	5.19E-03	2.03E-03	4.88E-04	1.85E-02
GWP-fossil	kg CO_2 eq	1.07E-02	5.18E-03	2.03E-03	4.87E-04	1.84E-02
GWP-biogenic	kg CO_2 eq	4.16E-05	1.21E-05	6.18E-07	4.45E-07	5.48E-05
GWP-luluc	kg CO_2 eq	7.04E-06	3.33E-06	2.83E-07	1.05E-06	1.17E-05
ODP	kg CFC11 eq	8.14E-10	3.60E-11	2.00E-11	3.60E-12	8.74E-10
AP	mol H+ eq	6.69E-05	8.75E-05	1.88E-05	4.67E-06	1.78E-04
EP-Freshwater	kg P eq	3.34E-07	4.70E-07	9.21E-08	2.42E-08	9.21E-07
EP-Marine	kg N eq	1.32E-05	6.67E-06	2.40E-06	5.89E-07	2.29E-05
EP-Terrestrial	mol N eq	1.40E-04	8.53E-05	2.67E-05	6.95E-06	2.59E-04
POCP	kg NMVOC eq	4.12E-05	2.75E-05	7.81E-06	2.28E-06	7.87E-05
ADP- M&M*	kg Sb eq	6.87E-02	2.94E-02	1.59E-02	2.86E-03	1.17E-01
ADP-fossil*	MJ	6.01E-07	9.22E-07	1.11E-08	3.20E-08	1.57E-06
WDP	m^3 depriv.	1.17E-02	1.91E-03	7.38E-04	1.28E-04	1.45E-02

* The results of this environmental impact indicator shall be used with care as the uncertainties of these results are high or as there is limited experience with the indicator.

Table 5-7 Environmental impacts- (TOPCon) BVM7609M-xxx-H-HC-BF (all black)

Category	Unit	Upstream	Core-infrastructure	Core-process	Downstream	Total
GWP-total	kg CO_2 eq	1.07E-02	5.13E-03	2.01E-03	4.83E-04	1.83E-02
GWP-fossil	kg CO_2 eq	1.06E-02	5.11E-03	2.00E-03	4.82E-04	1.82E-02
GWP-biogenic	kg CO_2 eq	4.16E-05	1.20E-05	5.82E-07	4.40E-07	5.46E-05
GWP-luluc	kg CO_2 eq	7.07E-06	3.30E-06	2.75E-07	1.04E-06	1.17E-05
ODP	kg CFC11 eq	8.07E-10	3.55E-11	1.91E-11	3.56E-12	8.65E-10
AP	mol H+ eq	6.63E-05	8.65E-05	1.85E-05	4.62E-06	1.76E-04

EP-Freshwater	kg P eq	3.31E-07	4.65E-07	9.09E-08	2.40E-08	9.11E-07
EP-Marine	kg N eq	1.31E-05	6.58E-06	2.37E-06	5.83E-07	2.26E-05
EP-Terrestrial	mol N eq	1.39E-04	8.42E-05	2.64E-05	6.88E-06	2.56E-04
POCP	kg NMVOC eq	4.08E-05	2.71E-05	7.70E-06	2.26E-06	7.79E-05
ADP- M&M*	kg Sb eq	6.81E-02	2.90E-02	1.56E-02	2.83E-03	1.16E-01
ADP-fossil*	MJ	5.99E-07	9.12E-07	1.05E-08	3.17E-08	1.55E-06
WDP	m^3 depriv.	1.16E-02	1.89E-03	7.21E-04	1.27E-04	1.43E-02

* The results of this environmental impact indicator shall be used with care as the uncertainties of these results are high or as there is limited experience with the indicator.

Caption:

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

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

5.2. Resources uses

Table 5-8 Resource use – (PERC) BVM7612M-xxx-H-HC-BF-DG

Category	Unit	Upstream	Core-infrastructure	Core-process	Downstream	Total
PERE	MJ	1.30E-02	7.99E-03	4.19E-03	5.12E-04	2.57E-02
PERM	MJ	1.17E-03	-1.17E-03	0.00E+00	0.00E+00	0.00E+00
PERT	MJ	1.42E-02	6.82E-03	4.19E-03	5.12E-04	2.57E-02
PENRE	MJ	1.07E-01	4.17E-02	2.59E-02	4.18E-03	1.78E-01
PENRM	MJ	5.53E-03	-5.53E-03	0.00E+00	0.00E+00	0.00E+00
PENRT	MJ	1.12E-01	4.17E-02	2.59E-02	4.18E-03	1.84E-01
SM	kg	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
NRSF	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FW	m3	3.33E-04	5.30E-05	1.11E-05	4.71E-06	4.01E-04

Table 5-9 Resource use – (PERC) BVM7612M-xxx-H-HC-BF

Category	Unit	Upstream	Core-infrastructure	Core-process	Downstream	Total
PERE	MJ	1.33E-02	8.13E-03	4.30E-03	5.26E-04	2.62E-02
PERM	MJ	1.20E-03	-1.20E-03	0.00E+00	0.00E+00	0.00E+00
PERT	MJ	1.45E-02	6.92E-03	4.30E-03	5.26E-04	2.62E-02
PENRE	MJ	1.10E-01	4.76E-02	2.66E-02	4.29E-03	1.88E-01
PENRM	MJ	5.17E-03	-5.17E-03	0.00E+00	0.00E+00	0.00E+00
PENRT	MJ	1.15E-01	4.24E-02	2.66E-02	4.29E-03	1.88E-01

SM	kg	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
NRSF	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FW	m3	3.41E-04	5.44E-05	1.14E-05	4.84E-06	4.12E-04

Table 5-10 Resource use – (TOPCon) BVM7612M-xxx-H-HC-BF-DG

Category	Unit	Upstream	Core-infrastructure	Core-process	Downstream	Total
PERE	MJ	1.18E-02	7.87E-03	4.18E-03	5.11E-04	2.43E-02
PERM	MJ	1.11E-03	-1.11E-03	0.00E+00	0.00E+00	0.00E+00
PERT	MJ	1.29E-02	6.76E-03	4.18E-03	5.11E-04	2.43E-02
PENRE	MJ	9.28E-02	4.62E-02	2.58E-02	4.17E-03	1.69E-01
PENRM	MJ	4.79E-03	-4.79E-03	0.00E+00	0.00E+00	0.00E+00
PENRT	MJ	9.76E-02	4.14E-02	2.58E-02	4.17E-03	1.69E-01
SM	kg	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
NRSF	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FW	m3	2.76E-04	5.29E-05	1.06E-05	4.71E-06	3.44E-04

Table 5-11 Resource use- (TOPCon) BVM7612M-xxx-H-HC-BF (3.2 /4.0mm glass)

Category	Unit	Upstream	Core-infrastructure	Core-process	Downstream	Total
PERE	MJ	1.21E-02	8.01E-03	4.25E-03	5.20E-04	2.49E-02
PERM	MJ	1.15E-03	-1.15E-03	0.00E+00	0.00E+00	0.00E+00
PERT	MJ	1.33E-02	6.86E-03	4.25E-03	5.20E-04	2.49E-02
PENRE	MJ	9.59E-02	4.70E-02	2.62E-02	4.25E-03	1.73E-01
PENRM	MJ	4.96E-03	-4.96E-03	0.00E+00	0.00E+00	0.00E+00
PENRT	MJ	1.01E-01	4.20E-02	2.62E-02	4.25E-03	1.73E-01
SM	kg	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
NRSF	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FW	m3	2.85E-04	5.38E-05	1.08E-05	4.79E-06	3.55E-04

Table 5-12 Resource use-(TOPCon) BVM7612M-xxx-H-HC

Category	Unit	Upstream	Core-infrastructure	Core-process	Downstream	Total
PERE	MJ	1.25E-02	8.27E-03	4.41E-03	5.39E-04	2.57E-02
PERM	MJ	1.19E-03	-1.19E-03	0.00E+00	0.00E+00	0.00E+00
PERT	MJ	1.37E-02	7.08E-03	4.41E-03	5.39E-04	2.57E-02
PENRE	MJ	9.91E-02	4.85E-02	2.72E-02	4.40E-03	1.79E-01
PENRM	MJ	5.18E-03	-5.18E-03	0.00E+00	0.00E+00	0.00E+00

PENRT	MJ	1.04E-01	4.33E-02	2.72E-02	4.40E-03	1.79E-01
SM	kg	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
NRSF	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FW	m3	2.95E-04	5.58E-05	1.12E-05	4.97E-06	3.67E-04

Table 5-13 Resource use-(TOPCon) BVM7610M-xxx-H-HC-BF (all black/silver frame)

Category	Unit	Upstream	Core-infrastructure	Core-process	Downstream	Total
PERE	MJ	1.22E-02	7.87E-03	4.23E-03	5.21E-04	2.48E-02
PERM	MJ	1.03E-03	-1.03E-03	0.00E+00	0.00E+00	0.00E+00
PERT	MJ	1.32E-02	6.83E-03	4.23E-03	5.21E-04	2.48E-02
PENRE	MJ	9.55E-02	4.80E-02	2.61E-02	4.25E-03	1.74E-01
PENRM	MJ	6.15E-03	-6.15E-03	0.00E+00	0.00E+00	0.00E+00
PENRT	MJ	1.02E-01	4.18E-02	2.61E-02	4.25E-03	1.74E-01
SM	kg	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
NRSF	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FW	m3	2.86E-04	5.40E-05	1.03E-05	4.79E-06	3.55E-04

Table 5-14 Resource use-(TOPCon) BVM7609M-xxx-H-HC-BF (all black)

Category	Unit	Upstream	Core-infrastructure	Core-process	Downstream	Total
PERE	MJ	1.19E-02	7.68E-03	4.17E-03	5.15E-04	2.42E-02
PERM	MJ	9.38E-04	-9.38E-04	0.00E+00	0.00E+00	0.00E+00
PERT	MJ	1.28E-02	6.74E-03	4.17E-03	5.15E-04	2.42E-02
PENRE	MJ	9.46E-02	4.74E-02	2.57E-02	4.21E-03	1.72E-01
PENRM	MJ	6.11E-03	-6.11E-03	0.00E+00	0.00E+00	0.00E+00
PENRT	MJ	1.01E-01	4.13E-02	2.57E-02	4.21E-03	1.72E-01
SM	kg	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
NRSF	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FW	m3	2.82E-04	5.34E-05	1.00E-05	4.75E-06	3.50E-04

Caption:

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

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

5.3. End-of-life-Waste

Table 5-15 Waste- (PERC) BVM7612M-xxx-H-HC-BF-DG

Category	Unit	Upstream	Core-infrastructure	Core-process	Downstream	Total
HWD	kg	2.00E-05	2.21E-06	2.36E-07	5.12E-08	2.25E-05
NHWD	kg	4.37E-04	3.08E-03	4.59E-05	1.99E-03	5.56E-03
RWD	kg	1.00E-07	5.06E-08	2.85E-09	3.17E-09	1.57E-07

Table 5-16 Waste- (PERC) BVM7612M-xxx-H-HC-BF

Category	Unit	Upstream	Core-infrastructure	Core-process	Downstream	Total
HWD	kg	2.06E-05	2.27E-06	2.42E-07	5.27E-08	2.31E-05
NHWD	kg	4.33E-04	3.22E-03	4.70E-05	2.05E-03	5.75E-03
RWD	kg	1.03E-07	5.19E-08	2.93E-09	3.26E-09	1.61E-07

Table 5-17 Waste- (TOPCon) BVM7612M-xxx-H-HC-BF-DG

Category	Unit	Upstream	Core-infrastructure	Core-process	Downstream	Total
HWD	kg	1.62E-05	2.21E-06	2.05E-07	5.12E-08	1.87E-05
NHWD	kg	4.04E-04	3.24E-03	4.57E-05	1.99E-03	5.68E-03
RWD	kg	8.95E-08	5.05E-08	2.79E-09	3.17E-09	1.46E-07

Table 5-18 Waste- (TOPCon) BVM7612M-xxx-H-HC-BF (3.2/4.0 mm glass)

Category	Unit	Upstream	Core-infrastructure	Core-process	Downstream	Total
HWD	kg	1.68E-05	2.25E-06	2.09E-07	5.21E-08	1.93E-05
NHWD	kg	4.12E-04	3.25E-03	4.65E-05	2.03E-03	5.73E-03
RWD	kg	9.24E-08	5.14E-08	2.83E-09	3.22E-09	1.50E-07

Table 5-19 Waste- (TOPCon) BVM7612M-xxx-H-HC

Category	Unit	Upstream	Core-infrastructure	Core-process	Downstream	Total
HWD	kg	1.74E-05	2.33E-06	2.16E-07	5.40E-08	2.00E-05
NHWD	kg	4.16E-04	3.24E-03	4.81E-05	2.10E-03	5.80E-03
RWD	kg	9.53E-08	5.32E-08	2.93E-09	3.34E-09	1.55E-07

Table 5-20 Waste- (TOPCon) BVM7610M-xxx-H-HC-BF (all black/silver frame)

Category	Unit	Upstream	Core-infrastructure	Core-process	Downstream	Total
HWD	kg	1.69E-05	2.25E-06	1.80E-07	5.21E-08	1.93E-05
NHWD	kg	4.10E-04	3.13E-03	4.57E-05	2.03E-03	5.61E-03
RWD	kg	9.50E-08	5.14E-08	2.70E-09	3.23E-09	1.52E-07

Table 5-21 Waste-(TOPCon) BVM7609M-xxx-H-HC-BF (all black)

Category	Unit	Upstream	Core-infrastructure	Core-process	Downstream	Total
HWD	kg	1.66E-05	2.22E-06	1.64E-07	5.16E-08	1.91E-05
NHWD	kg	4.07E-04	3.10E-03	4.49E-05	2.01E-03	5.56E-03
RWD	kg	9.42E-08	5.08E-08	2.60E-09	3.19E-09	1.51E-07

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

5.4. End-of-life-Output flows

Table 5-22 Output flows- (PERC) BVM7612M-xxx-H-HC-BF-DG

Category	Unit	Upstream	Core-infrastructure	Core-process	Downstream	Total
CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MFR	kg	0.00E+00	2.26E-03	0.00E+00	0.00E+00	2.26E-03
MER	kg	0.00E+00	2.65E-04	0.00E+00	0.00E+00	2.65E-04
ETE	MJ	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

Table 5-23 Output flows-(PERC) BVM7612M-xxx-H-HC-BF

Category	Unit	Upstream	Core-infrastructure	Core-process	Downstream	Total
CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MFR	kg	0.00E+00	2.18E-03	0.00E+00	0.00E+00	2.18E-03
MER	kg	0.00E+00	2.72E-04	0.00E+00	0.00E+00	2.72E-04
ETE	MJ	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

Table 5-24 Output flows- (TOPCon) BVM7612M-xxx-H-HC-BF-DG

Category	Unit	Upstream	Core-infrastructure	Core-process	Downstream	Total
CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MFR	kg	0.00E+00	2.19E-03	0.00E+00	0.00E+00	2.19E-03
MER	kg	0.00E+00	2.56E-04	0.00E+00	0.00E+00	2.56E-04
ETE	MJ	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

Table 5-25 Output flows-(TOPCon) BVM7612M-xxx-H-HC-BF (3.2/4.0 mm glass)

Category	Unit	Upstream	Core-infrastructure	Core-process	Downstream	Total
CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MFR	kg	0.00E+00	2.20E-03	0.00E+00	0.00E+00	2.20E-03

MER	kg	0.00E+00	2.64E-04	0.00E+00	0.00E+00	2.64E-04
ETE	MJ	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

Table 5-26 Output flows- (TOPCon) BVM7612M-xxx-H-HC

Category	Unit	Upstream	Core-infrastructure	Core-process	Downstream	Total
CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MFR	kg	0.00E+00	2.19E-03	0.00E+00	0.00E+00	2.19E-03
MER	kg	0.00E+00	2.74E-04	0.00E+00	0.00E+00	2.74E-04
ETE	MJ	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

Table 5-27 Output flows-(TOPCon) BVM7610M-xxx-H-HC-BF (silver frame/all black)

Category	Unit	Upstream	Core-infrastructure	Core-process	Downstream	Total
CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MFR	kg	0.00E+00	2.11E-03	0.00E+00	0.00E+00	2.11E-03
MER	kg	0.00E+00	3.11E-04	0.00E+00	0.00E+00	3.11E-04
ETE	MJ	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

Table 5-28 Output flows-(TOPCon) BVM7609M-xxx-H-HC-BF (all black)

Category	Unit	Upstream	Core-infrastructure	Core-process	Downstream	Total
CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MFR	kg	0.00E+00	2.10E-03	0.00E+00	0.00E+00	2.10E-03
MER	kg	0.00E+00	3.02E-04	0.00E+00	0.00E+00	3.02E-04
ETE	MJ	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

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

6. Calculation rules

6.1. Functional unit and Reference Service Life

Functional unit defined in this report is 1 kWh of electricity generated as output from the solar photovoltaic plant, from cradle-to-grave, with activities needed for a reference service of life (RSL) of 30 years.

Table 6-1 PV plant information

Parameters	Value		Source
	Amount	Unit	
Peak power of the plant	100000	KW	Boviet Solar
Plant latitude and longitude	N 11°5'58", E 106°9'57"	°	Boviet Solar
Plant altitude	70	m	Boviet Solar
Nominal solar irradiance	1971000~2062000	Wh/m²/year	Boviet Solar

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

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

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.

Following the EPDItaly PCR, the reference service life (RSL) of Solar modules is 30 years.

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

Where E_1 is the energy produced in the first year of operation, kWh/year, and deg is the degradation rate.

Table 6-2 PV plant information

Module	**First year energy generation (MWh)**	**30 years energy generation (MWh)**	**Performance ratio**
(PERC) BVM7612M-xxx-H-HC-BF-DG	152526	4259008	0.856
(PERC) BVM7612M-xxx-H-HC-BF	148404	4143908	0.832
(TOPCon) BVM7612M-xxx-H-HC-BF-DG	152679	4263280	0.856
(TOPCon) BVM7612M-xxx-H-HC-BF (3.2/4.0mm glass)	150009	4188725	0.841
(TOPCon) BVM7612M-xxx-H-HC	144687	4040118	0.812
(TOPCon) BVM7610M-xxx-H-HC-BF (all black/silver frame)	149938	4186743	0.841
(TOPCon) BVM7609M-xxx-H-HC-BF (all black)	151482	4229856	0.850

6.2. Assumptions

Table 6-3 List of assumptions

Categories	Items	Assumptions
Manufacturing stage (A1-A3)	Silicon wafer	Life cycle inventory (LCI) data of silicon ingot and the silicon wafer uses an average LCI data for China in IEA PVPS Task 12, 2020 for modelling.
Transportation stage (A2 & A4)	Transportation vehicle type	For the vehicle used in raw materials and product transportation, EURO 6 type vehicle with 16-32 ton capacity is assumed for modelling. Scenarios included are currently in use and are representative for one of the most probable alternatives.
Installation stage (A5)	Waste treatment of packaging materials	For the packaging materials of the PV module, pallets are assumed to be 75% recycled and 25% incinerated, while other paper and plastic packaging materials are assumed to be incinerated. For the packaging of electrical equipment, which mostly consists of metal materials, it is assumed that all materials are reused.
Use & Maintenance	Use (B1)	The use stage requires no energy and materials inputs, and has no emissions.
End-of-life (C1-C4)	De-construction (C1)	Decommissioning of PV modules is assumed to be taken with same energy consumption as for installation stage
	Waste transportation (C2)	Waste transportation distance from the de-installation plant to the waste treatment facilities is assumed to be 100 km for simplification purposes.
	Waste processing (C3)	The electricity consumption during this stage is 0.277kWh/kg module based on the data from IEA. For other electrical equipment, a default waste electric equipment shredding process taken from Ecoinvent database is considered.
	Disposal (C4)	Disposal scenarios are based on the WEEE and IEA report.

6.3. Cut-off rules

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

6.4. Data quality

Primary data (such as materials or energy flows that enter and leave the production system) is from Boviet manufacturing facilities in a reference period from Jan. 2023 to Dec. 2023 (annual average). Generic data related to the life cycle impacts of the material or energy flows that enter and leave the production system is sourced from Ecoinvent 3.10 "allocation, cut-off by classification - unit" database.

6.5. Allocations

The allocation is made in accordance with the provisions of EN 15804. Allocation refers to the partitioning of input or output flows of a process or a product system between the product systems under study and one or more other product systems. In this study, there are three types of allocation procedures considered:

Multi-input allocation

For data sets in this study, the electricity consumption and emissions of the cells are allocated based on quantity, the electricity consumption and emissions during the manufacturing stage of the PV modules are allocated based on power output, and the transportation of raw materials is allocated based on mass.

Multi-output allocation

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

End-of-life allocation

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

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

6.6. Electricity mix

In this LCA study, it is important to note that different electricity grid mixes are used for various stages of the life cycle. Specifically, the production of upstream silicon ingots and silicon wafers is sourced from mainland China, utilizing the China grid electricity mix. The production of solar cells and PV modules occurs in Vietnam, where the Vietnam grid electricity mix is applied. For the installation, operation, and end-of-life stages, which all take place in Vietnam, the Vietnam grid electricity mix is used.

7. LCA calculation scenarios

7.1. Distribution

At the reference period, the product is distributed worldwide. To model the electricity generation of the PV plant using the declared product, the product distribution comprises a scenario of transportation from the manufacturing site (Bac Giang Province, Vietnam) to the installation site, which in this study, is Tay Ninh Province, Vietnam. The ocean transportation distance is 1500 km, and the road transportation distance is 300 km.

7.2. Installation

At the installation stage, PV modules, along with other electrical equipment, are installed. The installation is based on a 100MW PV plant located at Tay Ninh Province, Vietnam. Electrical equipment and mounting structure, as well as the infrastructure foundation data is provided by Boviet Solar from the PV plant. All the electrical equipment is transported from Suzhou, mainland China to the port in Guangzhou via truck with a road distance of 1465 km. From Guangzhou Port, the equipment is transported by sea to Bin Qiao, Xining, Vietnam, for a distance of 2700 km, and then by truck for an additional 200 km (from the port to the installation site). For foundation materials, they are transported from local suppliers with a 100 km transportation distance. The waste generated from the product packaging, mainly consisting of waste wood pallets, is accounted for in this stage, transportation of waste is assumed as 200 km. For packaging waste, the treatment of the waste wood pallets is modeled as 75% recycling and 25% incineration. Other packaging materials, including paper and plastic film, are modeled as 100% incineration.

7.3. Use & Maintenance

For the use stage (B1) of the PV products, no energy and materials inputs, or emissions are involved. As for the maintenance stage (B2), water used for cleaning to maintain the performance is considered. The water consumption for cleaning the PV modules is calculated based on a daily consumption of two tanks, each holding 10,000 liters. The cleaning process last 15 days and is carried out twice a year. According to the operational and maintenance records of the PV plant over the past five years, a total of 300 modules and 2 inverters have been replaced (B4). No repair (B3), and refurbishment (B5) is required. As for operational electricity (B6) consumption, the plant consumes an average of 395424 kWh per year. For operational water consumption (B7), with approximately 20 workers at the PV plant using 5 tons of water per day, and assuming 360 working days per year, the total water consumption amounts to 1,800 tons

annually.

7.4. End-of-life

For end-of-life (EoL) stage, assumptions are made due to a lack of data. Decommissioning stage (C1) of PV modules is assumed to be taken with same energy consumption as for installation stage. Transportation distance from the plant site to the waste treatment site (C2) is assumed to be 100km. Waste processing (C3) stage is assumed to be mechanically treated to yield the bulk materials. This study refers to legal requirements issued by Waste Electrical and Electronic Equipment (WEEE) under the EU scenario.

7.5. Downstream process

In this study, from the PV plant to the grid, a 7 km transmission line is modelled, the distribution loss from the PV plant to the grid is 0.278% provided by Boviet Solar.

8. REFERENCES

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