ENVIRONMENTAL PRODUCT DECLARATION

Marley SolarTile®

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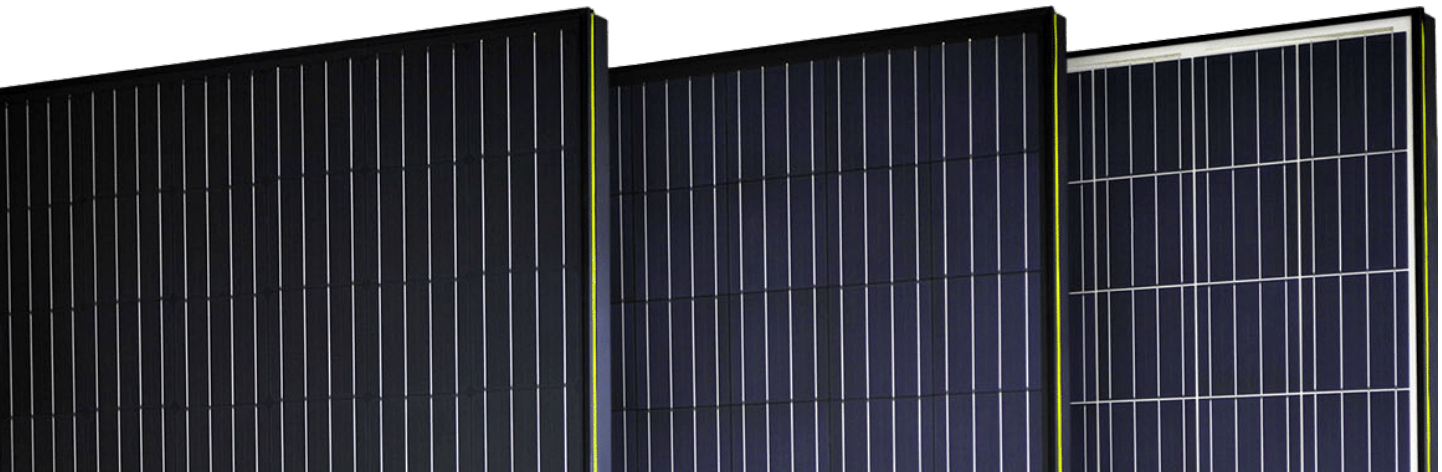
ENVIRONMENTAL PRODUCT DECLARATION

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

Clearline fusion

Programme:	The International EPD® System
Programme Operator:	EPD International AB
S-P Code:	S-P-06949
Publication Date:	2023-02-07
Validity Date:	2028-02-06
Geographical Scope:	Global

An EPD should provide current information and may be updated if conditions change. The stated validity is therefore subject to the continued registration and publication at www environdec.com.



viridian solar

PROGRAMME INFORMATION

ISO standard ISO 21930 and CEN standard EN 15804 serves as the core Product Category Rules (PCR)

Product Category Rules (PCR):
PCR 2019:14 Construction products, version 1.2.5, Construction EN 15804:2012 + A2:2019 Sustainability of Construction Works and
PCR 2019:14-c-PCR-016 c-PCR-016 Photovoltaic modules and parts thereof (adopted from EPD Norway NPCR 019 version 1.2)

PCR review was conducted by: The Technical Committee of the International EPD® System. Review chair: Claudia A. Peña, University of Concepción, Chile

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EPDs within the same product category but registered in different EPD programmes, 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 characterisation factors); have equivalent content declarations; and be valid at the time of comparison. For further information about comparability, see EN 15804 and ISO 14025.

Third-party verification
Independent third-party verification of the declaration and data, according to ISO 14025:2006, via:

✓ EPD verification by individual verifier

Third party verifier: Prof. Ing. Vladimír Kočí, Ph.D., MBA. LCA Studio Šárecká 5,16000 Prague 6 - Czech Republic

Approved by: The International EPD® System

Procedure for follow-up of data during EPD validity involves third party verifier:

Yes **No** ✓

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HOW TO READ THIS EPD?

An Environmental Product Declaration (EPD) is an ISO Type III Environmental Declaration based on ISO 14025 standard. An EPD transparently reports the environmental performance of products or services from a lifecycle perspective. The preparation of an EPD includes different stages, from acquiring raw materials to the end of life of the final product/service. EPDs are based on international standards and consider the entire value chain. Additionally, EPD is a third-party verified document. This EPD includes several sections described below.

1. General and Program Information

The first part of an EPD has information about the name of the manufacturer and product/service and other general information such as the validity and expiration dates of the document, the name of the program operator, geographical scope, etc. The second page states the standards followed and gives information about the program operator, third-party verifier, etc. The followed Product Category Rule (PCR) is indicated on the second page.

2. Company and Product Information

Information about the company and the investigated product is given in this section. It summarizes the characteristics of the product provided by the manufacturer. It also includes information about the product such as product composition and packaging.

3. LCA Information

LCA information is one of the most important parts of the EPD as it describes the functional/declared unit, time representativeness of the study, database(s) and LCA software, along with system boundaries. The table presented in this part has columns for each stage in the life cycle. The considered stages are marked 'X' whereas the ones that are not considered are labeled as 'ND' (Not Relevant). Not all EPDs consider the full life cycle assessment for a product's entire life stages. The 'System Boundary' page is also the place where one can find detailed information about the stages and the assumptions made.

4. LCA Results

The results of the Life Cycle Assessment analysis are presented in table format. The first column in each table indicates the name of the impact category and their measurement units are presented in the second column. These tables show an amount at each life cycle stage to see the impact of different indicators on different stages. Each impact can be understood as what is released through the production of the declared unit of the material—in this case, 1 Wp of manufactured photovoltaic module, from cradle-to-grave, with activities needed for a study period for a defined reference service life (≥80% of the labelled power output). The benefits of reuse/recycling of the declared product is reflected in this section.

The first impact in the table is global warming potential (GWP), which shows how much CO_2 is released at each stage. Other impacts include eutrophication potential, acidification potential, ozone layer depletion, land use related impacts, etc. The second table provides results for resource use and the third table is about the waste produced during the production. The fourth and final table shows the results for the GWP-GHG indicator, which is almost equivalent to the GWP-Total indicator mentioned previously. The only difference is that this indicator excludes the biogenic carbon content by following a certain methodology.

ABOUT VIRIDIAN SOLAR

Viridian Solar is a UK-based manufacturer of roof integrated solar modules. Clearline Fusion range of photovoltaic (electric) solar modules fit in the roof and take building integration of solar to the next level. Our solar products are designed at our headquarters near Cambridge.

In 2004, a team of innovative engineers and designers set themselves the challenge to design a new kind of solar system. They sought out partners from the building industry to help with the definition and specification of the product and quickly realized that cost wasn't the only thing holding back solar from mainstream acceptance. Aesthetics, durability and ease of installation were just as important.

The result of this collaboration with developers, construction companies, and other building professionals was launched in 2007 after extensive testing both as a building material and an energy generating product.

At that time there were no standard tests for weathertightness, durability, and safety of roof integrated solar and our work to develop the tests helped define the national standards that followed many years later.

In 2015 the company launched Clearline Fusion, a PV roofing system that is cost competitive with above-roof installations, but that draws on our extensive history and long track record in building integrated solar. Fusion has rapidly established itself as the UK's market leading roof integrated solar PV system and the choice of both volume housebuilders and individual property owners looking to reduce energy bills while maintaining the kerb appeal of their building.

In 2021 Viridian Solar was acquired by Marley Ltd, one of the biggest and most respected names in the UK roofing sector, providing a strong foundation for further growth. Viridian Solar has achieved certification for its management systems to ISO 9001 (Quality), ISO 14001 (Environmental) and ISO 45001 (Occupational Health and Safety).

ABOUT THE PRODUCT

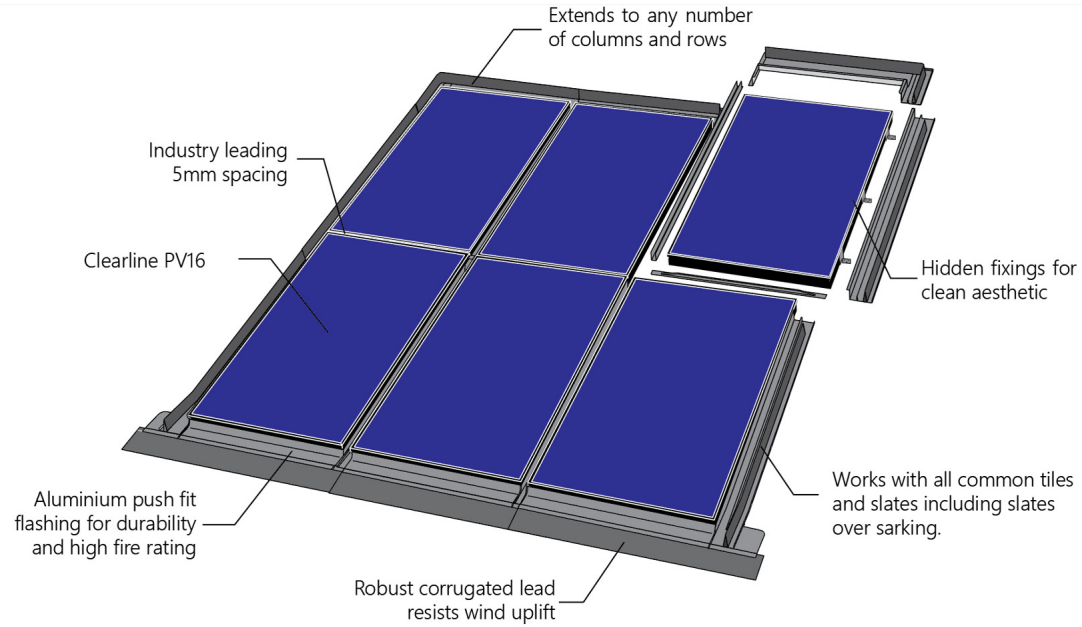
This EPD considers environmental performances of Viridian Solar's two mono-crystalline solar modules, PV16-405-M10 and PV16-335-G1. Differences in the environmental performance of the two investigated solar modules are analyzed and found less than 10%. The results in this EPD are for PV16-405-M10 mono-crystalline module since this product is the company's mainstream product which has longer lifespan in terms of product availability.

PV16-405-M10 photovoltaic module weighs 25 kg and has 1.95 m² total module area with 1.88 m² effective surface area. The module consists of 108 mono-crystalline cells with 185±18µm in thickness. The dimension of a single cell is 182 mm by 91 mm.

According to c-PCR-016, reference service life is taken as 25 years. For the packaging of the final product, cardboard, wood board, metal, and PE film are used. The amount of packaging is shown in the table below.

The product consists of the following materials. Material weights per functional unit is shown. In terms of weight, solar glass and aluminum frame are the two heaviest components of the PV module which together make up around 82.6% of the weight per functional unit.

Packaging Type	kg / FU
Cardboard (Corrugated board, paper)	1.65E-03
Woodboard	4.94E-03
Metal	1.65E-05
Plastic (PE Film)	1.02E-04



Materials	kg / FU	%
Solar Glass	3.70E-02	59.9
Aluminum Frame	1.40E-02	22.7
Ethylene vinyl acetate (EVA) / Polyolefin Encapsulant (POE)	4.27E-03	6.93
Insulation materials, labels, back sheet and flashing gasket	3.88E-03	6.28
Solar Cells	1.69E-03	2.74
Ribbon (string+busbar)	6.30E-04	1.02
Junction Box	2.64E-04	0.43

ABOUT THE PRODUCT

Clearline fusion roof-integrated solar PV system consists of PV16 modules and flashing kits. The PV16 modules are made by fabricating PV laminates to begin with these laminates consist of layers of glass, PV cells, string connectors, EVA and back sheet; they are laid out in a prescribed order and connected electrically by soldering process. These layers are then laminated under heat and pressure to form a sealed unit. The completed PV laminates are to be framed by aluminum extrusions and furnished with junction boxes to become functional modules. Flashing gaskets are to be added at last to complete the PV16 modules.

Clearline Fusion has high resistance to spread of flame and fire penetration in all European fire safety tests, achieving BRoof T1, T2, T3 and T4. Installation times of below 45 minutes per kWp are achieved.

Mechanical Specification for PV16-405-M10

Aperture Area	m^2	1.885
Width	mm	1,134
Length	mm	1,722
Thickness	mm	70
Weight	kg	25.0
Static roof loading (distributed)	kg/m^2	12.8
Characteristic wind resistance	kPa	4.24
Ultimate design load	kPa	4.24
Positive design load	IEC 61215	5.40
Roofing system fire rating	EN 13501-5	BRoof (T1, T2, T3, T4)
Power Warranty	% rated	90% 10 years, 80% 25 years
Standards	-	IEC 61215, 61730, TUV, MCS05, MCS12, CEC

LCA INFORMATION

Functional Unit:	1 Wp of manufactured photovoltaic module, from cradle-to-grave, with activities needed for a study period for a reference service of 25 years (≥80% of the labelled power output).
Time Representativeness:	2021
Database(s) and LCA Software Used:	Ecoinvent version 3.8 and SimaPro version 9.3.
System Boundaries:	Cradle to gate with options, modules C1–C4, module D and with optional modules (A1–A3 + C + D and A4 + A5)

	Product Stage			Construction Process Stage		Use Stage							End of Life Stage				Benefits and Loads
	Raw Material Supply	Transport	Manufacturing	Transport	Construction Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational Energy Use	Operational Water Use	Deconstruction / Demolition	Transport	Waste Processing	Disposal	Future reuse. recycling or energy recovery potentials
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	ND	ND	ND	ND	ND	ND	ND	X	X	X	X	X
Geography	CN	CN	CN	GLO	GLO	-	-	-	-	-	-	-	GLO	GLO	GLO	GLO	GLO
Specific Data Used	>90%	>90%	>90%	>90%	>90%	-	-	-	-	-	-	-	-	-	-	-	-
Variation - Products	<10%					-	-	-	-	-	-	-	-	-	-	-	-
Variation - Sites	0%					-	-	-	-	-	-	-	-	-	-	-	-

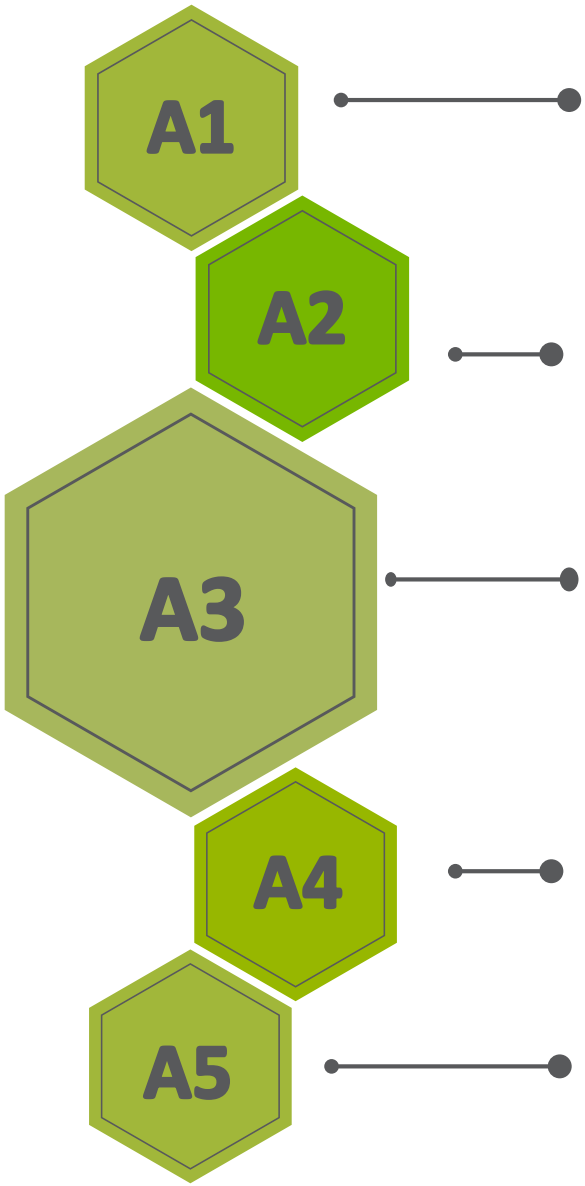
(X = Included in LCA, ND= Not Declared, NR= Not Relevant)

LCA INFORMATION

The inventory for the LCA study is based on the 2021 production numbers. LCA results are presented for PV16-405-M10 photovoltaic module of Viridian Solar. The results are expressed for 1 Wp of manufactured photovoltaic module.

Allocations	For allocations, ISO 14025 standard is followed. Water consumption, energy consumption, and raw material transportation were weighted according to 2021 production figures. In addition, hazardous and non-hazardous waste amounts were also allocated from the 2021 total waste generation.
Cut-Off Criteria	1% cut-off applied. Data for elementary flows to and from the product system contributing to a minimum of 99% of the declared environmental impacts have been included.
REACH Regulation	No substances included in the Candidate List of Substances of Very High Concern for authorization under the REACH regulations are present in this product either above the threshold for registration with the European Chemicals Agency or above 0.1% (wt/wt).
LCA Modelling, Calculation and Data Quality	The results of the LCA with the indicators as per EPD requirement are given in the LCA result tables. All energy calculations were obtained using the Cumulative Energy Demand (LHV) methodology, while freshwater use is calculated with selected inventory flows in SimaPro according to the PCR. There are no co-product allocations within the LCA study underlying this EPD. The SimaPro 9.3 LCA software and the Ecoinvent 3.8 LCA database were used to calculate the environmental impacts. The regional energy dataset is used for all energy calculations.
Geographical Scope	The geographical scope of this EPD is Global.

SYSTEM BOUNDARIES AND DESCRIPTION



A1 - Raw Material Supply
This stage includes extraction and processing of raw materials for the manufacturing of mono-crystalline photovoltaic module. Main materials used in the production are silicon cells, solar glass, aluminum, back sheet (consist of 88% PET and 12% PDVF materials), 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.

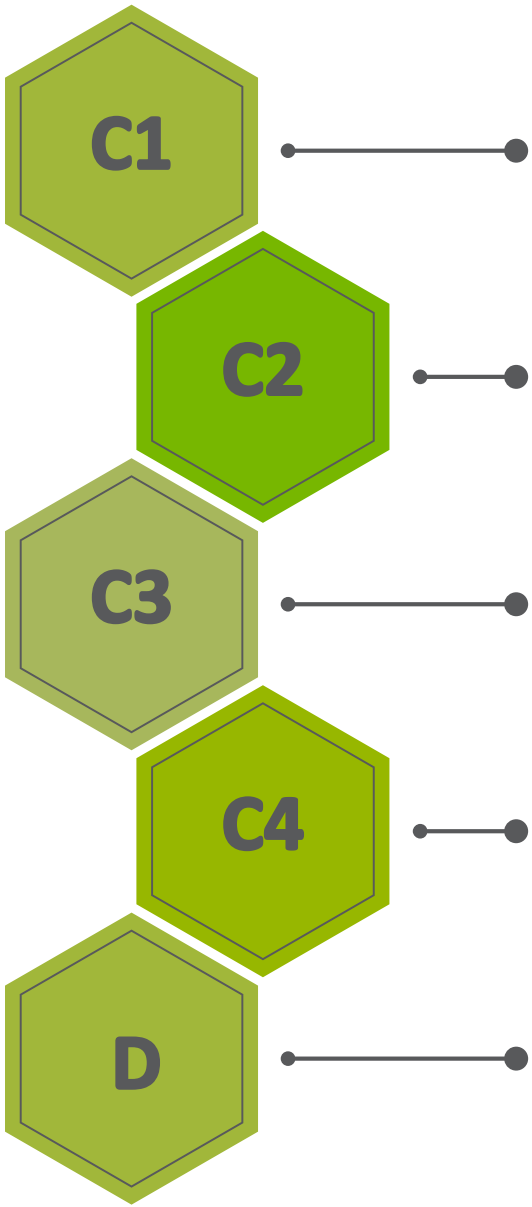
A2 - Raw Material Transportation
In this module, transportation is considered in the context of the transportation of raw materials to the production plant and the transportation within the plant. The main mean for transportation of raw materials is by trucks.

A3 - Manufacturing
Environmental impacts due to the production of PV16-405-M10 mono-crystalline 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) and adding flashing gaskets to complete the PV16 modules.

A4 - Transport to the Site
This stage considers transportation of the solar modules to the intended market locations. Main markets for the PV modules are Scotland, England and Wales, and EU. The transportation routes (by transpceanic ships and trucks) and the distances are individually provided by the manufacturer.

A5 - Construction 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.

SYSTEM BOUNDARIES AND DESCRIPTION



C1 - Deconstruction/Demolition
The energy use for on-site dismantling is included in this stage. However, according to the manufacturer, the required energy for dismantling is very low and it is under the 1% cut-off criteria. Thus, effects of this stage is assumed zero.

C2 - Waste Transport
This stage is related to the transportation of modules when they come to their end of life. Default scenario of 50 km waste transport distance is considered.

C3 - Waste Processing
This stage includes waste processing of different parts of the PV modules. Default conservative scenarios from the C-PCR-016 are used. According to the PCR, metal parts of the modules are recycled (70%) and plastic parts are incinerated with energy recovery.

C4 - Disposal
This stage considers the disposal of any waste that are left after waste processing. Default conservative disposal scenarios from c-PCR-016 are used.

D - Benefits and Loads
This module includes any reuse, recycling, or energy recovery benefits beyond the system boundary. It is assumed that recycled metal parts of modules substitute the use of virgin metals. In addition, heat recovery benefit from burning plastic parts is considered.

LCA RESULTS												
Impact Category	**Unit**	**A1**	**A2**	**A3**	**A1-A3**	**A4**	**A5**	**C1**	**C2**	**C3**	**C4**	**D**
GWP - Total	kg CO_2 eq	6.84E-01	6.86E-05	2.66E-02	7.11E-01	1.62E-02	1.56E-02	0	2.91E-05	1.57E-02	1.64E-04	-1.15E-01
GWP - Fossil	kg CO_2 eq	6.86E-01	6.85E-05	2.84E-02	7.14E-01	1.62E-02	1.57E-04	0	2.91E-05	1.50E-02	1.63E-04	-1.13E-01
GWP - Biogenic	kg CO_2 eq	-1.77E-03	-8.25E-09	-1.92E-03	-3.69E-03	7.03E-07	1.45E-02	0	-3.50E-09	6.39E-04	1.25E-06	-5.99E-04
GWP - Luluc	kg CO_2 eq	2.55E-04	5.00E-08	4.49E-05	3.00E-04	1.08E-05	1.99E-07	0	2.12E-08	2.30E-07	1.65E-07	-1.70E-03
ODP	kg CFC-11 eq	6.25E-08	1.36E-11	7.64E-10	6.33E-08	3.33E-09	2.35E-11	0	5.76E-12	7.73E-11	4.96E-11	-9.73E-09
AP	mol H+ eq	4.46E-03	2.23E-06	1.46E-04	4.61E-03	4.38E-04	1.70E-06	0	9.44E-07	3.48E-06	1.38E-06	-9.62E-04
EP - Freshwater	kg P eq	1.92E-04	2.24E-09	6.49E-06	1.98E-04	6.61E-07	3.90E-08	0	9.51E-10	9.98E-08	4.73E-08	-6.16E-05
EP - Marine	kg N eq	8.02E-04	5.48E-07	4.09E-05	8.43E-04	1.08E-04	1.22E-05	0	2.32E-07	1.71E-06	4.74E-07	-1.12E-04
EP - Terrestrial	mol N eq	8.33E-03	6.09E-06	3.59E-04	8.70E-03	1.19E-03	3.55E-06	0	2.58E-06	1.57E-05	5.16E-06	-1.16E-03
POCP	kg NMVOC	2.53E-03	1.58E-06	8.97E-05	2.62E-03	3.12E-04	4.58E-06	0	6.68E-07	3.98E-06	1.49E-06	-3.76E-04
**ADPE	kg Sb eq	1.92E-05	9.39E-11	5.33E-08	1.93E-05	2.53E-08	5.07E-10	0	3.98E-11	1.90E-09	5.33E-10	-6.14E-06
**ADPF	MJ	6.83E+00	8.77E-04	2.92E-01	7.12E+00	2.17E-01	2.46E-03	0	3.72E-04	2.77E-03	3.83E-03	-1.49E+00
WDP	m^3 depriv.	2.17E-01	1.51E-06	4.67E-03	2.22E-01	4.77E-04	8.22E-05	0	6.40E-07	1.97E-04	1.67E-04	-2.75E-02
PM	disease inc.	5.61E-08	2.13E-12	2.19E-09	5.83E-08	7.57E-10	1.57E-11	0	9.04E-13	2.30E-11	2.76E-11	-8.00E-09
*IR	kBq U-235 eq	1.95E-02	3.96E-06	1.24E-03	2.07E-02	9.90E-04	1.65E-05	0	1.68E-06	1.92E-05	1.80E-05	-1.32E-02
**ETP - FW	CTUe	2.20E+01	5.37E-04	8.37E-01	2.28E+01	1.44E-01	3.10E-02	0	2.28E-04	3.59E-02	2.73E-03	-4.22E+00
**HTTP - C	CTUh	5.48E-10	4.13E-14	9.69E-12	5.58E-10	8.98E-12	1.29E-13	0	1.75E-14	2.07E-12	1.17E-13	-2.85E-10
**HTTP - NC	CTUh	2.07E-08	3.47E-13	3.01E-10	2.10E-08	1.07E-10	2.38E-11	0	1.47E-13	2.86E-11	1.83E-12	-6.81E-09
**SQP	Pt	1.78E+00	1.18E-04	2.99E-01	2.08E+00	7.77E-02	4.10E-03	0	4.99E-05	9.78E-04	9.18E-03	-2.17E-01

Acronyms	GWP-total: Climate change, GWP-fossil: Climate change- fossil, GWP-biogenic: Climate change - biogenic, GWP-luluc: Climate change - land use and transformation, ODP: Ozone layer depletion, AP: Acidification terrestrial and freshwater, EP-freshwater: Eutrophication freshwater, EP-marine: Eutrophication marine, EP-terrestrial: Eutrophication terrestrial, POCP: Photochemical oxidation, ADPE: Abiotic depletion - elements, ADPF: Abiotic depletion - fossil resources, WDP: Water scarcity, PM: Respiratory inorganics - particulate matter, IR: Ionising radiation, ETP-FW: Ecotoxicity freshwater, HTP-c: Cancer human health effects, HTP-nc: Non-cancer human health effects, SQP: Land use related impacts, soil quality.
Legend	A1: Raw Material Supply, A2: Transport, A3: Manufacturing, A1-A3: Sum of A1, A2, and A3, A4: Transport, A5: Installation, C1: Deconstruction/Demolition, C2: Transport, C3: Waste Processing, C4: Disposal, D: Benefits and Loads Beyond the System Boundary.
***Disclaimer 1**	This impact category 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 materials is also not measured by this indicator.
****Disclaimer 2**	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.

RESOURCE USE

Impact Category	Unit	A1	A2	A3	A1-A3	A4	A5	C1	C2	C3	C4	D
PERE	MJ	5.69E-01	5.92E-06	7.28E-02	6.42E-01	1.68E-03	1.31E-04	0	2.51E-06	2.12E-04	4.99E-02	-4.32E-01
PERM	MJ	0	0	0	0	0	0	0	0	0	0	0
PERT	MJ	5.69E-01	5.92E-06	7.28E-02	6.42E-01	1.68E-03	1.31E-04	0	2.51E-06	2.12E-04	4.99E-02	-4.32E-01
PENRE	MJ	6.83E+00	8.77E-04	2.91E-01	7.12E+00	2.17E-01	2.46E-03	0	3.72E-04	2.77E-03	9.84E-01	-1.49E+00
PENRM	MJ	0	0	0	0	0	0	0	0	0	0	0
PENRT	MJ	6.83E+00	8.77E-04	2.91E-01	7.12E+00	2.17E-01	2.46E-03	0	3.72E-04	2.77E-03	9.84E-01	-1.49E+00
SM	kg	0	0	0	0	0	0	0	0	0	0	0
RSF	MJ	0	0	0	0	0	0	0	0	0	0	0
NRSF	MJ	0	0	0	0	0	0	0	0	0	0	0
FW	m^3	6.23E-03	8.02E-08	2.62E-04	6.49E-03	2.55E-05	2.13E-06	0	3.40E-08	1.34E-05	4.32E-06	-5.37E-04

Acronyms PERE: Use of renewable primary energy excluding resources used as raw materials, PERM: Use of renewable primary energy resources used as raw materials, PERT: Total use of renewable primary energy, PENRE: Use of non-renewable primary energy excluding 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, SM: Secondary material, RSF: Renewable secondary fuels, NRSF: Non-renewable secondary fuels, FW: Net use of fresh water.

WASTE&OUTPUT FLOWS

Impact Category	Unit	A1	A2	A3	A1-A3	A4	A5	C1	C2	C3	C4	D
HWD	kg	0	0	0	0	0	0	0	0	0	0	0
NHWD	kg	0	0	56.3E-6	56.3E-6	0	0	0	0	0	0	0
RWD	kg	0	0	0	0	0	0	0	0	0	0	0
CRU	kg	0	0	0	0	0	0	0	0	0	0	0
MFR	kg	0	0	0	0	0	0	0	0	0.037	0	0
MER	kg	0	0	0	0	0	0	0	0	0.006	0	0
EE (Electrical)	MJ	0	0	0	0	0	0	0	0	0	0	0
EE (Thermal)	MJ	0	0	0	0	0	0	0	0	0	0	0

Acronyms HWD: Hazardous waste disposed, NHWD: Non-hazardous waste disposed, RWD: Radioactive waste disposed, CRU: Components for reuse, MFR: Material for recycling, MER: Materials for energy recovery, EE (Electrical): Exported energy electrical, EE (Thermal): Exported energy, Thermal.

CLIMATE IMPACT

Indicator	Unit	A1	A2	A3	A1-A3	A4	A5	C1	C2	C3	C4	D
*GWP-GHG	kg CO_2 eq	6.65E-01	6.81E-05	2.81E-02	6.93E-01	1.61E-02	1.00E-02	0	2.89E-05	1.50E-02	1.61E-04	-1.12E-01

GWP-GHG = Global Warming Potential total excl. biogenic carbon following IPCC AR5 methodology
* The indicator includes all greenhouse gases included in GWP-total but excludes biogenic carbon dioxide uptake and emissions and biogenic carbon stored in the product. This indicator is thus equal to the GWP indicator originally defined in EN 15804:2012+A1:2013

GLOSSARY OF TERMS

Global Warming Potential, GWP	Global warming is a concept expressing warming of the atmosphere leading to climate change. One of the human activities which has the greatest effect on global warming is the burning of fossil fuels such as petroleum, coal and natural gas. In LCA, global warming is expressed in terms of the equivalent weight of carbon dioxide (CO_2) emitted.
Ozone Depletion Potential, ODP	Ozone layer depletion is a concept expressing the reduction of ozone in the stratosphere and depletion of the ozone layer (the 'ozone hole') as a consequence of emissions of man-made resources such as CFCs, HCFCs, chlorine, bromine, etc. Damage to the ozone layer reduces its ability to prevent UV light entering the earth's atmosphere, increasing the amount of carcinogenic UVB light hitting the earth's surface. In LCA, ozone layer depletion is expressed in terms of the equivalent weight of CFC-11 emitted.
Acidification Potential, AP	Acidification is an impact category expressing the toxic impact that acidifying substances have on soil, underground water-courses, ground water, organisms, ecosystems and materials. Reaction of acidic gases with water in the atmosphere creates 'acid rain'. The formation of acid rains causes a reduction in biodiversity. In LCA, acidification is expressed in terms of the equivalent weight of sulphur dioxide (SO_2) emitted.
Eutrophication Potential, EP	It is an abnormal proliferation of vegetation in the aquatic ecosystems caused by the addition of nutrients into rivers, lakes or ocean which determinates a lack of oxygen. The eutrophication potential is mainly influenced by emission into water of phosphates and nitrates. Its occurrence can lead to damage to ecosystems, increasing mortality of aquatic fauna and flora and to loss of species that are dependent on low-nutrient environments. In LCA, EP is expressed in mass of PO_4^{3-} eq.
Formation potential of tropospheric ozone photochemical oxidants, POCP	POCP is the formation of reactive substances (mainly ozone) which are injurious to human health and ecosystems and which also may damage crops. This problem is also indicated with "summer smog". In LCA, POCP is expressed in kg C_2H_4 eq.
Abiotic Depletion Potential, ADP	In LCA, resource depletion is one of the impact categories expressing how much of the world's natural resources (petroleum, iron ore, etc.) are used up. It has global, regional and local aspects of impact and expresses the amount of mineral/ fossil fuel used. In LCA, fossil and non-fossil resource depletion are expressed in terms of the MJ and Sb eq. respectively.

ABOUT USE PHASE

According to PCR 2019:14-c-PCR-016 c-PCR-016 Photovoltaic modules and parts thereof, maintenance (B2) shall include the following activities:

- The use of energy, water and detergent for regular cleaning of the PV module throughout the service life.
- Replacement of parts with a reference service life shorter than the declared product.

Since the use of energy, water and detergent for the regular cleaning of the modules have minimal environmental impact throughout the product's service life and are very dependent based on the location of installation, its impact is taken as zero. Similarly, the second bullet point is not relevant for the considered product.

Moreover, operational energy use (B6 stage) is also relevant for PV modules. Generally, PV modules do not require energy to operate and the energy production by a PV module depends on multiple factors such as installed power peak (Wp), degradation factor, geographic location and angle of the modules to the sun. For this reason, energy production should be site-specific and shall be calculated by using below formula.

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

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

where 'E_1' is the energy produced in the first year of operation (kWh/year), 'RSL' is the reference service life (year) for energy-producing unit, and 'deg' is the yearly degradation rate. As stated in the related PCR, produced energy should be site-specific and shall therefore not be declared in the LCA and EPD. Thus, B6 stage is not included in the analysis.

REFERENCES

GPI/ General Programme Instructions of the International EPD System. Version 4.0.

EN ISO 9001/ Quality Management Systems - Requirements

EN ISO 14001/ Environmental Management Systems - Requirements

EN ISO 50001/ Energy Management Systems - Requirements

ISO 14020:2000/ Environmental Labels and Declarations — General principles

EN 15804:2012+A2:2019/ Sustainability of construction works - Environmental Product Declarations — Core rules for the product category of construction products

ISO 14025/ DIN EN ISO 14025:2009-11: Environmental labels and declarations - Type III environmental declarations — Principles and procedures

ISO 14040/44/ DIN EN ISO 14040:2006-10, Environmental management - Life cycle assessment - Principles and framework (ISO14040:2006) and Requirements and guidelines (ISO 14044:2006)

PCR for Construction Products and Construction Services/ Prepared by IVL Swedish Environmental Research Institute, Swedish Environmental Protection Agency, SP Trä, Swedish Wood Preservation Institute, Swedisol, SCDA, Svenskt Limträ AB, SSAB, The International EPD System, 2019:14 Version 1.2.5

PCR – 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 semiconductor materials, version 1.1. The Norwegian EPD Foundation, IFE, REC Group, Sunpower, Solenergiklyngen, Norsuncorp, Statsbygg, Asplan Vlak, Innos, Elektrikerne, Otovo.

The International EPD® System/ The International EPD® System is a programme for type III environmental declarations, maintaining a system to verify and register EPD®s as well as keeping a library of EPD®s and PCRs in accordance with ISO 14025. www.environdec.com

Ecoinvent / Ecoinvent Centre, www.ecoinvent.org

SimaPro/ SimaPro LCA Software, Pré Consultants, the Netherlands, www.pre-sustainability.com

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