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ECO PLATFORM EPD VERIFIED

Owner: Ennogie ApS
No.: MD-23028-EN
Issued: 17-03-2023
Valid to: 17-03-2028

3rd PARTY **VERIFIED**

EPD

VERIFIED ENVIRONMENTAL PRODUCT DECLARATION | **ISO 14025 & EN 15804**

Owner of declaration
Ennogie ApS
Orebygårdvej 16
7400 Herning, Denmark
CVR: 33148879

Program
EPD Danmark
www.epddanmark.dk

☐ Industry EPD
☒ Product EPD

Declared Product
Building integrated photovoltaic (BIPV) module, ERS-0191 (130W)

Number of declared datasets: 2

Production site
Ennogie, Orebygårdvej 16, 7400 Herning, Denmark

The product is not manufactured using green certificates (GO) for the energy consumption in A3.

Product(s) use
The product is a building integrated photovoltaic module (BIPV) with the function of producing electricity and waterproofing the building envelope.

Functional unit
1 Wp of manufactured photovoltaic module, from cradle-to-grave, with activities needed for a study period of 25 years (≥80% of the labelled power output)

Year of data
2021

EPD version
[1], [March 2023]

Issued: 17-03-2023
Valid to: 17-03-2028

Basis of calculation
This EPD is developed in accordance with the European standard EN 15804:2012+A2:2019.

Comparability
EPDs of construction products may not be comparable if they do not comply with the requirements in EN 15804. EPD data may not be comparable if the datasets used are not developed in accordance with EN 15804 and if the background systems are not based on the same database.

Validity
This EPD has been verified in accordance with ISO 14025:2010 and is valid for 5 years from the date of issue.

Use
The intended use of an EPD is to communicate scientifically based environmental information for construction products, for the purpose of assessing the environmental performance of buildings.

EPD type
☐Cradle-to-gate with modules C1-C4 and D
☐Cradle-to-gate with options, modules C1-C4 and D
☒Cradle-to-grave and module D
☐Cradle-to-gate
☐Cradle-to-gate with options

CEN standard EN 15804:2012+A2:2019 serves as the core PCR

Independent verification of the declaration and data, according to EN ISO 14025:2010

☐ internal ☒ external

Third party verifier:

Linda Høibye, Life Cycle Assessment Consulting

Martha Katrine Sørensen
EPD Danmark

Life cycle stages and modules (MND = module not declared)																
Product			Construction process		Use							End of life				Beyond the system boundary
Raw material supply	Transport	Manufacturing	Transport	Installation process	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction demolition	Transport	Waste processing	Disposal	Re-use, recovery and recycling potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Product Information

Product description:

The product assessed in this study is the BIPV module, ERS-0191 (130W), produced by Ennogie ApS. The BIPV module consists of a frameless mono c-SI photovoltaic laminate with a black surface, which provides a coherent black aesthetic. In comparison to a traditional photovoltaic module, the ERS-0191 replaces the roof itself. When installed, the modules will overlap both vertically and horizontally hence providing a waterproof building envelope as any other roof with the added benefit of producing electricity. Datasheet for the ERS-0191 (130W) can be found here:

- **Datasheet:** ERS-0191 (130 W)

The main product components are shown in the table below. Materials account for 100% of the mass of the declared product.

Material	Weight-% of product
Tempered Glass	82.3%
Steel Rail	8.2%
PoE encapsulant	6.6%
Shingled mono c-SI cells	1.6%
Electrical (i.e. wiring)	0.7%
Acrylic tape	0.3%
Rubber strip	0.3%
Total	**100%**

The product packaging is shown in the table below. Materials account for 100% of the mass of the product packaging.

Material	Weight-% of packaging
Pallet	71.3%
Cardboard	13.7%
Steel screws	13.0%
Plastic foil, PE	1.0%
PET band	0.8%
Steel fastening	0.2%
Total	**100%**

Representativity:

This declaration, including data collection and the modeled foreground system including results, represents the production of the declared product manufactured by Ennogie on the production site located in Herning, Denmark, which is also the representative geographical area. Product specific data are based on average values collected in 2021. Background data is based on the database ecoinvent 3.8, which is published in 2021 and complies with EN 15804:2012+A2:2019, section 6.3.8.2, by being less than 10 years old. Generally, the used background datasets are of reasonable quality, and the majority of the datasets are only a couple of years old. All most all datasets are from Denmark, Germany, Europe or Asia and electricity is country specific. Where data quality has been lacking adjustments have been performed to ensure representability.

Hazardous Substances:

The building integrated photovoltaic module, ERS-0191 (130W), by Ennogie ApS does not contain substances listed in the "Candidate List of Substances of Very High Concern for authorization" (http://echa.europa.eu/candidate-list-table)

Essential Characteristics:

Electricity production is regarded as one of the most essential properties of photovoltaics. As prescribed by NPCR 029:2022 v.1.2, section 6.2.5, the energy produced by a PV module depends on the installed power peak [Wp], degradation factor, geographic location and direction/placement of the installation. Produced electricity over the lifetime of the ERS-0191 (130W) should therefore be calculated at a building level assessment.

Mechanical Properties	Unit	Value
Length (installed)	mm	1200
Width (installed)	mm	600
Height	mm	30-40 (sloped)
Surface area of module	m²	0.72
Weight per module	kg	13.97
Weight per 1 m²	kg	19.4

Electrical Properties	Unit	Value
Cell type	-	Mono c-SI, shingled
Cell layout	-	Two parallel strings of 76 active cells
Nominal power [-0/+3]	W	130
Nominal power per 1 m²	W	175
Current at max. power	A	3.1
Voltage at max. power	V	41.94
Short circuit current	A	3.26
Open circuit voltage	V	51.1

Further technical information can be obtained by contacting Ennogie ApS or on their website.

Reference Service Life (RSL):
The reference service (RSL) life is declared to be 25 years as detailed in NPCR 029:2022 v1.2.

It should, however, be noted that the product has two functions to fulfill. The results are hence reported according to the reference service life of the energy producing unit.

Energy Producing Unit: Reference service life of 25 years for ≥80% of the labelled power output based on NPCR 029:2022 v1.2.

Roof Waterproofing: Reference service life of 50 years based on BUILD Report 2021:32 by The Department of Built Environment (BUILD) at Aalborg University (AAU).

The RSL values presumes a correct installation (A5) and maintenance (B2) in accordance with the manuals provided by Ennogie ApS:

- **Manual:** https://ennogie.com/en/documentation/

Pictures of Product:

The BIPV module ERS-0191 (130W) produced by Ennogie ApS

Example of BIPV roof by Ennogie at HC Lumbyesvej, Ikast, built in the year 2018

LCA Background

Functional Unit:
As prescribed by NPCR 029:2022 v1.2, section 6.3.1, the functional unit (FU) is defined as:

- 1 Wp of manufactured photovoltaic module with a reference service life of 25 years (≥80% of the labelled power output).

Results of this study will be displayed for both the functional unit of 1 Wp and 1 m² of roof. The following table displays the mass per Wp as well as the relevant factor to convert the results from 1 Wp to 1 m² of BIPV module.

Name	Unit	Value
Functional unit	Wp	1
Conversion factor to 1 kg.	Wp/kg	12.53
Conversion factor to 1 m^2	Wp/m^2	175

Product Category Rules (PCR):
This EPD is developed according to the core product category rules (PCR) for construction products detailed in EN 15804:2012+A2:2019, and the following two complementary standards:

- NPCR 029:2022 v1.2 – Part B for photovoltaic modules
- NPCR 022:2022 v2.0 – Part B for roof water-proofing

Guarantee of Origin – Certificates:
The ERS-0191 (130W) is not produced using guarantees of origin (GOs) for the energy consumption during the manufacturing stage at Ennogie ApS in Herning (A3).

Foreground System:
The production at Ennogie ApS (A3) is modelled based on site-specific data for the year 2021. The electricity consumption is modelled as an average supply mix in Denmark. The remaining activities are likewise modelled with average supply mixes representing the individual countries (e.g. CN & DE) or regions (e.g. EU & RoW) pertaining to the specific processes in the value chain.

Background System:
The database, ecoinvent 3.8, (published in 09-2021) is utilized for the background system. As a result, both upstream- and downstream activities are based on average supply mixes for the specific country or region depending on the given dataset.

System Boundary:
This EPD is based on a cradle-to-grave LCA and covers all the life cycle modules A1-A3, A4-A5, B1-B7, C1-C4, and D, in which 100 weight-% of the product has been accounted for.

The general rules for the exclusion of inputs and outputs follows the requirements specified in EN 15804:2012+A2:2019, section 6.3.6, where the total of neglected input flows per module shall be a maximum of 5 % of energy usage and mass and 1 % of renewable and non-renewable primary energy usage and mass for unit processes. In addition, particular care has been taken to include materials and flows known to have the potential to cause significant emissions into air, water and soil related to the environmental indicators assessed in this study. In this respect, conservative assumptions in combination with plausibility considerations and expert judgement has been used to demonstrate compliance with this criterion.

Product stage (A1-A3):
The product stage comprises the acquisition of all raw materials, products and energy, transport to the production site, packaging and waste processing up to the ”end-of-waste” state or final disposal. The LCA results are declared in aggregated form for the product stage, which means, that the sub-modules A1, A2 and A3 are declared as one module A1-A3.

The active module ERS-0191 (130W) consists of photovoltaic laminate with a shingled mono c-SI cell type. The PV laminate consists of six individual layers: (i) tempered glass, (ii) transparent lamination foil, (iii) shingled mono c-Si cells, (iv) transparent lamination foil, (v) black lamination foil, and (vi) tempered glass. Two steel rails with Magnelis® coating are installed on the bottom side of the PV laminate for mounting the BIPV on the roof. The laminate is secured using double-sided gray moldable acrylic foam tape and a rubber strip.

The production facilities of Ennogie ApS are primarily utilized for assembly, since the majority of components are pre-manufactured i.e. the PV laminate and steel rails. In this respect, Ennogie ApS primarily assembles a series of components

into the final product ready for transportation to the building site.

The heat is entirely supplied by a heat pump on site and the production site of Ennogie ApS in Herning, Denmark, exclusively utilizes electric forklifts for internal transport

Construction Stage (A4-A5):
The transportation between Ennogie ApS in Herning and the building site can generally be classified as small batches through direct sales with an assumed distance of 300 km.

It should be recognized that the installation process will vary depending on the specific building. Some construction projects can be done almost manually, while others require the use of an electrical- or diesel construction lift to transport materials to the roof. While assumptions for lift operation based on average site data are included in this EPD (See additional technical information on scenarios), the following ancillary components should be considered at building level assessment as prescribed by the standard NPC 029:2022. V1.2 for photovoltaic modules:

- Wiring
- Switches
- Solar inverters
- Battery banks
- Battery charger
- Screws, fasteners and other additional materials
- Materials for the mounting system of the module
- Other electrical components and systems necessary to connect the photovoltaic module to the electrical grid
- Personnel activities and transport of personnel

Furthermore, NPCR 022:2022 V2.0 for roof waterproofing, specifies that insulation, battens, roof sheathing and other construction systems necessary to carry the roof waterproofing product shall not be included in the EPD.

Use Stage (B1-B7):
The ERS-0191 (130W) is considered to be static after the installation and no direct emissions are expected during the life span of the ERS-0191 (130W).

Limited maintenance (B2) is required for the ERS-0191 (130W) and conservatively pertains to cleaning. It should be noted, that the design of the ERS-0191 (130W) makes it difficult for dirt to accumulate on the surface area of the roof. As a result, rain will for the most part be sufficient in keeping the BIPV modules clean. However, in some instances, cleaning can be necessary due to pollen from nearby trees. As this is primarily happens seasonally, an annual maintenance cycle is assumed for the BIPV modules.

No repair, replacement, or refurbishment (B3-B5) due to damage is expected within the reference service life of 25 years. Furthermore, there is generally no operational water- and energy consumption (B6-B7) associated with the use stage. As previously stated, the electricity produced by a PV module depends on the installed power peak [Wp], degradation factor, geographic location and cardinal direction of the installation. The electricity production of the ERS-0191 (130W) should therefore be calculated at a building level assessment. Please refer to the *Additional Technical Information* in this EPD or Section 6.2.5 in NPCR 029:2022 v1.2 for an overview of how the electricity production of the ERS-0191 (130W) should be calculated.

End of Life (C1-C4):
The deconstruction of the products covered by this study is assumed to be done manually with exception of lift operation. The lift operation will vary depending on the building, but is assumed to be the same as the installation process in this EPD.

The collection and waste treatment of photovoltaics is regulated by EU's Directive 2012/19/EU on Waste Electrical and Electronic Equipment (WEEE). This entails a structured system of waste collection due to the extended producer responsibility, which means that the developers and importers of photovoltaics are responsible for the product throughout the whole lifetime.

For the waste treatment of the photovoltaic modules, Denmark has no end-processing facilities and only a few pre-processing facilities for electronic waste. As a result, photovoltaics are expected to be exported to Germany for waste treatment.

The mechanical treatment in laminated glass recycling plants represents a state-of-the-art process for recycling c-Si modules and the waste processing of the PV modules are therefore

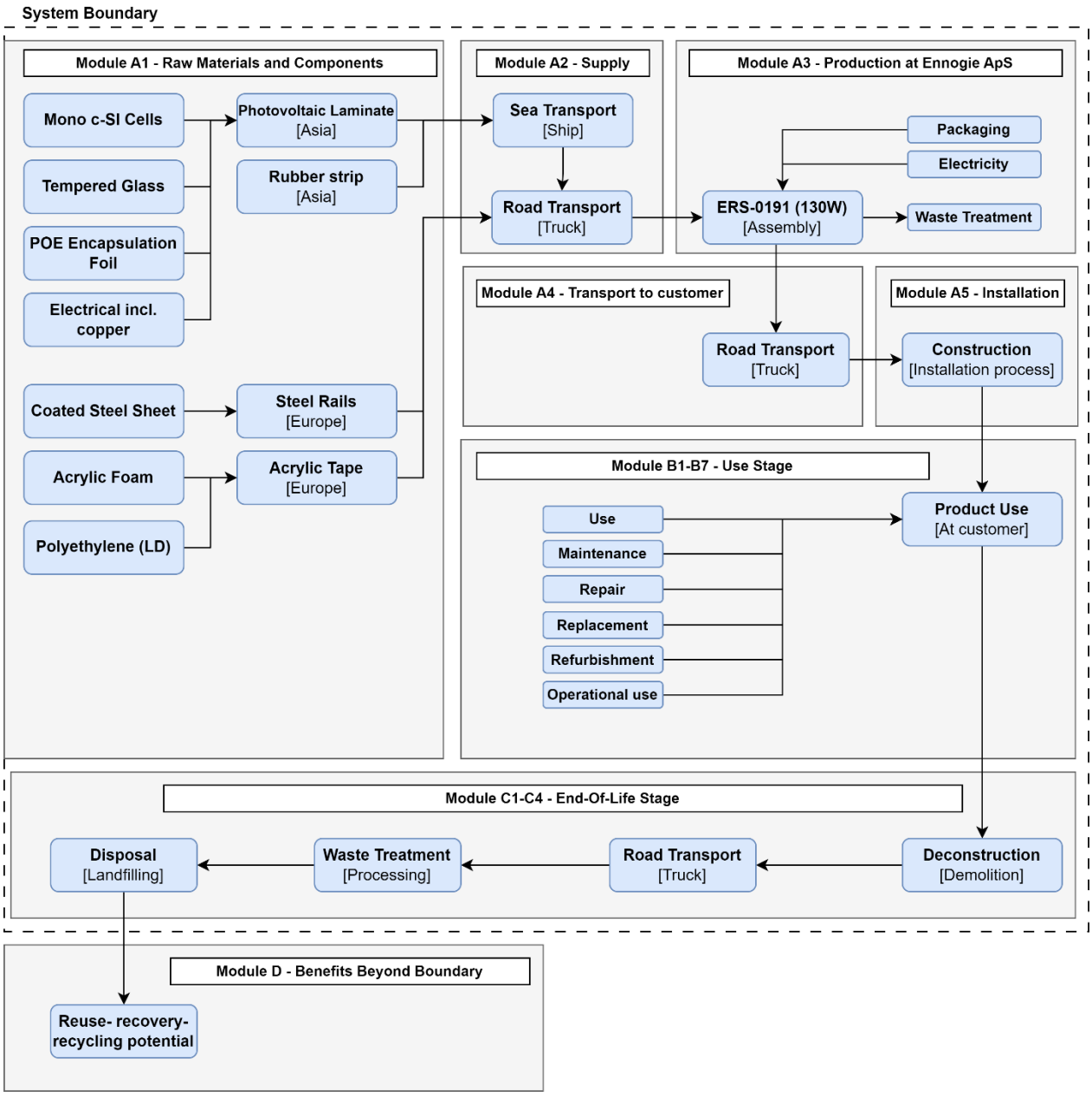
assumed to be performed based on these processes. NPCR 029:2022 v.1.2 includes a default conservative scenarios for life cycle modules C3 for waste processing and disposal (C4), which is used for the waste treatment of the photovoltaic modules.

Re-use, recovery, & recycling potential (D): Several of the materials used in the production have potential benefits and load beyond the system boundary. These include the following:

- Glass – 100% of the recycled glass is used for insulation
- Steel – 95% steel (made from virgin ores), 5% loss
- Copper – 95% copper (made from virgin ores), 5% loss
- Silicon – 86% metallurgical grade silicon, 14% loss
- Municipal Incineration: 30% electricity (Average), 56% heat (Average), 14% loss.

Electricity generated through the waste incineration at the CHP plant is assumed to replace the average German electricity mix, while thermal energy is utilized as district heating in Germany.

Flowchart:



LCA Results

Due to the multiple functions of the BIPV module two datasets are presented for the ERS-0191 (130W) i.e. 1 Wp and 1 m² equivalent to 175 Wp. The datasets can be found on the following pages:

- **Page 8-9:** 1 Wp of ERS-0191 (130W)
- **Page 10-11:** 1 m² of ERS-0191 (130W)

Active BIPV Module – 1 Wp of ERS-0191(130W)

ENVIRONMENTAL IMPACTS PER 1 Wp – ERS-0191 (130W)												
Parameter	**Unit**	**A1-A3**	**A4**	**A5**	**B1**	**B2**	**B3-B7**	**C1**	**C2**	**C3**	**C4**	**D**
GWP-total	[kg CO_2 eq.]	9.46E-01	8.23E-03	1.23E-02	0.00E+00	2.26E-02	0.00E+00	1.81E-03	1.85E-02	3.62E-02	8.28E-04	-6.87E-02
GWP-fossil	[kg CO_2 eq.]	9.57E-01	8.22E-03	3.60E-03	0.00E+00	2.26E-02	0.00E+00	1.81E-03	1.84E-02	3.48E-02	8.25E-04	-6.52E-02
GWP-biogenic	[kg CO_2 eq.]	-1.19E-02	7.90E-06	8.72E-03	0.00E+00	8.58E-06	0.00E+00	6.71E-07	1.66E-05	1.31E-03	2.19E-06	-3.35E-03
GWP-luluc	[kg CO_2 eq.]	9.46E-04	3.87E-06	1.23E-06	0.00E+00	2.24E-06	0.00E+00	1.79E-07	7.24E-06	2.18E-05	1.09E-07	-7.50E-05
ODP	[kg CFC 11 eq.]	1.17E-07	1.85E-09	5.52E-10	0.00E+00	4.78E-09	0.00E+00	3.82E-10	4.27E-09	8.95E-10	1.95E-10	-3.60E-09
AP	[mol H^+ eq.]	5.92E-03	3.27E-05	1.27E-05	0.00E+00	9.57E-05	0.00E+00	7.66E-06	7.49E-05	1.32E-04	3.95E-06	-6.40E-04
EP-freshwater	[kg PO_4 eq.]	3.33E-04	6.17E-07	8.91E-07	0.00E+00	6.97E-07	0.00E+00	5.54E-08	1.19E-06	1.59E-05	2.48E-08	-8.10E-05
EP-marine	[kg N eq.]	1.40E-03	9.51E-06	4.54E-06	0.00E+00	3.49E-05	0.00E+00	2.79E-06	2.25E-05	1.92E-05	9.85E-06	-7.20E-05
EP-terrestrial	[mol N eq.]	1.34E-02	1.04E-04	4.72E-05	0.00E+00	3.83E-04	0.00E+00	3.06E-05	2.46E-04	1.96E-04	1.63E-05	-7.50E-04
POCP	[kg NMVOC eq.]	4.69E-03	3.19E-05	1.37E-05	0.00E+00	1.15E-04	0.00E+00	9.16E-06	7.55E-05	5.04E-05	4.75E-06	-2.40E-04
ADPm[1]	[kg Sb eq.]	5.18E-05	3.74E-08	4.29E-09	0.00E+00	1.15E-08	0.00E+00	9.20E-10	6.41E-08	1.87E-06	8.55E-10	-1.00E-05
ADPf[1]	[MJ]	1.10E+01	1.23E-01	4.32E-02	0.00E+00	3.07E-01	0.00E+00	2.45E-02	2.79E-01	2.04E-01	1.29E-02	-8.23E-01
WDP[1]	[m^3 world eq. deprived]	9.63E-01	4.06E-04	1.41E-04	0.00E+00	1.71E-03	0.00E+00	3.84E-05	8.35E-04	3.95E-03	7.00E-05	-1.31E-02
Caption	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 = Ozone Depletion; AP = Acidification; EP-freshwater = Eutrophication – aquatic freshwater; EP-marine = Eutrophication – aquatic marine; EP-terrestrial = Eutrophication – terrestrial; POCP = Photochemical zone formation; ADPm = Abiotic Depletion Potential – minerals and metals; ADPf = Abiotic Depletion Potential – fossil fuels; WDP = water use											
Disclaimer	[1] The results of this environmental indicator shall be used with care as the uncertainties on these results are high or as there is limited experienced with the indicator.											

ADDITIONAL ENVIRONMENTAL IMPACTS PER 1 Wp – ERS-0191 (130W)												
Parameter	**Unit**	**A1-A3**	**A4**	**A5**	**B1**	**B2**	**B3-B7**	**C1**	**C2**	**C3**	**C4**	**D**
PM	[Disease incidence]	7.45E-08	6.12E-10	2.43E-10	0.00E+00	2.22E-09	0.00E+00	1.78E-10	1.59E-09	6.34E-10	8.68E-11	-2.90E-09
IRP[2]	[kBq U235 eq.]	5.83E-02	6.51E-04	2.87E-04	0.00E+00	1.38E-03	0.00E+00	1.11E-04	1.43E-03	2.32E-03	6.32E-05	-7.34E-03
ETP-fw[1]	[CTUe]	3.35E+01	1.00E-01	3.07E-02	0.00E+00	1.80E-01	0.00E+00	1.44E-02	2.18E-01	9.75E-01	8.59E-03	-4.23E+00
HTP-c[1]	[CTUh]	9.61E-10	3.66E-12	2.30E-12	0.00E+00	2.04E-11	0.00E+00	1.63E-12	7.05E-12	2.96E-11	1.82E-13	-2.20E-10
HTP-nc[1]	[CTUh]	3.75E-08	1.01E-10	4.27E-11	0.00E+00	1.63E-10	0.00E+00	1.30E-11	2.28E-10	1.84E-09	3.95E-12	-6.30E-09
SQP[1]	-	5.51E+00	7.24E-02	1.03E-02	0.00E+00	3.91E-02	0.00E+00	3.12E-03	1.92E-01	8.23E-02	2.88E-02	-4.41E-01
Caption	PM = Particulate Matter emissions; IRP = Ionizing radiation – human health; ETP-fw = Eco toxicity – freshwater; HTP-c = Human toxicity – cancer effects; HTP-nc = Human toxicity – non cancer effects; SQP = Soil Quality (dimensionless)											
Disclaimers	[1] The results of this environmental indicator shall be used with care as the uncertainties on these results are high or as there is limited experienced with the indicator.											
	[2] 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.											

RESOURCE USE PER 1 Wp – ERS-0191 (130W)												
Parameter	**Unit**	**A1-A3**	**A4**	**A5**	**B1**	**B2**	**B3-B7**	**C1**	**C2**	**C3**	**C4**	**D**
PERE	[MJ]	1.89E+00	2.07E-03	1.37E-01	0.00E+00	1.77E-03	0.00E+00	1.38E-04	3.93E-03	2.70E-02	2.83E-04	-1.55E-01
PERM	[MJ]	1.35E-01	0.00E+00	-1.35E-01	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]	2.03E+00	2.07E-03	1.57E-03	0.00E+00	1.77E-03	0.00E+00	1.38E-04	3.93E-03	2.70E-02	2.83E-04	-1.55E-01
PENRE	[MJ]	1.07E+01	1.23E-01	4.32E-02	0.00E+00	3.07E-01	0.00E+00	2.45E-02	2.79E-01	5.31E-01	1.29E-02	-8.23E-01
PENRM	[MJ]	3.27E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-3.27E-01	0.00E+00	0.00E+00
PENRT	[MJ]	1.10E+01	1.23E-01	4.32E-02	0.00E+00	3.07E-01	0.00E+00	2.45E-02	2.79E-01	2.04E-01	1.29E-02	-8.23E-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
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
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
FW	[m^3]	2.42E-02	1.55E-05	1.02E-05	0.00E+00	4.62E-05	0.00E+00	1.40E-06	3.11E-05	1.71E-04	1.55E-05	-6.70E-04
Caption	PERE = Use of renewable primary energy excluding renewable primary energy resources used as raw materials; PERM = Use of renewable primary energy resources used as raw materials; PERT = Total use of renewable primary energy resources; PENRE = Use of non renewable primary energy excluding non renewable primary energy resources used as raw materials; PENRM = Use of non renewable primary energy resources used as raw materials; PENRT = Total use of non renewable primary energy resources; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Use of non renewable secondary fuels; FW = Net use of fresh water											

WASTE CATEGORIES AND OUTPUT FLOWS PER 1 Wp – ERS-0191 (130W)												
Parameter	**Unit**	**A1-A3**	**A4**	**A5**	**B1**	**B2**	**B3**	**C1**	**C2**	**C3**	**C4**	**D**
HWD	[kg]	7.08E-04	3.29E-07	1.07E-07	0.00E+00	8.40E-07	0.00E+00	6.72E-08	7.28E-07	1.92E-07	1.46E-08	-1.20E-06
NHWD	[kg]	1.50E-01	5.20E-03	6.35E-04	0.00E+00	4.11E-04	0.00E+00	3.28E-05	1.43E-02	2.51E-02	9.07E-02	-1.05E-02
RWD	[kg]	2.48E-05	8.22E-07	2.67E-07	0.00E+00	2.12E-06	0.00E+00	1.69E-07	1.89E-06	8.15E-07	8.63E-08	-2.60E-06
CRU	[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
MFR	[kg]	9.85E-04	0.00E+00	1.39E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.84E-02	0.00E+00	0.00E+00
MER	[kg]	7.34E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EEE	[MJ]	1.26E-03	0.00E+00	2.84E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.33E-02	0.00E+00	0.00E+00
EET	[MJ]	4.71E-03	0.00E+00	1.07E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.74E-01	0.00E+00	0.00E+00
Caption	HWD = Hazardous waste disposed; NHWD = Non hazardous waste disposed; RWD = Radioactive waste disposed; CRU = Components for re-use; MFR = Materials for recycling; MER = Materials for energy recovery; EE = Exported energy											

BIOGENIC CARBON CONTENT PER 1 Wp – ERS-0191 (130W)		
Parameter	**Unit**	**At the factory gate**
Biogenic carbon content in product	[kg C]	0.00E+00
Biogenic carbon content in accompanying packaging	[kg C]	3.33E-03
Note	1 kg biogenic carbon is equivalent to 44/12 kg of CO_2	

Active BIPV Module – 1 m² of ERS-0191 (130W)

ENVIRONMENTAL IMPACTS PER 1 m² – ERS-0191 (130W)												
Parameter	**Unit**	**A1-A3**	**A4**	**A5**	**B1**	**B2**	**B3-B7**	**C1**	**C2**	**C3**	**C4**	**D**
GWP-total	[kg CO_2 eq.]	1.66E+02	1.44E+00	2.16E+00	0.00E+00	3.96E+00	0.00E+00	3.16E-01	3.23E+00	6.33E+00	1.45E-01	-1.20E+01
GWP-fossil	[kg CO_2 eq.]	1.68E+02	1.44E+00	6.30E-01	0.00E+00	3.95E+00	0.00E+00	3.16E-01	3.23E+00	6.09E+00	1.44E-01	-1.14E+01
GWP-biogenic	[kg CO_2 eq.]	-2.09E+00	1.38E-03	1.53E+00	0.00E+00	1.50E-03	0.00E+00	1.17E-04	2.91E-03	2.30E-01	3.83E-04	-5.86E-01
GWP-luluc	[kg CO_2 eq.]	1.66E-01	6.77E-04	2.15E-04	0.00E+00	3.92E-04	0.00E+00	3.13E-05	1.27E-03	3.82E-03	1.91E-05	-1.31E-02
ODP	[kg CFC 11 eq.]	2.05E-05	3.24E-07	9.66E-08	0.00E+00	8.37E-07	0.00E+00	6.69E-08	7.47E-07	1.57E-07	3.41E-08	-6.30E-07
AP	[mol H^+ eq.]	1.04E+00	5.72E-03	2.22E-03	0.00E+00	1.67E-02	0.00E+00	1.34E-03	1.31E-02	2.31E-02	6.91E-04	-1.12E-01
EP-freshwater	[kg PO_4 eq.]	5.83E-02	1.08E-04	1.56E-04	0.00E+00	1.22E-04	0.00E+00	9.70E-06	2.08E-04	2.78E-03	4.34E-06	-1.42E-02
EP-marine	[kg N eq.]	2.46E-01	1.66E-03	7.95E-04	0.00E+00	6.11E-03	0.00E+00	4.88E-04	3.94E-03	3.36E-03	1.72E-03	-1.26E-02
EP-terrestrial	[mol N eq.]	2.35E+00	1.82E-02	8.26E-03	0.00E+00	6.70E-02	0.00E+00	5.36E-03	4.31E-02	3.43E-02	2.85E-03	-1.31E-01
POCP	[kg NMVOC eq.]	8.20E-01	5.58E-03	2.40E-03	0.00E+00	2.01E-02	0.00E+00	1.60E-03	1.32E-02	8.82E-03	8.31E-04	-4.20E-02
ADPm[1]	[kg Sb eq.]	9.06E-03	6.55E-06	7.51E-07	0.00E+00	2.01E-06	0.00E+00	1.61E-07	1.12E-05	3.27E-04	1.50E-07	-1.75E-03
ADPf[1]	[MJ]	1.92E+03	2.15E+01	7.55E+00	0.00E+00	5.37E+01	0.00E+00	4.29E+00	4.88E+01	3.56E+01	2.25E+00	-1.44E+02
WDP[1]	[m^3 world eq. deprived]	1.68E+02	7.11E-02	2.47E-02	0.00E+00	2.99E-01	0.00E+00	6.72E-03	1.46E-01	6.91E-01	1.23E-02	-2.29E+00
Caption	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 = Ozone Depletion; AP = Acidification; EP-freshwater = Eutrophication – aquatic freshwater; EP-marine = Eutrophication – aquatic marine; EP-terrestrial = Eutrophication – terrestrial; POCP = Photochemical zone formation; ADPm = Abiotic Depletion Potential – minerals and metals; ADPf = Abiotic Depletion Potential – fossil fuels; WDP = water use											
Disclaimer	[1] The results of this environmental indicator shall be used with care as the uncertainties on these results are high or as there is limited experienced with the indicator.											

ADDITIONAL ENVIRONMENTAL IMPACTS PER 1 m² – ERS-0191 (130W)												
Parameter	**Unit**	**A1-A3**	**A4**	**A5**	**B1**	**B2**	**B3-B7**	**C1**	**C2**	**C3**	**C4**	**D**
PM	[Disease incidence]	1.30E-05	1.07E-07	4.25E-08	0.00E+00	3.89E-07	0.00E+00	3.12E-08	2.78E-07	1.11E-07	1.52E-08	-5.08E-07
IRP[2]	[kBq U235 eq.]	1.02E+01	1.14E-01	5.02E-02	0.00E+00	2.42E-01	0.00E+00	1.94E-02	2.51E-01	4.06E-01	1.11E-02	-1.28E+00
ETP-fw[1]	[CTUe]	5.87E+03	1.75E+01	5.38E+00	0.00E+00	3.14E+01	0.00E+00	2.51E+00	3.81E+01	1.71E+02	1.50E+00	-7.40E+02
HTP-c[1]	[CTUh]	1.68E-07	6.41E-10	4.03E-10	0.00E+00	3.57E-09	0.00E+00	2.85E-10	1.23E-09	5.18E-09	3.19E-11	-3.85E-08
HTP-nc[1]	[CTUh]	6.56E-06	1.77E-08	7.47E-09	0.00E+00	2.85E-08	0.00E+00	2.28E-09	3.99E-08	3.22E-07	6.91E-10	-1.10E-06
SQP[1]	-	9.65E+02	1.27E+01	1.81E+00	0.00E+00	6.85E+00	0.00E+00	5.47E-01	3.35E+01	1.44E+01	5.05E+00	-7.71E+01
Caption	PM = Particulate Matter emissions; IRP = Ionizing radiation – human health; ETP-fw = Eco toxicity – freshwater; HTP-c = Human toxicity – cancer effects; HTP-nc = Human toxicity – non cancer effects; SQP = Soil Quality (dimensionless)											
Disclaimers	[1] The results of this environmental indicator shall be used with care as the uncertainties on these results are high or as there is limited experienced with the indicator.											
	[2] 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.											

RESOURCE USE PER 1 m² – ERS-0191 (130W)												
Parameter	**Unit**	**A1-A3**	**A4**	**A5**	**B1**	**B2**	**B3-B7**	**C1**	**C2**	**C3**	**C4**	**D**
PERE	[MJ]	3.32E+02	3.63E-01	2.40E+01	0.00E+00	3.10E-01	0.00E+00	2.42E-02	6.88E-01	4.73E+00	4.95E-02	-2.70E+01
PERM	[MJ]	2.37E+01	0.00E+00	-2.37E+01	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]	3.55E+02	3.63E-01	2.75E-01	0.00E+00	3.10E-01	0.00E+00	2.42E-02	6.88E-01	4.73E+00	4.95E-02	-2.70E+01
PENRE	[MJ]	1.86E+03	2.15E+01	7.55E+00	0.00E+00	5.37E+01	0.00E+00	4.29E+00	4.88E+01	9.29E+01	2.25E+00	-1.44E+02
PENRM	[MJ]	5.73E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-5.73E+01	0.00E+00	0.00E+00
PENRT	[MJ]	1.92E+03	2.15E+01	7.55E+00	0.00E+00	5.37E+01	0.00E+00	4.29E+00	4.88E+01	3.57E+01	2.25E+00	-1.44E+02
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
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
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
FW	[m^3]	4.23E+00	2.71E-03	1.79E-03	0.00E+00	8.09E-03	0.00E+00	2.45E-04	5.44E-03	2.99E-02	2.71E-03	-1.17E-01
Caption	PERE = Use of renewable primary energy excluding renewable primary energy resources used as raw materials; PERM = Use of renewable primary energy resources used as raw materials; PERT = Total use of renewable primary energy resources; PENRE = Use of non renewable primary energy excluding non renewable primary energy resources used as raw materials; PENRM = Use of non renewable primary energy resources used as raw materials; PENRT = Total use of non renewable primary energy resources; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Use of non renewable secondary fuels; FW = Net use of fresh water											

WASTE CATEGORIES AND OUTPUT FLOWS PER 1 m² – ERS-0191 (130W)												
Parameter	**Unit**	**A1-A3**	**A4**	**A5**	**B1**	**B2**	**B3**	**C1**	**C2**	**C3**	**C4**	**D**
HWD	[kg]	1.24E-01	5.76E-05	1.87E-05	0.00E+00	1.47E-04	0.00E+00	1.18E-05	1.27E-04	3.36E-05	2.56E-06	-2.10E-04
NHWD	[kg]	2.62E+01	9.10E-01	1.11E-01	0.00E+00	7.19E-02	0.00E+00	5.74E-03	2.51E+00	4.39E+00	1.59E+01	-1.83E+00
RWD	[kg]	4.34E-03	1.44E-04	4.67E-05	0.00E+00	3.71E-04	0.00E+00	2.96E-05	3.31E-04	1.43E-04	1.51E-05	-4.55E-04
CRU	[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
MFR	[kg]	1.72E-01	0.00E+00	2.43E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.22E+00	0.00E+00	0.00E+00
MER	[kg]	1.28E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EEE	[MJ]	2.20E-01	0.00E+00	4.98E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.63E+01	0.00E+00	0.00E+00
EET	[MJ]	8.25E-01	0.00E+00	1.87E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.05E+01	0.00E+00	0.00E+00
Caption	HWD = Hazardous waste disposed; NHWD = Non hazardous waste disposed; RWD = Radioactive waste disposed; CRU = Components for re-use; MFR = Materials for recycling; MER = Materials for energy recovery; EE = Exported energy											

BIOGENIC CARBON CONTENT PER 1 m² – ERS-0191 (130W)		
Parameter	**Unit**	**At the factory gate**
Biogenic carbon content in product	[kg C]	0.00E+00
Biogenic carbon content in accompanying packaging	[kg C]	5.83E-01
Note	1 kg biogenic carbon is equivalent to 44/12 kg of CO_2	

Additional Information

Technical Information on Electricity Production:

The electricity production of the photovoltaic modules will depending on several variables e.g. installed power peak (Wp), degradation factor, geographic location, and cardinal orientation of the installation. For this reason, the produced electricity over the lifetime of the ERS-0191 (130W) will vary depending on the specific construction project.

As a result, the produced electricity of the ERS-0191 (130W) is not declared in this environmental product declaration (EPD). Instead, the necessary information is included to calculate the total produced electricity for the given building based on site specific data. For calculating the energy production, the following formulas are applied as specified in NPCR 029:2022, section 6.2.5:

Energy production for the first year:

$$E_1 = S_{rad} \times A \times y \times PR \times (1 - deg)$$

Energy production for the second year:

$$E_2 = E_1 \times (1 - deg)$$

Energy production for any given year:

$$E_n = E_1 \times (1 - deg)^n$$

Energy production for the full reference service life (RSL):

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

The following table lists the applied parameters:

Parameter	Description	Unit	Value
S_{rad}	Site specific annual average solar radiation on module (shading not included). The annual radiation must take into consideration the specific inclination (i.e. scope and tilt) and orientation.	kWh/kWp/year	Site specific
A	Total surface area of the active BIPV installation (5.7143E-03 m²/Wp)	m²	Site specific
y	Module yield i.e. electrical power of the module under standard test conditions[1] (STC) divided by the area of the module (A) as declared in the EPD.	kWp/m²	0.175
PR	Performance ratio as a coefficient for losses. Site specific performance ratio can be modelled with PV simulation software tools, e.g. PVSyst or similar, and accounts for losses from inverters, temperatures, DC cables, AC cables, shading, weak radiation, dust, and snow etc. [2]	-	Site specific
deg	Yearly degradation rate. If no data is available, a default linear degradation rate of 0.007 (0.07%) per year is assumed.	%	0.7
n	Year of operation	-	-
RSL	Reference service life of the energy producing unit	years	25

Please refer to the Danish Building Code, Technical Provision 11, §297 - §298 and supplementary guidance on the climate impact of buildings provided in Section 1.8 - Emissionsfaktorer for additional information concerning photovoltaic modules in a building level assessment.

Interpretation:

Examining the impact contributions of production activities (A1-A3) for the ERS-0191 (130W), it is clear that the production of photovoltaic laminate (A1) contributes to a significant amount to the overall environmental impact across the majority of indicators. The electricity consumption associated with the production of the photovoltaic laminate (A1) is the most dominant contributor within the product system. This especially pertains to the global warming from fossil sources (GWP-fossil), acidification (AP), eutrophication (EP), photochemical ozone formation (POCP), and abiotic depletion of fossil fuels (ADPf).

[1] The ratio is given for standard test conditions: irradiance 1000 W/m2, cell temperature 25 °C, wind speed 1 m/s, AM1.5.
[2] For guidance on the calculation of site specific performance ratio (PR) please contact Ennogie AoS.

Emissions can largely be prescribed to the large share of fossil energy sources in the Chinese electricity supply with a particular emphasis on the mining and combustion of hard coal.

Overall, limited impact is seen during the use stage (B1-B7). It should, however, be noted that no electricity production is represented in the system model. This is because electricity production must be calculated at a building level c.f. NPCR 029:2022 v2.0. In this respect, a significant amount of avoided emissions are expected during the use stage, where the ERS-0191 (130W) will serve as both a roof and energy producing unit. Concerning the waste treatment (C1-C4), a limited impact is seen in comparison to the production stage (A1-A3). Lastly, benefits and loads beyond the system boundary (D) is counteracting ≈5-15% of the impact for most impact categories with the exception of water deprivation (WDP).

Technical Information on Scenarios:

A4 - Transport to the building site	Unit	Value
Fuel type	-	Diesel
Vehicle type	-	Truck (7.5-16 ton)
Classification	EURO5	-
Transport distance	km	300
Capacity utilization (including empty runs)	%	32.9

A5 - Installation	Unit	Value
Description of installation	-	Manual
Operating hours of lift	h/m²	0.025
Waste materials (packaging)	kg/m²	1.95

B2 - Maintenance	Unit	Value
Maintenance process	-	Cleaning (Optional)
Maintenance cycle	number/year	1
Net fresh water consumption during maintenance	Kg/cycle	0.2
Operating hours of lift	h/cycle	0.013

C1-C4 - End of life	Unit	Value
For reuse	kg/m²	0.00
For recycling	kg/m²	3.54
For energy recovery	kg/m²	1.31
For final disposal	kg/m²	14.55

D - Re-use, recovery and recycling potential	Unit	Value
Municipal incineration at CHP facility (DE)		
Electricity	%	30%
Heat	%	56%
Loss	%	14%
Recycling – Photovoltaic cells (DE)		
Metallurgical grade silicon	%	86%
Loss	%	14%

Indoor Air:

The EPD does not give information on release of dangerous substances to indoor air because the horizontal standards on measurement of release of regulated dangerous substances from construction products using harmonized test methods according to the provisions of the respective technical committees for European product standards are not available.

Soil and Water:

The EPD does not give information on release of dangerous substances to soil and water because the horizontal standards on measurement of release of regulated dangerous substances from construction products using harmonized test methods according to the provisions of the respective technical committees for European product standards are not available.

References

Publisher	www.epddanmark.dk
Program Operator	Danish Technological Institute Buildings & Environment Gregersensvej DK-2630, Taastrup www.teknologisk.dk
LCA-practitioner	NIRAS A/S Østre Havnegade 12 DK-9000, Aalborg www.niras.dk Project manager: Yana Ramsheva LCA practitioners: Asbjørn Uldbjerg Bundgaard and Natascha Frandsen QA/internal review: Jesper Jakobsen
LCA software /background data	SimaPro 9.4.0.2 Ecoinvent 3.8 (Published d. 09-2021)
3rd party verifier	Linda Høibye Life Cycle Assessment Consulting DK-7120 Vejle Øst

Ecoinvent 3.8
https://ecoinvent.org/

General program instructions
Version 2.0
www.epddanmark.dk

EN 15804
DS/EN 15804 + A2:2019 - "Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products"

EN 50583-1:2016
EN 50583-1:2016 – Photovoltaics in buildings – Part 1: BIPV Modules

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EN 50583-2:2016 – Photovoltaics in buildings – Part 2: BIPV Systems

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NPCR 022:2022 v2.0 – Part B for Roof waterproofing.

NPCR 029:2022 v1.2
NPCR 029:2022 v1.2 – 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

EN 15942
DS/EN 15942:2011 – ” Sustainability of construction works – Environmental product declarations – Communication format business-to-business”

ISO 14025
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ISO 14040
DS/EN ISO 14040:2008 – ” Environmental management – Life cycle assessment – Principles and framework”

ISO 14044
DS/EN ISO 14044:2008 – ” Environmental management – Life cycle assessment – Requirements and guidelines”