Environmental Product Declaration

In accordance with ISO 14025:2006 and EN 15804:2012+A2:2019/AC:2021 for:

N-TOPCon Bifacial G12R

Manufactured by SAATVIK GREEN ENERGY LIMITED AND ITS SUBSIDIARY (SAATVIK SOLAR INDUSTRIES PVT LTD)

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An EPD may be updated or depublished if conditions change. The stated validity is therefore subject to the continued registration and publication at: www.environdec.com

General Information

Programme Information:

Programme: The International EPD System

Address: EPD International AB Box 21060 SE-100 31 Stockholm, Sweden

Website: www.environdec.com;

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Information about verification and reference PCR: CEN standard EN 15804 serves as the core Product Category Rules (PCR)
Product Category Rules: PCR 2019:14 Construction products, version 2.0.1 Photovoltaic modules and parts thereof (c-PCR to PCR 2019:14) (adopted from EPD Norway 2022-04-27
PCR review was conducted by: The Technical Committee of the International EPD® System. See www.environdec.com/TC for a list of members. PCR Review chair of V2.0.1: Rob Rouwette & Co-chair: Noa Meron. The review panel may be contacted via the Secretariat https://www.environdec.com/about-us/the-international-epd-system-about-the-system.
Independent third-party verification of the declaration and data, according to ISO 14025:2006: EPD process verification ✓ EPD verification

Third party verifier **Vijay Thakur** Independent EPD & LCA Verifier Eco-Assure Verification & Advisory vijay.thakur@ecoassurance.in	Approved Individual verifier by International EPD System Technical Committee, supported by the Secretariat
LCA Study Conducted by Sunil Kumar SIPL Pvt Ltd. New Delhi, India sunil@siplsustainability.com	

The EPD owner has the sole ownership, liability, and responsibility for the EPD. EPDs within the same product category but from different programs may not be comparable. EPDs of construction products may not be comparable if they do not comply with EN 15804. For further information about comparability, see EN 15804 and ISO 14025.

EPDs within the same product category but registered in different EPD programs, or not compliant with EN 15804, may not be comparable. For two EPDs to be comparable, they must be based on the same PCR (including the same version number) or be based on fully-aligned PCRs or versions of PCRs; cover products with identical functions, technical performances and use (e.g. identical declared/functional units); have equivalent system boundaries and descriptions of data; apply equivalent data quality requirements, methods of data collection, and allocation methods; apply identical cut-off rules and impact assessment methods (including the same version of characterization factors); have equivalent content declarations; and be valid at the time of comparison. For further information about comparability, see EN 15804 and ISO 14025.

Information about EPD Owner

Mr. Amresh Kumar Ray (Saatvik Green Energy Ltd) Email: amresh.ray@saatvikgroup.com

Saatvik Green Energy Ltd ('Saatvik") ranks among the "Top Solar Panel Manufacturers" in India with an annual current production capacity of 4.8GW/Annum, having its state-of-the-art manufacturing facility based in Ambala (Haryana). Saatvik Green Energy Ltd specializes in the manufacturing of high-quality solar PV modules. Established with a focus on delivering cutting-edge solar technology, Saatvik caters to both domestic and international markets. The company's product portfolio includes a range of MonoPERC, Bifacial & N-TopCon solar modules which are designed for various applications, including industrial, commercial, and utility-scale solar projects. Since its inception, the company has supplied more than 500+ High-efficiency Solar PV modules across domestic and international markets.
Saatvik Green Energy Ltd plans to expand with an integrated cell and module manufacturing plant in Odisha. Company will set up an initial 4.8 GW/ Annum cell manufacturing unit by FY 27 & also will set up 4GW/Annum Solar PV module manufacturing by FY26.

Saatvik's versatile modules power a broad range of applications, from institutional rooftops and commercial buildings to large utility-scale installations. Saatvik's technology not only meets today's energy demands but also supports a sustainable future by enabling clean energy generation across industries.
SAATVIK Offerings:-

- Tailored Solutions – ranging from few kW to multiple MW's
- 25 years' serviceability – Offering AMC
- Lifecycle Asset Management
- A variety of business models to suit your needs
    - Capex
    - PPA/OPEX (Pay as You Go Model)

Product-related or management system-related certifications:

Saatvik Green Energy Limited is an ISO 9001:2015, ISO 14001:2015, ISO 45001:2018 certified company.

IEC 61215-1:2021, IEC 61215-1-1:2021, IEC 61215-2:2021, IEC 61730-1:2023, IEC 61730-2:2023, EN IEC 61215-1:2021, EN IEC 61215-1-1:2021, EN IEC 61215-2:2021, EN IEC 61730-1:2018, EN IEC 61730-2:2018 , UL 61215-1:2021, UL 61215-1-1:2021, UL 61215-2:2021, UL 61730-1:2022, UL 61730-2:2022, CSA C22.2 No. 61730-1:19, CSA C22.2 No. 61730-2:19 , IS 14286 (Part 1/Sec 1) : 2023/ IEC 61215-1-1: 2021, IS/IEC 61730-1: 2023, IS/IEC 61730-2:2023, Sand & Dust - IEC 60068-2-68, Salt Mist- IEC 61701, Ammonia Corrosion- IEC 62716, PAN File-IEC 61853-1:2011, IAM Testing - IEC 61853-2:2016, PID- IEC 62804, LeTID IEC TS 63342: 2022 , CEC Testing-IEC 61215, RoHS , Reach , PV cycle

Name and Location of production site(s): the Plants are within 3km to each other.

- Plant-02: Saatvik Solar Industries Private Limited Hadbast No. 222, Village Dubli, Sub, Tehsil Saha, Distt. Ambala, Haryana-133101
- Plant-03: Saatvik Solar Industries Private Limited Village Mohri, Tehsil Shahbad Markanda, Ambala Road, District Kurukshetra, Haryana-136135

Product Information

N-TOPCon G12R Module is designed for higher power output and better efficiency among different types of modules including P-Type Module. Saatvik's N-TOPCon Solar PV Modules are built using the most advanced next-generation N-type cell technology and have seamless compatibility with standard racking and inverters. These panels are optimized with a G12R wafer size, ideal for utility-scale and high-output commercial installations.

Product Name: N-TOPCon G12R Bifacial Solar panel

Product Identification: Framed dual glass bifacial solar PV module

Product Description: Monocrystalline N-TOPCon Bifacial Solar Module containing 132 half-cut cells. These modules can be used in residential, commercial, and industrial buildings for electricity generation for various applications. They are also ideal for off-grid applications, utility-scale projects, transportation, public infrastructure, and specialized uses like floating solar also. **Similar product from the company is N-TOPCon M10R Bifacial Solar panel.**

UN CPC Code: 0461 Electric motors, solar panel, generators and transformers, and parts thereof.

Geographical scope: The product is manufactured in India while the use and end of life of product is global.

The technical specifications of the product are mentioned in below:

Features	Description
1. General Information:	
Type	Monocrystalline Bifacial Solar Module
Power Output (Pmax)	625 Watt-peak (Wp)
Cell Technology	N-TOPCon
Cell Configuration	132 half-cut cells
2. Electrical Characteristics:	
Maximum Power Voltage (Vmp)	41.11V
Maximum Power Current (Imp)	15.21A
Open Circuit Voltage (Voc)	48.98A
Short Circuit Current (Isc)	16.10A
Module Efficiency (%)	23.12%
3. Mechanical Characteristics:	
Dimensions	2382 mm (L) x 1134 mm (W) x 30 mm (T)
Weight	33.6 kgs, Packaging weight 1.93 Kg extra
Solar Cells per Module (Units) / Arrangement	132 cells / (11x6 || 11x6)
Solar Cell Type & Size	N TOPCON 182.3*105 (Half Cut)
Front (Material / Thickness)	2 mm Low Iron HTAR semi-tempered glass
Back Glass (Material / Thickness)	2 mm Low Iron Printed semi-tempered glass
Encapsulate	PID Free & UV Resistant
Junction Box (Protection degree / Material)	IP68 / Weatherproof PPO
Cable & Connector (Protection degree / Type)	IP68 rated / MC4 compatible
Cable cross - section & length	4 mm^2 & Length 350mm

Frame	Anodized Aluminium Alloy
4. Temperature Characteristics:	
Temperature coefficient of Current (Isc), α (%/ºC)	0.046
Temperature coefficient of Voltage (Voc), ß (%/ºC))	-0.26
Temperature coefficient of Power (Pm), γ (%/ºC)	-0.30

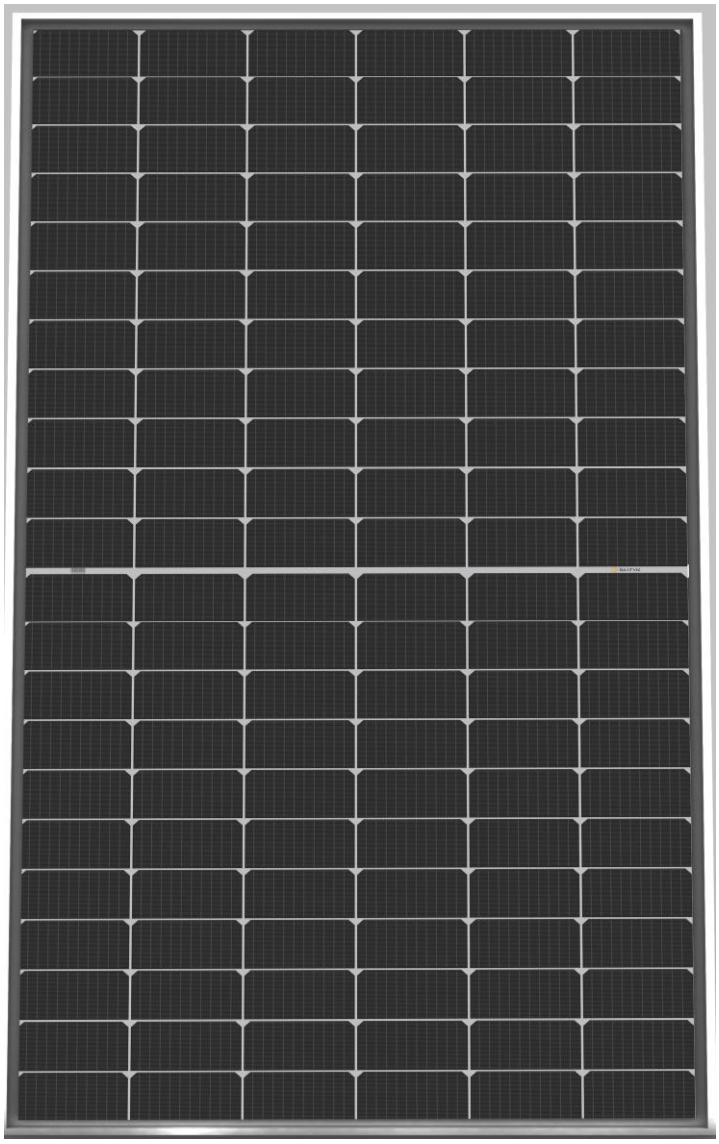


Figure 1: N-TOPCon Bifacial G12R

Declared/Functional Unit

The Functional unit is a 1Wp of N-TOPCon Bifacial G12R. (0.057kg per Wp including packaging).

Area of 1 panel is 2.7m2.

Content Declaration

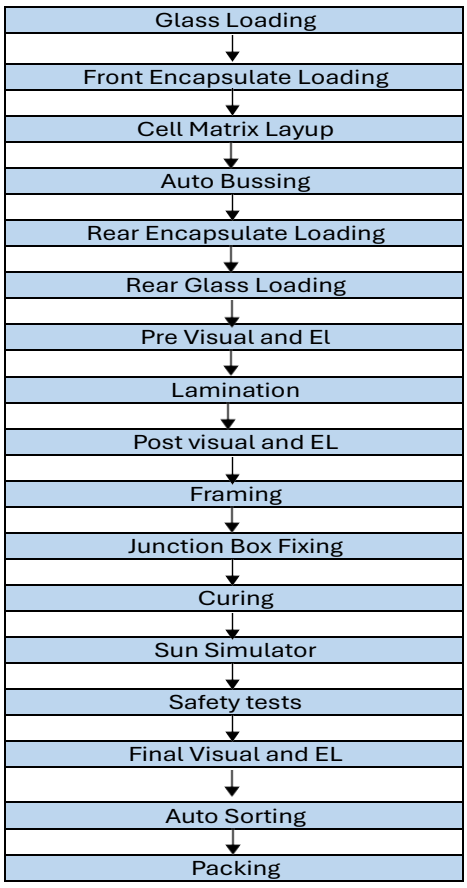
Table.1. Content declaration of N-TOPCon Bifacial *G12R*

Product Components	Content, kg	Post-consumer recycled material, mass-% of product	Biogenic material, mass-% of product	Biogenic material, kg C/product or declared unit
Glass-Front+ Back	26.80	0	0	0
Front Encapsulate loading + Rear Encapsulate loading	2.60	0	0	0
Aluminium	2.70	0	0	0
Solar cell	0.72	0	0	0
Ribbon	0.22	0	0	0
Junction Box	0.11	0	0	0
Plotting Sealant [A&B]	0.03	0	0	0
Frame Sealant	0.45	0	0	0
TOTAL	**33.63Kg**			

Packaging Materials	Content, kg	Mass-% (versus the product declared unit)	Biogenic material, kg C/product or declared unit
Plastic	0.18	0.54 %	0.00
Wooden pallet with Nails	1.19	3.54%	0.59
Corrugated Board	0.56	1.66%	0.28
Paper	0.01	0.02%	4E-3
TOTAL	1.93	5.76%	0.88

At the date of issue of this declaration, there is no “Substance of Very High Concern” (SVHC) in concentration above 0.1% by weight, and neither do their packaging, following the European REACH regulation (Registration, Evaluation, Authorization and Restriction of Chemicals).

Bifacial Solar Panel Manufacturing Flow Chart



Flow diagram of N-TOPCon Bifacial G12R.

LCA INFORMATION:

Geographical scope:	Manufacturing - India Use and Disposal - Global
Functional unit: **Mass conversion:**	1Wp of manufactured G12R solar module [4.3E-03 m^2 of panel] 0.057kg per Wp included packaging.
UN CPC Code:	UN CPC code: 461 Electric motors, solar panel, generators and transformers, and parts thereof.
System Boundary:	System boundary is Cradle to grave (A + B + C + D). As per PCR The result tables only contain values or the letters "ND" (Not Declared). It is not possible to specify ND for mandatory indicators. ND shall only be used for voluntary parameters that are not quantified because no data is available. Therefore, only B2 is shown in results as others from B1 to B7 have no value.
Reference service life:	RSL is 30 years Degradation As per PCR Power Degradation is 0.7% per year. Product Warranty: 12 Years of product warranty.
Time representativeness:	Primary data from the manufacturing site, suppliers and the electricity mix collected for the period starting from January 2025
Database(s) and LCA software used:	Ecoinvent v3.11 (allocation, cut-off by classification) database and SimaPro v10.2 software have been used for the LCA calculations. LCA methods used are EN 15804: A2 compliant based on EF 3.1.
Data quality and data collection:	According to EN 15804:2012+A2:2019/AC:2021 based on EF 3.1, specific data was used for module A3 (Processes the manufacturer has influence over) and was gathered from Saatvik manufacturing units at Ambala. Specific data includes actual product weights, amounts of raw materials used, product content, energy consumption, transport figures, water consumption and amounts of wastes.
Allocation:	In this study, allocation has not been applied.
Cut-off rules:	Life Cycle Inventory data for a minimum of 99 % of total inflows to the life cycle stages have been included and a cut-off rule of 1% regarding energy, mass and environmental relevance was applied. Impacts caused by treatment operations have been calculated lower than 1% environmental relevance.

Modules declared, geographical scope, share of primary data (in GWP-GHG results) and data variation (in GWP-GHG results):

X: Module Declared ND: Module not Declared	Product stage			Installation stage		Use stage							End of life stage				Resource recovery stage
	Raw material supply	Transport	Manufacturing	Transport	Construction installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction demolition	Transport	Waste processing	Disposal	Recycling potential
Module	**A1**	**A2**	**A3**	**A4**	**A5**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**C1**	**C2**	**C3**	**C4**	**D**
Modules declared	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Geography	GLO	GLO	IN	GLO	GLO	GLO	GLO	GLO	GLO	GLO	GLO	GLO	GLO	GLO	GLO	GLO	GLO
Specific data used	14.6%				-		-	-	-	-	-	-	-				-
Variation – products	Not relevant				-		-	-	-	-	-	-	-	-	-	-	-
Variation – sites	Less than 10%				-		-	-	-	-	-	-	-	-	-	-	-

Table.2. Data quality assessment based on data collection during LCA

Data quality information according to EN 15941: 2023	
Data collection	Data collection period – 2025
Sites used	Manufacturing site: Ambala, Haryana
Geography	Produced in India
	Sold: Across Globe
	Use and disposal: Across Globe
Technology	Modern
Averaging	100% of production
LCI/LCA database	Ecoinvent v.3.11
EPD used	None
Data Quality Scheme	EN 15804 :2012+A2:2019, Annex E, Table E.2
Use of fair data with more than 15% of a core impact	Used core phase (manufacturing) data: 14.6%, which has maximum impacts
Use of Poor relevant data	Relevant data used
Use of very poor relevant data	None

Table.3. Data quality during LCA modelling & total share of primary data (GWP-GHG results)

Process	Source type	Source	Reference Year	Data category	%Share of primary data of GWP-GHG results for A1-A3
Glass	Database	Ecoinvent 3.11	2025	Secondary data	0
Aluminium+ other metal	Database	Ecoinvent 3.11	2025	Secondary data	0
Silicon	Database	Ecoinvent 3.11	2025	Secondary data	0
Others (Boards, papers etc.)	Database	Ecoinvent 3.11	2025	Secondary data	0
Electricity	Collected Data + Database	Ecoinvent 3.11	2025	Primary Data	8.16
Transportation	Collected Data + Database	Ecoinvent 3.11	2025	Primary Data	6.56
Total share of primary data of GWP-GHG results for A1-A3					14.6%

Note: The share of primary data is calculated based on GWP-GHG results. It is a simplified indicator for data quality that does not capture all relevant aspects of data quality. The indicator is not comparable across product categories

A1-A3 - Cradle to Gate – Mandatory Module

The product stage of the products is subdivided into 3 modules A1, A2 and A3 respectively "Raw material supply", "transport to the manufacturer" and "manufacturing and packaging". The aggregation of the modules A1, A2, and A3 is allowed by EN 15804:2012+A2:2019. This rule is applied in this EPD and denoted by A1-A3.

- **A1- Raw material supply:**
  This stage includes extraction and processing of raw materials for the manufacturing of N-TOPCon Bifacial G12R photovoltaic module. Main materials used in the production are silicon cells, solar glass, aluminium, back sheet (silica gel, ethylene vinyl acetate (EVA)/polyolefin encapsulant (POE), junction box (consists of cable, connector and diode), and some minor parts such as plastics and copper.

- **A2- Raw Material Transportation**
  In this module, transportation is considered in the context of the transportation of raw materials to the production plant and the transportation within the plant. The main mean for transportation of raw materials is by trucks.

- **A3- Manufacturing**
  Environmental impacts due to the production of N-TOPCon Bifacial G12R photovoltaic module are considered in this module. Following processes are included: production of high-grade silicon, melting and ingot forming, wafer production, solar cell production, module production (cutting, taping, soldering, sheet cutting, mounting and packing) complete the G12R modules.

- **A4 – Transportation to the Site**
  This stage considers transportation of the solar modules to the intended market locations. Main markets for the PV modules are India and USA. The transportation routes (by container ships and trucks) and the distances are individually provided by the manufacturer

- **A5 – Installation**
  For this module, waste treatment of packaging materials is considered. It is assumed that no additional waste is generated during the installation. In addition, considering 1% cut-off rule, the energy needed during the installation becomes negligible and assumed to be zero. Biogenic balancing for packaging has been done in A5.

B1 -B7 Use Stage

The use stage is divided into the following modules:

The product has a reference service life of 30 years. This assumes that the product will last in situ with no requirements for repair, replacement or refurbishment throughout this period. Therefore, it has no impact at this stage, except for maintenance B2. However, as per cPCR the equations for the user of the EPD to be able to calculate the total produced electricity for the declared module is given.

- **B1: Use**
  No material or energy inputs, nor any emissions, occur during the use phase at the installation site.

- **B2: Maintenance**
  According to PCR EN 17074, only the maintenance by cleaning glass with water and cleaning agent is included in this study.

- **B3: Repair**
  Under standard operating conditions, no repair activities are anticipated for the PV module during its service life.
- **B4: Replacement**
  Replacement of the PV module within the defined reference service life is not expected under normal operating conditions.
- **B5: Refurbishment**
  Refurbishment of the PV module is not required throughout its operational period.
- **B6: Operational energy use**
  The PV module does not consume any operational energy during use.
- **B7: Operational water use**
  No operational water consumption is associated with the PV module.

Energy production in the first year of operation:

(1) E1 = Srad * A * y * PR * (1- deg)
E1 = Energy produced in the first year of operation, kWh/year
Srad = Site specific annual average solar radiation on module (shadings not included), kWh/kWp/year. The annual radiation must take into consideration the specific inclination (slope, tilt) and orientation.
A = Area of module, from functional unit (FU), m2 (stated in the EPD).
y = Module yield: electrical power, kWp for standard test conditions (STC) of the module divided by the area of the module (stated in the EPD).
STC: The ratio is given for standard test conditions: irradiance 1000 W/m2, cell temperature 25 °C, wind speed 1 m/s, AM1.5.
PR = Performance ratio, coefficient for losses.

- Inverter losses
- Temperature losses
- DC cables losses
- AC cables losses
- Shadings
- Losses at weak radiation
- Losses due to dust, snow
- Other Losses

deg = yearly degradation rate (stated in the EPD).
Degradation
If no data is available, a default linear degradation rate of 0.007 (0.7 %) per year shall be applied. Product specific degradation rate may be used if based on evidence (third-party validated report like DNV or other similar third-party validated documentation/certificates).
The nameplate capacity of the PV module, as printed in the data sheet, shall be used as the starting point of the degradation curve. If uncertainties on performance measurements are factored in the performance tolerance provided on the data sheet, e.g. +2.5 % / -0 %, the nameplate capacity without calculating uncertainties shall be used.
Energy production second year of operation:
E2 = E1 * (1 - deg)
Energy production n year of operation:
En = E1 * (1 – deg) n-1
Energy production over reference service life of module, assuming linear annual degradation:
$E_{RSL} = E_1 * (1 + \sum_{n-1}^{RSL-1} - 1(1 - deg)^n)$
RSL = Reference service life for energy-producing unit, from functional unit (FU), stated in the EPD
n = year of operation

C1 – C4 End of Life Stage

C1 – Deconstruction and Dismantling: The dismantling phase of the solar module involves manual and mechanical removal from the mounting structure. The overall environmental impact of this stage is minimal compared to the total life cycle of the product. For Module C1, an energy consumption of approximately 2.6 MJ per functional unit has been considered, based on the Ecoinvent database. No significant emissions or material losses occur during this phase.

Deinstallation data taken from "An Updated Life Cycle Assessment of Utility-Scale Solar Photovoltaic Systems Installed in the United States" by NREL.

C2 - Transport to waste processing:

The dismantling phase of the solar module involves manual and mechanical removal from the mounting structure. The overall environmental impact of this stage is minimal compared to the total life cycle of the product. For Module C1, an energy consumption of approximately 2.6 MJ per functional unit has been considered, based on the Ecoinvent database. No significant emissions or material losses occur during this phase.

Recycling and Landfilling distances were provided by EPD owner Saatvik Green Energy Ltd.

Table 4: Parameters C2 Module

Parameters C2 Module	
Transport by Truck	Lorry >25 metric ton, 80% utilization
Distance to Recycling site	25km
Distance to Landfilling site	25km
Database	Ecoinvent 3.11

C3 - Waste processing for reuse, recovery, and/or recycling: Approximately 80% of aluminium, glass, and other metals are recovered as scrap for recycling, whereas the remaining 20% is disposed of via landfilling. As per PCR electricity required for sorting is 1.8kWh per ton of material. Weight of aluminium and glass that is sorted is 80% of 29.5 Kgs. 29.5 x 0.8 = 23.6 Kgs material is sorted that requires = 23.6 x1.8 /1000= 0.042 kWh is required.

C4 - Final Disposal:

Out of the total waste 20% is sent to landfill at 25 Kms while the remaining 80% is directed to recycling.

D - Reuse, Recovery, or Recycling:

Module D reports the environmental aspects of recycled scrap generated at the end of life minus that used at the production stage. Benefits accrued due to scrap aluminium and glass are reported in D.

Electricity Modelling

94% of electricity is taken from Northern Electricity Grid of India and 6% from the solar. Climate impact as kg CO2 eq./kWh using the GWP-GHG indicator for Northern Electricity Grid of India is 1.32 kg CO2 eq./ kWh and for Solar panel is 0.064 Kg CO2 eq./kWh

Conversion factor

W_p for 1 m^2 of panel = 231.38 W_p; Weight of Panel for 1 W_p = 0.057kg with packaging.

Environmental Performance

" The estimated impact results are only relative statements, which do not indicate the endpoints of the impact categories, exceeding threshold values, safety margins and/or risks."

N-TOPCon Bifacial G12R SOLAR PANEL

EN 15804:2012+A2:2019/AC:2021EF3.1 characterization factors and calculation methods are used.

Table 5: Potential environmental impact – mandatory indicators according to EN15804:2012+A2:2019/AC:2021

Results for 1 Wp of N-TOPCon Bifacial G12R																
Indicator	**Unit**	**A1-A3**	**A4**	**A5**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**C1**	**C2**	**C3**	**C4**	**D**
GWP- total	kg CO_2 eq.	3.79E-01	3.46E-02	1.48E-02	0.00E+00	1.82E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.86E-03	2.93E-03	1.44E-03	1.61E-03	-3.06E-02
GWP-biogenic	kg CO_2 eq.	-6.06E-04	1.92E-05	6.06E-04	0.00E+00	4.60E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.40E-03	1.40E-03	1.40E-03	3.37E-05	-2.91E-05
GWP- Fossil	kg CO_2 eq.	3.80E-01	3.45E-02	1.33E-02	0.00E+00	1.82E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.65E-04	1.53E-03	4.60E-05	1.63E-03	-3.05E-02
GWP- luluc	kg CO_2 eq.	8.66E-05	1.89E-05	3.28E-05	0.00E+00	2.37E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.47E-08	5.68E-07	1.19E-08	4.89E-06	-5.86E-05
ODP	kg CFC 11 eq.	8.55E-08	4.48E-10	3.47E-10	0.00E+00	3.51E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.63E-12	3.27E-11	4.07E-13	5.40E-12	-1.22E-09
AP	mol H+ eq.	1.67E-03	1.30E-04	3.13E-04	0.00E+00	9.74E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.39E-06	3.75E-06	6.43E-07	5.97E-06	-2.48E-04
EP-freshwater	kg P eq	1.83E-04	4.04E-06	2.30E-05	0.00E+00	6.91E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.27E-08	1.41E-07	1.92E-08	2.34E-05	-8.29E-06
EP- marine	kg N eq.	3.88E-04	2.82E-05	2.45E-05	0.00E+00	2.00E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.96E-06	1.90E-06	1.21E-06	1.55E-06	-4.19E-05
EP-terrestrial	mol N eq.	3.38E-03	3.08E-04	2.89E-04	0.00E+00	2.05E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.26E-05	1.09E-05	3.51E-06	1.57E-05	-4.61E-04
POCP	kg NMVOC eq.	1.40E-03	1.33E-04	8.80E-05	0.00E+00	6.24E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.19E-06	6.15E-06	1.48E-06	4.59E-06	-1.31E-04
ADP-minerals&metals*	kg Sb eq.	5.05E-05	1.46E-07	3.18E-06	0.00E+00	8.30E-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.29E-10	6.99E-09	7.96E-11	2.01E-09	-3.17E-07
ADP-fossil*	MJ	5.21E+00	6.61E-02	8.91E-02	0.00E+00	1.41E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.62E-04	2.00E-03	4.95E-05	1.01E-02	-2.63E-01
WDP*	m^3	3.85E+02	2.22E-03	5.57E-03	0.00E+00	6.49E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.57E-05	8.81E-05	3.74E-06	2.35E-04	-5.45E-01
Acronyms	GWP-Total= Global Warming Potential total , 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 end compartment; EP-marine = Eutrophication potential, fraction of nutrients reaching marine end compartment; EP-terrestrial = Eutrophication potential, Accumulated Exceedance; POCP = Formation potential of tropospheric ozone; ADP-minerals & metals = Abiotic depletion potential for non-fossil resources; ADP-fossil = Abiotic depletion for fossil resources potential; WDP = Water (user) deprivation potential, deprivation-weighted water consumption															
**Disclaimer: The results of this environmental impact indicator shall be used with care as the uncertainties on these results are high or as there is limited experienced with the indicator.*																

The estimated impact results are only relative statements, which do not indicate the endpoints of the impact categories, exceeding threshold values, safety margins and/or risks. The use of Module A1-A3 results without the consideration of Module C

Table 6: Potential Environmental impact-additional mandatory

Results for 1 Wp of N-TOPCon Bifacial G12R																
Indicator	**Unit**	**A1-A3**	**A4**	**A5**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**C1**	**C2**	**C3**	**C4**	**D**
GWP-GHG	KgCO2 eq	3.80E-01	3.45E-02	1.33E-02	0.00E+00	1.79E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.26E-03	2.32E-03	8.41E-04	1.56E-03	-3.01E-02
Acronyms	GWP-GHG = Global Warming Potential															

The GWP-GHG indicator is identical to GWP-total except that the characterisation factor (CF) for biogenic CO2 is set to zero.

Table 7: Potential environmental impact – additional mandatory and voluntary indicator.

Results for 1 Wp of N-TOPCon Bifacial G12R																
Indicator	**Unit**	**A1-A3**	**A4**	**A5**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**C1**	**C2**	**C3**	**C4**	**D**
PM/RI	[disease inc.]	1.35E-08	1.84E-09	1.93E-09	0.00E+00	1.31E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.15E-10	5.88E-10	5.08E-10	6.93E-11	-4.66E-09
IRP*	[kBq U235 eq]	8.69E-02	4.29E-04	5.56E-04	0.00E+00	1.57E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.65E-06	3.84E-05	3.30E-07	4.11E-05	-1.97E-03
ET-freshwater	[CTUe]	4.80E+00	1.51E-01	2.14E-01	0.00E+00	1.46E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.05E-03	8.05E-03	2.47E-03	6.74E-03	-3.07E-01
HT-cancer	[CTUh]	1.49E-10	6.14E-12	3.31E-11	0.00E+00	1.47E-18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.83E-13	1.01E-12	7.40E-13	1.03E-12	-1.78E-11
HT-non-cancer	[CTUh]	1.22E-08	2.70E-10	2.72E-09	0.00E+00	5.54E-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.45E-11	7.63E-11	6.38E-11	1.47E-11	-2.52E-10
SQP	[pt]	1.08E+00	1.85E-01	1.01E-01	0.00E+00	4.59E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.57E-03	9.82E-03	1.21E-03	1.34E-02	-7.72E-02
Acronyms	PM = Particulate matter emissions; IRP = Ionizing radiation, human health; ET-freshwater = Eco-toxicity (freshwater); HT-cancer = Human toxicity, cancer effects; HT-non-cancer = Human toxicity, non-cancer effects; SQP = Potential soil quality index (SQP)															

*Disclaimer: The impact category Ionizing radiation, human health [kBq U235 eq.] deals mainly with the eventual impact of low dose ionizing radiation on human health of the nuclear fuel cycle. It does not consider effects due to possible nuclear accidents, occupational exposure nor due to radioactive waste disposal in underground facilities. Potential ionizing radiation from the soil, from radon and from some construction material is also not measured by this indicator.

The results of this environmental impact indicator shall be used with care as the uncertainties on these results are high or as there is limited experienced with the indicator (ETP-fw, HTP-c, HTP-nc, SQP).
)The estimated impact results are only relative statements, which do not indicate the endpoints of the impact categories, exceeding threshold values, safety margins and/or risks. The use of Module A1-A3 results without the consideration of Module C.

Table 8: Use of resources:

Results for 1 Wp of N-TOPCon Bifacial G12R																
Indicator	**Unit**	**A1-A3**	**A4**	**A5**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**C1**	**C2**	**C3**	**C4**	**D**
PERE	MJ	1.49E+00	1.29E-04	7.94E-02	0.00E+00	2.36E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.01E-05	4.81E-04	5.76E-06	2.07E-03	-3.09E-02
PERM	MJ	6.56E-02	0.00E+00	-6.56E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PERT	MJ	1.12E+00	8.03E-03	2.15E-02	0.00E+00	2.36E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.01E-05	4.81E-04	5.76E-06	2.07E-03	-3.09E-02
PENRE	MJ	6.39E+00	1.04E-01	3.57E-01	0.00E+00	1.48E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.74E-04	2.08E-03	5.19E-05	1.07E-02	-2.82E-01
PENRM	MJ.	1.51E-02	0.00E+00	-1.51E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	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	5.72E+00	6.93E-02	9.36E-02	0.00E+00	1.48E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.74E-04	2.08E-03	5.19E-05	1.07E-02	-2.82E-01
SM	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
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
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
FW	m^3	2.64E-03	6.01E-05	1.44E-04	0.00E+00	1.51E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.51E-07	2.85E-06	1.11E-07	5.76E-06	-1.27E-02
NTOP	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 re-sources; 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 9: Waste production

Results for 1 Wp of N-TOPConPAN Bifacial G12R																
Indicator	**Unit**	**A1-A3**	**A4**	**A5**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**C1**	**C2**	**C3**	**C4**	**D**
Hazardous waste disposed	Kg	4.89E-04	3.12E-06	8.35E-06	0.00E+00	1.12E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.07E-08	1.47E-07	2.73E-09	4.80E-03	-5.99E-06
Non-hazardous waste disposed	Kg	3.43E-02	1.32E-02	1.43E-02	0.00E+00	1.51E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.46E-05	6.69E-04	2.10E-05	1.10E-03	-1.62E-03
Radioactive waste disposed	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

Table 10: Output flows

Results for 1 Wp of N-TOPCON Bifacial G12R																
Indicator	**Unit**	**A1-A3**	**A4**	**A5**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**C1**	**C2**	**C3**	**C4**	**D**
Components for re-use	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
Material for recycling	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	4.83E-02	0.00E+00	0.00E+00
Materials for energy recovery	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
Materials for energy recovery	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
Exported energy, thermal	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

Additional Result:

The corresponding end-of-life scenarios—including 100% recycling and 100% landfill and 100% recycling benefit— are declared separately below, with the resulting environmental performance indicators reported for each scenario. These results are presented to ensure transparency and allow clear interpretation and comparison of the potential end-of-life pathways in line with EPD requirements.

Table11: Results of 100% recycling

Indicator	Unit	C1	C2	C3	C4	D
Climate change	kg CO2 eq	1.86E-03	2.93E-03	1.21E-04	0.00E+00	-3.83E-02
Climate change - Biogenic	kg CO2 eq	1.40E-03	1.40E-03	7.37E-07	0.00E+00	-3.63E-05
Climate change - Fossil	kg CO2 eq	4.65E-04	1.53E-03	1.20E-04	0.00E+00	-3.82E-02
Climate change - Land use and LU change	kg CO2 eq	5.47E-08	5.68E-07	2.54E-07	0.00E+00	-7.33E-05
ODP	kg CFC11 eq	6.63E-12	3.27E-11	7.73E-13	0.00E+00	-1.53E-09
AP	mol H+ eq	4.39E-06	3.75E-06	5.98E-07	0.00E+00	-3.10E-04
EP-freshwater	kg P eq	3.27E-08	1.41E-07	5.78E-08	0.00E+00	-1.04E-05
EP- marine	kg N eq	2.96E-06	1.90E-06	1.21E-07	0.00E+00	-5.23E-05
EP-terrestrial	mol N eq	2.26E-05	1.09E-05	1.21E-06	0.00E+00	-5.77E-04
POCP	kg NMVOC eq	7.19E-06	6.15E-06	3.58E-07	0.00E+00	-1.64E-04
ADP-minerals & metals	kg Sb eq	2.29E-10	6.99E-09	1.17E-10	0.00E+00	-3.96E-07
ADP-fossil	MJ	2.62E-04	2.00E-03	1.09E-03	0.00E+00	-3.29E-01
WDP	m3 W eq. Dep	1.57E-05	8.81E-05	1.73E-05	0.00E+00	-6.81E-01
GWP-GHG	kg CO2 eq	1.26E-03	2.32E-03	1.18E-04	0.00E+00	-3.76E-02

Indicator	Unit	C1	C2	C3	C4	D
PM/RI	[disease inc.]	6.15E-10	5.88E-10	1.15E-10	0.00E+00	-5.82E-09
IRP	[kBq U235 eq]	2.65E-06	3.84E-05	1.56E-05	0.00E+00	-2.46E-03
ET-freshwater	[CTUe]	3.05E-03	8.05E-03	1.56E-01	0.00E+00	-3.84E-01
HT-cancer	[CTUh]	7.83E-13	1.01E-12	2.48E-13	0.00E+00	-2.23E-11
HT-non-cancer	[CTUh]	6.45E-11	7.63E-11	1.48E-11	0.00E+00	-3.15E-10
SQP	[pt]	1.57E-03	9.82E-03	2.23E-02	0.00E+00	-9.65E-02

Indicator	Unit	C1	C2	C3	C4	D
PERE	MJ	4.01E-05	4.81E-04	2.65E-04	0.00E+00	-3.86E-02
PERM	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PERT	MJ	4.01E-05	4.81E-04	2.65E-04	0.00E+00	-3.86E-02
PENRE	MJ	2.74E-04	2.08E-03	1.98E-03	0.00E+00	-3.52E-01
PENRM	MJ.	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PENRT	MJ	2.74E-04	2.08E-03	1.98E-03	0.00E+00	-3.52E-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	m^3	4.51E-07	2.85E-06	-1.60E-05	0.00E+00	-1.59E-02

Indicator	Unit	C1	C2	C3	C4	D
Hazardous waste disposed	Kg	4.07E-08	1.47E-07	1.11E-07	0.00E+00	-7.49E-06
Non-hazardous waste disposed	Kg	2.46E-05	6.69E-04	4.45E-02	0.00E+00	-2.02E-03
Radioactive waste disposed	Kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Indicator	Unit	C1	C2	C3	C4	D
Components for re-use	Kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Material for recycling	Kg	0.00E+00	0.00E+00	5.70E-02	0.00E+00	0.00E+00
Materials for energy recovery	Kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Materials for energy recovery	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Exported energy, thermal	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table12: Results of 100% Landfilling

Indicator	Unit	C1	C2	C3	C4	D
Climate change	kg CO2 eq	1.86E-03	2.93E-03	0.00E+00	3.08E-04	0.00E+00
Climate change - Biogenic	kg CO2 eq	1.40E-03	1.40E-03	0.00E+00	0.00E+00	0.00E+00
Climate change - Fossil	kg CO2 eq	4.65E-04	1.53E-03	0.00E+00	3.08E-04	0.00E+00
Climate change - Land use and LU change	kg CO2 eq	5.47E-08	5.68E-07	0.00E+00	3.06E-09	0.00E+00
ODP	kg CFC11 eq	6.63E-12	3.27E-11	0.00E+00	1.15E-10	0.00E+00
AP	mol H+ eq	4.39E-06	3.75E-06	0.00E+00	2.49E-06	0.00E+00
EP-freshwater	kg P eq	3.27E-08	1.41E-07	0.00E+00	2.39E-08	0.00E+00
EP- marine	kg N eq	2.96E-06	1.90E-06	0.00E+00	1.03E-06	0.00E+00
EP-terrestrial	mol N eq	2.26E-05	1.09E-05	0.00E+00	1.13E-05	0.00E+00
POCP	kg NMVOC eq	7.19E-06	6.15E-06	0.00E+00	3.36E-06	0.00E+00
ADP-minerals & metals*	kg Sb eq	2.29E-10	6.99E-09	0.00E+00	3.27E-10	0.00E+00
ADP-fossil	MJ	2.62E-04	2.00E-03	0.00E+00	7.95E-03	0.00E+00
WDP	m3 W eq. Dep	1.57E-05	8.81E-05	0.00E+00	1.47E-02	0.00E+00
GWP-GHG	kg CO2 eq	1.26E-03	2.32E-03	0.00E+00	3.07E-04	0.00E+00

Indicator	Unit	C1	C2	C3	C4	D
PM/RI	[disease inc.]	6.15E-10	5.88E-10	0.00E+00	5.18E-11	0.00E+00
IRP	[kBq U235 eq]	2.65E-06	3.84E-05	0.00E+00	3.08E-05	0.00E+00
ET-freshwater	[CTUe]	3.05E-03	8.05E-03	0.00E+00	3.27E-03	0.00E+00
HT-cancer	[CTUh]	7.83E-13	1.01E-12	0.00E+00	1.23E-13	0.00E+00
HT-non-cancer	[CTUh]	6.45E-11	7.63E-11	0.00E+00	1.97E-12	0.00E+00
SQP	[pt]	1.57E-03	9.82E-03	0.00E+00	1.43E-02	0.00E+00

Indicator	Unit	C1	C2	C3	C4	D
PERE	MJ	4.01E-05	4.81E-04	0.00E+00	6.89E-05	0.00E+00
PERM	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PERT	MJ	4.01E-05	4.81E-04	0.00E+00	6.89E-05	0.00E+00
PENRE	MJ	2.74E-04	2.08E-03	0.00E+00	9.30E-03	0.00E+00
PENRM	MJ.	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PENRT	MJ	2.74E-04	2.08E-03	0.00E+00	9.30E-03	0.00E+00
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	m^3	4.51E-07	2.85E-06	0.00E+00	3.76E-04	0.00E+00

Indicator	Unit	C1	C2	C3	C4	D
Hazardous waste disposed	Kg	4.07E-08	1.47E-07	0.00E+00	3.42E-09	0.00E+00
Non-hazardous waste disposed	Kg	2.46E-05	6.69E-04	0.00E+00	5.70E-02	0.00E+00
Radioactive waste disposed	Kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Indicator	Unit	C1	C2	C3	C4	D
Components for re-use	Kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Material for recycling	Kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Materials for energy recovery	Kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Materials for energy recovery	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Exported energy, thermal	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Abbreviations

List of abbreviations used in this EPD data:

Abbreviation	Definition
EN	European Norm (Standard)
EF	Environmental Footprint
GPI	General Programme Instructions
ISO	International Organization for Standardization
CEN	European Committee for Standardization
CLC	Co-location centre
CPC	Central product classification
GHS	Globally harmonized system of classification and labelling of chemicals
GRI	Global Reporting Initiative
SVHC	Substances of Very High Concern
ND	Not Declared
EoL	End of Life
RSL	Reference Service Life

Version History

Original Version of the EPD, 2026-02-02

References

- EN 15804 EN 15804:2012+A2:2019: Sustainability of construction works — Environmental Product Declarations — Core rules for the product category of construction products.
- ISO 14025 ISO 14025:2010 Environmental labels and declarations — Type III environmental declarations — Principles and procedures
- ISO 14040 ISO 14040:2006 Environmental management - Life cycle assessment - Principles and framework
- ISO 14044 ISO 14044:2006 Environmental management - Life cycle assessment - Requirements and guidelines
- NMD 2019 NMD STICHTING NATIONAL ENVIRONMENTAL DATABASE: Environmental Performance Assessment Method for Construction; 1.1 (March 2022); Rijswijk
- PCR A NPCR PART A: Construction products and services Version 2.0.1, 2021-03-24
- PCR B NPCR 029:2022: Part B for photovoltaic modules used in the building and construction industry, including production of cell, wafer, ingot block, solar grade silicon, solar substrates, solar superstrates and other solar grade semi-conductor materials; Version 1.2.
- The International EPD® System / The General Programme Instructions v5.0.1 / https://www.environdec.com/contentassets/95ee9211a9614f1faa7461ff32cecc91/general-
- An Updated Life Cycle Assessment of Utility-Scale Solar Photovoltaic Systems Installed in the United States Brittany L. Smith, Ashok Sekar, Heather Mirletz, Garvin Heath, and Robert Margolis

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