# Risen Energy Co., Ltd.

# Environmental Product Declaration

**Product name:**

Mono-crystalline silicon photovoltaic (PV) modules:

**RSM144-9-xxxBNDG**
**RSM144-10-xxxBNDG**

**Site Plants:**

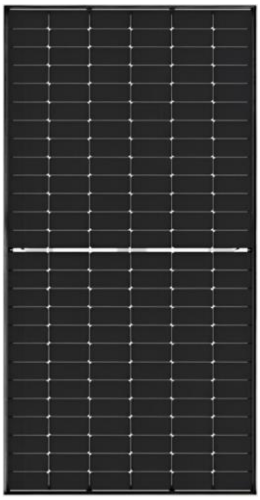
- No.1, Middle Xingke Road Ninghai County 315609 Ningbo City, Zhejiang Province PEOPLE'S REPUBLIC OF CHINA

**In accordance with ISO 14025**

| | |
|---|---|
| Program operator | EPD Italy |
| Publisher | EPD Italy |

| | |
|---|---|
| Declaration Number | RSM-EPD24-01 |
| Registration Number | EPDITALY0896 |

| | |
|---|---|
| Issue Date | 18/06/2025 |
| Valid to | 18/06/2030 |



RSM144-10-xxxBNDG PV module

www.epditaly.it

*EPD owner:*

**Risen Energy Co., Ltd.**

Meilin, Ninghai, 315609 Ningbo, Zhejiang, PEOPLE'S REPUBLIC OF CHINA

https://en.risen.com/

marketing@risen.com

Contact information: Hu **Ziyun,**

huzy@risenenergy.com

# 1. Introduction

### 1.1. Company introduction

Risen Energy Co., Ltd., founded in 1986 and listed on the Chinese stock exchange in 2010 (Stock Code: 300118), is a global leader in the development, manufacturing, and distribution of photovoltaic (solar) products and solutions. The company specializes in providing high-efficiency solar modules, energy storage systems, and integrated solar power solutions. Risen Energy is committed to accelerating the transition to renewable energy, offering cutting-edge technology and reliable products for residential, commercial, and utility-scale applications.

With an annual module production capacity of 30 GW and annual sales exceeding 20 billion RMB, Risen Energy continues its international expansion with offices and sales networks in over 20 countries across Europe, Asia, North America, and other regions. The company stands out for its long-term vision, leading the global energy revolution with advanced solar solutions.

To support this vision, Risen Energy established the Global Photovoltaic Research Institute in November 2023. This institute is dedicated to integrated technology research, product development, and innovation management to provide low-carbon photovoltaic solutions and enhance the competitiveness of the company's products and technologies. As a global platform for photovoltaic technology exchange, the institute promotes the dissemination and application of photovoltaic technologies, contributing to achieving the goal of carbon neutrality and sustainable growth for the company worldwide, laying a solid foundation for the vision of "Risen Energy grows for hundreds of years." The company's production facilities are strategically located in key regions, allowing it to efficiently serve international markets and further solidify its role in the global transition to clean energy.

### 1.2. Product technical description

Both Risen's PV modules are under TOPCon cells technology and are bifacial modules. This bifacial technology enables additional energy harvesting from rear side (up to 30%). It includes the highest power up to 590 for RSM144-9-xxxBNDG and 615 Wp for RSM144-10-xxxBNDG and up to 22.8% module efficiency.

| Module reference | Cell technology | Number of full cells | Cell cut | Number of Busbars | Module type |
|---|---|---|---|---|---|
| RSM144-9-xxxBNDG | TOPCon | 72 | Half-cells | 16 | Bifacial |
| RSM144-10-xxxBNDG | TOPCon | 72 | Half-cells | 16 | Bifacial |

The 2 bi-facial PV module series analyzed in this LCA refer to panels that are manufactured in the same way. The main difference is the width of cells. It leads to changes in the dimensions of some components such as solar-glass, frame and EVA/POE/EPE.

The following chart illustrates the production process of photovoltaic modules in Risen's module factories in Ningbo.

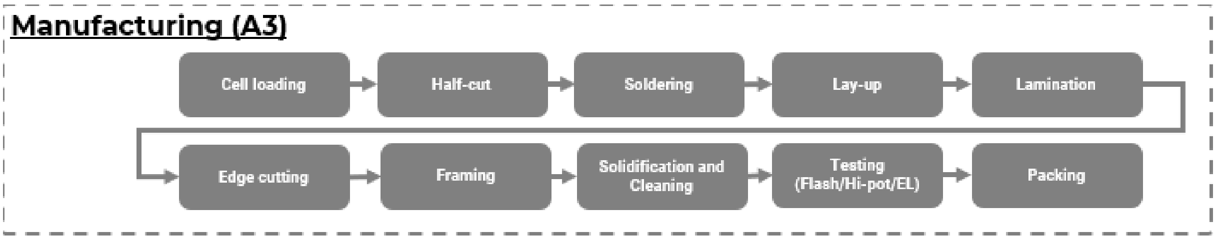



***Figure 1. Risen's PV module manufacturing process***

# 2. General information

| | |
|---|---|
| EPD owner | Risen Energy Co., Ltd. |
| Address of EPD owner | Meilin, Ninghai, 315609 Ningbo, Zhejiang, PEOPLE'S REPUBLIC OF CHINA |
| Product name | Mono-crystalline silicon photovoltaic (PV) modules :<br>RSM144-9-xxxBNDG and RSM144-10-xxxBNDG |
| Name and location of production sites: | Risen Energy (Ningbo) Co.,Ltd.<br>No.1, Middle Xingke Road Ninghai County 315609 Ningbo City, Zhejiang Province PEOPLE'S REPUBLIC OF CHINA |
| Field of application | Electricity generation |
| Program operator | EPDItaly - info@epditaly.it |
| Address of program operator | Via Gaetano de Castillia, 10, 20124 Milano MI, Italy |
| CPC code | 171 "Electrical energy" |
| Product category rules (PCR) | PCR EPDItaly014 – ELECTRICITY PRODUCED BY PHOTOVOLTAIC MODULES - Rev. 1.2 valid until 15/03/2026 GPI : Regulations of the EPDItaly Programme 6.0 |
| External audit | The PCR review was performed by Ing. Daniele Pace, Arch. Michele Paleari, Ing. Sara Toniolo - info@epditaly.it<br>Independent verification of the declaration and data, carried out according to ISO 14025: 2010.<br>☐ Internal ☑ External<br>Third-party verification carried out by: ICMQ S.p.A., via Gaetano De Castillia n° 10 – 20124 Milan, Italy.<br>Accredited by Accredia. |
| LCA Consultant | The LCA and report is written by PINK Strategy: "Environmental Product Declaration of Mono-crystalline silicon photovoltaic (PV) modules" V. 1.2 dated 18/04/2025<br>pink DARE PINK, GO GREEN<br>www.pink-strategy.fr<br>Address: 38 avenue Léon Gaumont 75020 Paris<br>Contact person: Hamza CHIKH<br>contact@pink-strategy.fr |
| Comparability | EPDs from different programs are not necessarily comparable. Full compliance with the PCR only allows EPD comparability if all stages of the life cycle have been considered. Nevertheless, discrepancies are possible. Note that different LCA software and background LCI data sets may lead to different results. |
| Liability | The owner of the declaration is responsible for the information and supporting evidence. The LCA consultant has no responsibility for the further use of this report for other applications. EPDItaly disclaims all liability in relation to the manufacturer's information. |

# 3.SCOPE AND TYPE OF EPD

## 3.1. Scope of EPD

The present EPD study is a cradle-to-grave analysis. All life cycle stages of the products are taken into account, i.e., the extraction of raw materials, manufacturing, upstream and downstream transportation, installation, use, maintenance, and end-of-life.

Table 1 illustrates the life cycle stages included in the LCA study according to the PCR EPDItaly014 and EN15804 norm.

<table>
<tr><th>Life cycle stages according to EPDItaly PCR</th><th colspan="3">Life cycle stages according to EN15804</th><th>Scope</th></tr>
<tr><td>Upstream Module</td><td rowspan="3">Product stage</td><td>A1</td><td>Raw material supply</td><td>X</td></tr>
<tr><td rowspan="15">Core Module</td><td>A2</td><td>Transport (to the manufacturer)</td><td>X</td></tr>
<tr><td>A3</td><td>Manufacturing</td><td>X</td></tr>
<tr><td rowspan="2">Construction stage</td><td>A4</td><td>Transport (to installation site)</td><td>X</td></tr>
<tr><td>A5</td><td>Construction – installation process</td><td>X</td></tr>
<tr><td rowspan="7">Use stage</td><td>B1</td><td>Use</td><td>X</td></tr>
<tr><td>B2</td><td>Maintenance</td><td>X</td></tr>
<tr><td>B3</td><td>Repair</td><td>X</td></tr>
<tr><td>B4</td><td>Replacement</td><td>X</td></tr>
<tr><td>B5</td><td>Refurbishment</td><td>X</td></tr>
<tr><td>B6</td><td>Operational energy use</td><td>X</td></tr>
<tr><td>B7</td><td>Operational water use</td><td>X</td></tr>
<tr><td rowspan="4">End-of-life stage</td><td>C1</td><td>De-construction and demolition</td><td>X</td></tr>
<tr><td>C2</td><td>Transport (to waste processing)</td><td>X</td></tr>
<tr><td>C3</td><td>Waste processing</td><td>X</td></tr>
<tr><td>C4</td><td>Disposal</td><td>X</td></tr>
<tr><td>Downstream Module</td><td>Electricity dissipation and plant infrastructure at end of life</td><td>Dowstream</td><td>Electricity distributed to the grid and plant infrastructure at end of life</td><td>X</td></tr>
<tr><td></td><td>Benefits and loads beyond the system boundary</td><td>D</td><td>reuse, recovery and/or recycling potentials</td><td>MND</td></tr>
<tr><td colspan="5">Caption: X = modules declared in the Table of Modules; MND = modules not declared in the Table of Modules.</td></tr>
</table>

***Table 1: EPD Scope***

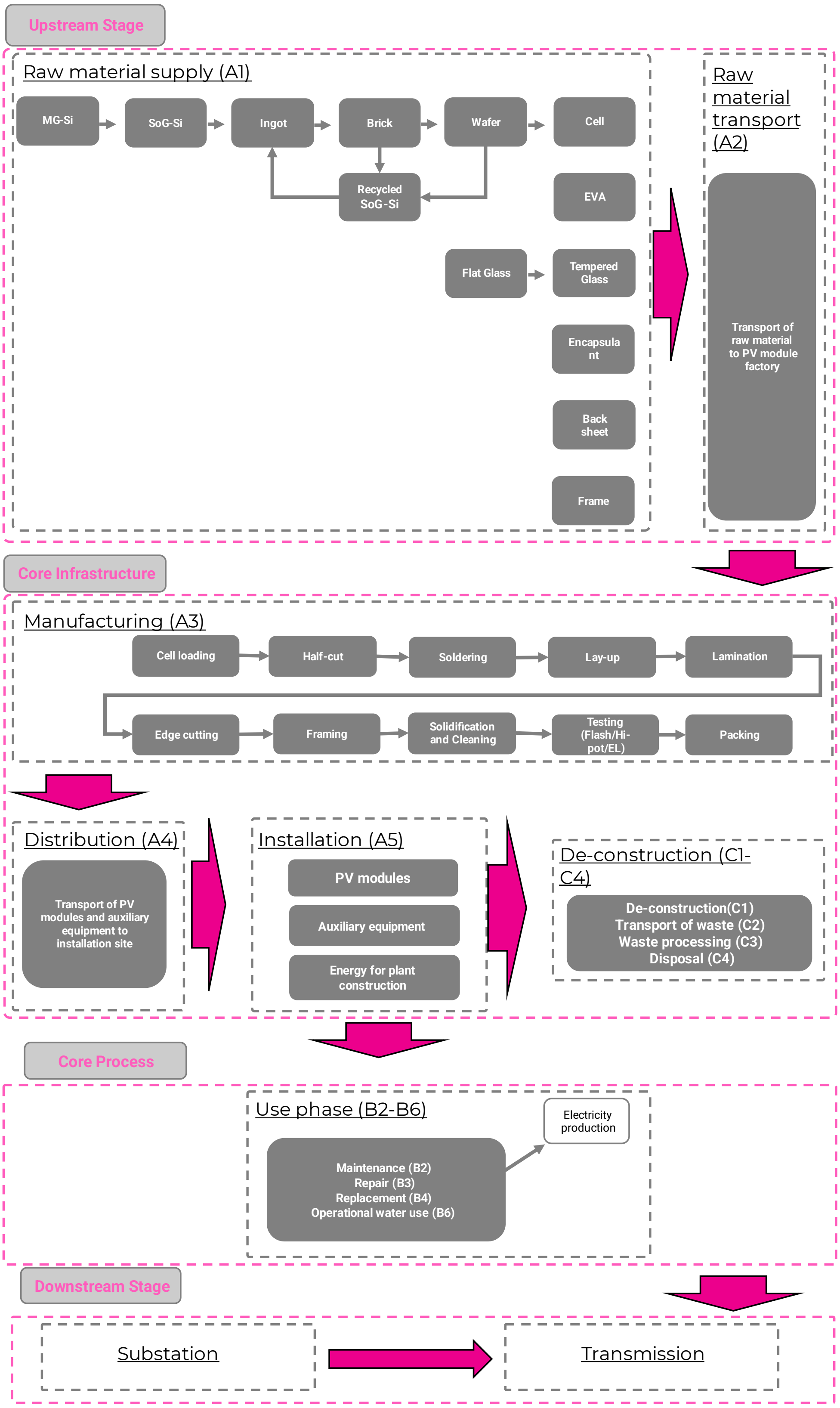



***Figure 2. Risen's PV module manufacturing process***

## 3.2. Type of EPD

The present EPD study is a product-specific EPD. The following bi-facial mono-crystalline silicon photovoltaic (PV) modules (in total 2 products) are analyzed:

| Module series | Power output range (W) |
|---|---|
| RSM144-9-xxxBNDG | 550-590 |
| RSM144-10-xxxBNDG | 570-610 |

***Table 2. PV modules products models***

## 3.3. Geographical coverage

All products are produced by Risen in Ningbo factories in China. Cells, wafer and ingot are manufactured in China.

The present EPD study is based on the scenario that the PV power plant is installed in the city of Rome in Italy. The end-of-life of PV modules is considered to be in Italy.

## 3.4. Applied database

Generic data for raw materials for PV module manufacturing and packaging; natural resources, such as water, energy, waste disposal and transport were taken from the LCI-database Ecoinvent 3.9, allocation, Cut-off by classification -unit with adaptation of regional energy and material data collected by PINK Strategy.

## 3.5. Software

The Life Cycle Assessment was performed with the software SimaPro 9.5.

## 3.6. Time representativeness

The data collection started on 1$^{st}$ March 2023 and ended on 29st February 2024.

# 4. Detailed product description

## 4.1. Declared unit and Reference service life

In the EPD study, the declared unit is 1 kWh of electricity generated as output from the solar photovoltaic plant in Roma during 30 years. The environmental impact from this study was calculated and reported per functional unit. The calculation methodology of functional unit is explained in Chapter 6.

Following the EPD PCR, the reference service life (RSL) of Risen modules is assumed to be 30 years.

## 4.2. Product description

Risen is committed to provide high-quality solar photovoltaic modules. The present study analyses the following 2 product ranges of bi-facial mono-crystalline silicon photovoltaic (PV) modules produced by Risen:

- RSM144-9-xxxBNDG
- RSM144-10-xxxBNDG

The maximum power generated by the analyzed module series is up to 610Wp (PV module RSM144-10-xxxBNDG) with a module efficiency of up to 22.3%. The 1st-year power degradation of the photovoltaic module series under analysis is no more than 1% and their subsequent annual power degradation is no more than 0.40%.

| Module reference | Number of full cells | Cell Size | Cell Type | Module surface ($m^2$) | Module Type | Module Efficiency (%) | Power output (Wp) |
|---|---|---|---|---|---|---|---|
| RSM144-9-xxxBNDG | 72 | 182.2x182.2±3mm | TOPCon | 2,58 | Bifacial | 21.3 – 22.3 | 550-590 |
| RSM144-10-xxxBNDG | 72 | 182.2x192±3mm | TOPCon | 2,70 | Bifacial | 21.1 – 22.2 | 570-610 |

***Table 3. Module characteristics***

### 4.3. Material Composition

| Components/Main substance | CAS No. | Units | RSM144-9-xxxBNDG | RSM144-10-xxxBNDG |
|---|---|---|---|---|
| Solar cell (Half cells) / Si | 7440-21-3 | pcs | 72 | 72 |
| Junction box / Cu | 7440-50-8 | kg/pcs | 0,08 | 0,08 |
| Ribbon string / Cu | 7440-50-8 | kg/pcs | 0,18 | 0,19 |
| Ribbon interconnection / Cu | 7440-50-8 | kg/pcs | 0,05 | 0,05 |
| Aluminum frame / Al | 7429-90-5 | kg/pcs | 2,49 | 2,57 |
| Solar glass / Na2O·nSiO2 | 1344-09-8;106985-35-7 | kg/pcs | 25,62 | 26,80 |
| POE ($CH_2CH_2O$) | 25322-68-3 | kg/pcs | 0 | 1,29 |
| EVA / (C2H4)x.(C4H6O2)y | 24937-78- 8 | kg/pcs | 1,28 | 1,32 |
| EPE / (C2H4)x.( $C_3H_6$)y | 25038-59-9 | kg/pcs | 1,23 | 0 |
| Silicon / SiO2 | 112926-00-8 | kg/pcs | 0,30 | 0,30 |
| Ethanol / C2H5OH | 000064-17-5 | kg/pcs | 0,00 | 0,00 |

***Table 4: Material composition***

### 4.4. Raw material transportation

The transport of raw materials happens from their place of production to the PV panels' manufacturing sites in Ningbo (China) by trucks.

Distances were calculated in accordance with the supplier's address given by Risen.

### 4.5. Raw material allocation

The raw materials' allocation was defined by considering the production quantity, dimensions difference between PV panels with different cell sizes and modules with larger wafer sizes, and losses from the manufacturing process. PV module packaging includes paper, plastic packaging as well as wood pallets. The following tables explain the allocation of the material composition of Risen's photovoltaic modules.

| Parameter | Unit | Bi-facial | |
|---|---|---|---|
| | | RSM144-9-xxxBNDG | RSM144-10-xxxBNDG |
| Weight of PV module and packaging | Kg | 32,351 | 33,413 |
| **Plastics** | | | |
| Ethylene-vinyl acetate (EVA) | % | 3,77% | 3,81% |
| Polyolefin (POE) | % | 0,00% | 3,81% |
| Polypropylene (EPE) | % | 3,77% | 0,00% |
| Silicone | % | 0,93% | 0,90% |
| **Metals** | | | |
| Aluminium | % | 7,69% | 7,70% |
| Copper | % | 0,90% | 0,90% |
| **Others** | | | |
| Cells | % | 2.24% | 2.28% |
| Glass | % | 79,21% | 80,20% |
| **Packaging** | | | |
| Polyethylene terephthalate (PET) | % | 0,27% | 0,27% |
| Paper/Cardboard | % | 0,81% | 0,83% |
| Wood | % | 3,09% | 3,14% |

***Table 5. Allocation of material composition of PV modules in Ningbo factory***

## *4.6. Production process*

The 2 bi-facial PV module series analyzed in this LCA refer to panels that are manufactured in the same way. The main difference is the width of cells. It leads to changes in the dimensions of some components such as solar-glass, frame and EVA/POE/EPE.

For the manufacturing phase, the following parameters were taken into account as the inputs of this process:

- Raw materials and auxiliary material production and transportation;
- Energy consumption;
- Tap water consumption;
- Waste (including transport to waste treatment plant);
- Wastewater.

The following chart illustrates the production process of photovoltaic modules in Risen's module factories in Ningbo.

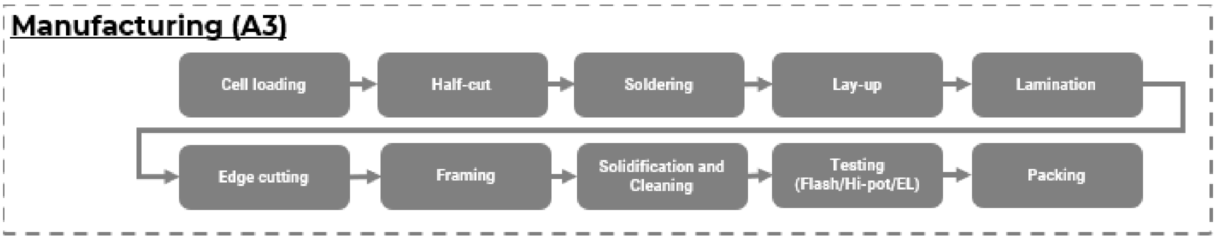



***Figure 3. Risen's PV module manufacturing process***

The manufacturing process starts with the loading of cells that are half-cut with a laser. Copper tabs are then soldered to the individual solar cells after which the front of one cell is interconnected to the back of the next cell to form a string. This is followed by the lay-up process. During the lay-up process, strings of soldered cells, glass, and foils are placed on top of each other and the connecting of the strings happens.

The manufacturing process continues with the lamination where the encapsulation foil is cured at an elevated temperature. The next stage is edge trimming, where the edges of the encapsulation and back sheet foils are cut off. Once edges have been cut, the framing process begins. This phase involves sealing the edges of the module with silicone and framing it with an aluminum frame. Once the silicone has solidified, the PV modules are cleaned. The next step is the assembly of the junction box. The junction box is attached to the laminate with silicone.

The PV modules undergo testing, such as solar simulation, where the module's power in Watts-peak (Wp) is determined by exposing it to a flash of 1000 W/m². Finally, the completed PV modules are packaged for distribution.

## *4.7. PV module transportation*

This life cycle assessment is promoted by the use of Risen panels for the Italian market. Therefore, the LCA modeling for the transportation data was based on the scenario that the PV modules are transported from the production plant in China to a roof-mounted PV plant in Italy. The mean of transportation is both trucks and ship.

## *4.8. Installation and reference service life*

As Risen is a module manufacturer, PINK Strategy has built a model for the impact of installation based on more than 10 years of Solstyce experience and multiple LCAs performed for other EPC and Photovoltaic developers.

According to industry practices and in order to maximize PV panel efficiency for the present EPD study, floor mounted application has been considered. For the scope of this assessment, the installation activity involves the action of placing the solar panel in a solar-irradiation-exposed location.

Auxiliary equipment is considered including an electric installation system, inverters, transformers and the roof mounting system. The transport of auxiliary equipment and the waste disposal of the packaging materials were also considered in this module.

The construction impact for roof-mounted PV installations is primarily confined to using large lifting engines for delivering equipment to the rooftop, with the remainder of the tasks being carried out using small, rechargeable manual tools that have a negligible impact.

The reference service life for the PV modules is 30 years. The energy produced by a photovoltaic module depends on the installed power peak [Wp] and the module efficiency, the latter decreases with time, due to performance changes during lifespan according to degradation rate. Linear annual degradation was assumed over reference service life (RSL). The current technology of PV modules with monocrystalline silicon cells, used in Risen photovoltaic panels, sees its power decrease at most of 0.40 % for bi-facial PV modules per year according to datasheets.

The total electricity generation from the plant to the grid during RSL is listed in the table below.

| Description | Source | Unit | Bi-facial | |
|---|---|---|---|---|
| | | | RSM144-9-xxxBNDG | RSM144-10-xxxBNDG |
| Specific production | PVGIS simulation | KWh/KWp/year | 1 501 | 1 501 |
| First-year production | PVGIS simulation | KWh for first year production | 149 694 | 150 189 |
| Electricity over RSL | PINK calculation | KWh/PV | 25 088 | 25 938 |

***Table 6. Energy production over Reference service life***

## *4.9. End-of-life*

In this EPD study, the end-of-life phase covers the dismantling of the PV power plant, the transportation of wastes to the waste treatment facility, the waste processing, and the final disposal of wastes. Energy is needed to dismantle the PV power plant. The electricity consumption during the dismantling of the PV plant (C1) was considered the same as the electricity consumption during the construction stage (A5).

Then, the product will be first transported to a waste treatment center of recycling for PV panels in Italy. In the waste treatment facility, the sorting of the PV module parts happens. After the recuperation of recyclable parts, the rest of the materials considered as not-recyclable will be transported to disposal for incineration or landfill, while recyclable materials will be transported to each EoL treatment plant according to their nature.

The entire waste treatment process is carried out using mechanical technology only as illustrated in Figure 2. The PV module is dismantled manually, separated mainly into an aluminum frame, the junction box, and the PV module. Subsequently, the module is first cut into strips and then ground.

A mechanical process makes it possible to separate the shredded material into different fractions (glass, ferrous metals, non-ferrous metals, polymers, silicon, and final waste). In this EPD study, according to the actual scenario on today's market, cells are considered as stored because of economic factors till an efficient recycling process is in practice.

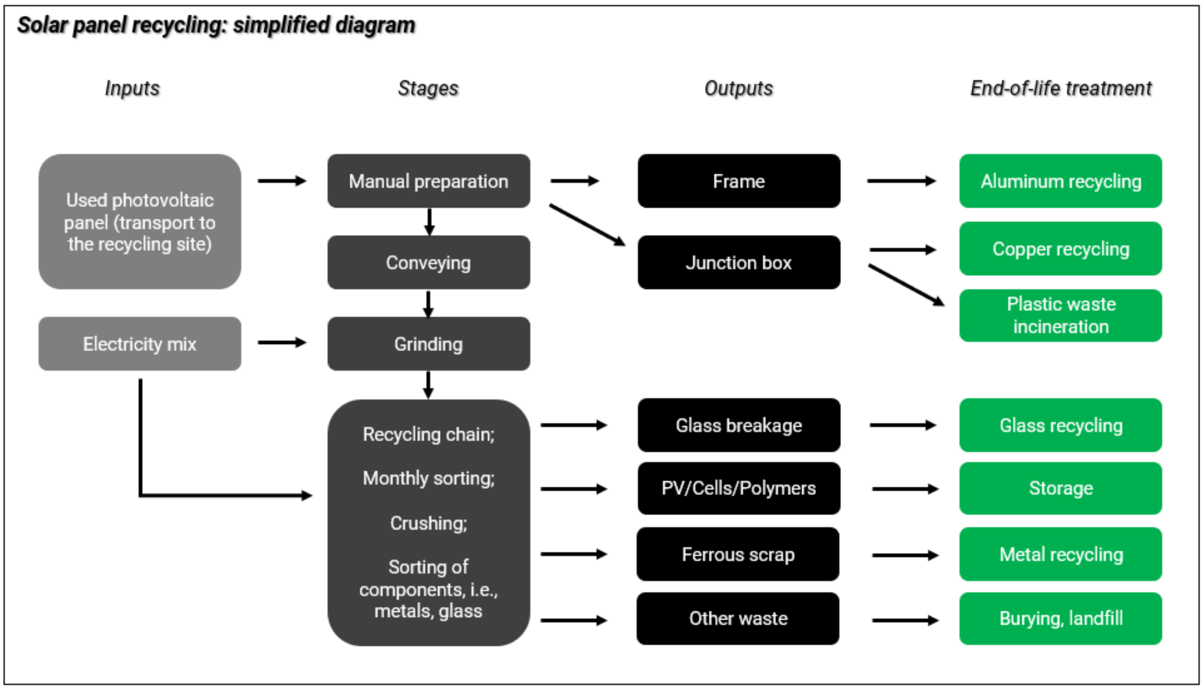



***Figure 4. Recycling diagram of Fraunhofer IBP***

# 5.LCA results

The present LCA study is made by following the requirements of PCR EPDItaly014 and based on the recommended impact analysis method for the calculation. Environmental impact indicators have been calculated by following the characterization factors included in EN 15804:2012+A2:2019. Results are showed by environmental impact indicators, resource use indicators and output flows and waste categories indicators.

## 5.1. LCA Results – Environmental impact per functional unit

| Impact category | Unit | Total | Upstream Module | Core-infrastructure | Core process | Dowstream |
|---|---|---|---|---|---|---|
| Climate change - total | kg CO2 eq | **2,20E-02** | 1,21E-02 | 2,00E-03 | 6,51E-03 | 1,34E-03 |
| Climate change - Fossil | kg CO2 eq | **2,19E-02** | 1,21E-02 | 2,00E-03 | 6,48E-03 | 1,33E-03 |
| Climate change - Biogenic | kg CO2 eq | **7,29E-05** | 5,02E-05 | 1,85E-06 | 1,56E-05 | 5,32E-06 |
| Climate change - land use and change | kg CO2 eq | **2,65E-05** | 8,46E-06 | 1,02E-06 | 2,50E+01 | 8,02E-07 |
| Ozone depletion | kg CFC11 eq | **4,02E-10** | 2,61E-10 | 2,94E-11 | 7,90E-11 | 3,32E-11 |
| Acidification | mol H+ eq | **1,54E-04** | 7,37E-05 | 1,36E-05 | 6,22E-05 | 4,50E-06 |
| Eutrophication, freshwater | kg P eq | **8,87E-07** | 5,33E-07 | 2,92E-08 | 3,07E-07 | 1,73E-08 |
| Photochemical ozone formation | kg NMVOC eq | **9,47E-05** | 4,32E-05 | 1,33E-05 | 3,02E-05 | 7,95E-06 |
| Resource use, minerals and metals | kg Sb eq | **7,77E-07** | 3,53E-07 | 8,63E-09 | 4,01E-07 | 1,43E-08 |
| Resource use, fossils | MJ | **2,44E-01** | 1,26E-01 | 2,18E-02 | 7,90E-02 | 1,72E-02 |
| Water use | m3 depriv. | **8,90E-03** | 7,36E-03 | 5,45E-05 | 1,39E-03 | 9,66E-05 |

***Table 7. LCA results of RSM144-9-xxxBNDG module on environmental impact per DU***

| Impact category | Unit | Total | Upstream Module | Core-infrastructure | Core process | Dowstream |
|---|---|---|---|---|---|---|
| Climate change - total | kg CO2 eq | **2,22E-02** | 1,24E-02 | 1,99E-03 | 6,55E-03 | 1,29E-03 |
| Climate change - Fossil | kg CO2 eq | **2,21E-02** | 1,23E-02 | 1,99E-03 | 6,52E-03 | 1,28E-03 |
| Climate change - Biogenic | kg CO2 eq | **6,99E-05** | 5,13E-05 | 1,82E-06 | 1,57E-05 | 1,09E-06 |
| Climate change - land use and change | kg CO2 eq | **2,66E-05** | 8,59E-06 | 1,01E-06 | 2,50E+01 | 7,64E-07 |
| Ozone depletion | kg CFC11 eq | **4,01E-10** | 2,61E-10 | 2,93E-11 | 7,94E-11 | 3,17E-11 |
| Acidification | mol H+ eq | **1,55E-04** | 7,50E-05 | 1,36E-05 | 6,25E-05 | 4,26E-06 |
| Eutrophication, freshwater | kg P eq | **8,96E-07** | 5,42E-07 | 2,91E-08 | 3,08E-07 | 1,69E-08 |
| Photochemical ozone formation | kg NMVOC eq | **9,55E-05** | 4,42E-05 | 1,33E-05 | 3,04E-05 | 7,67E-06 |
| Resource use, minerals and metals | kg Sb eq | **7,84E-07** | 3,60E-07 | 8,62E-09 | 4,02E-07 | 1,32E-08 |
| Resource use, fossils | MJ | **2,46E-01** | 1,28E-01 | 2,16E-02 | 7,95E-02 | 1,66E-02 |
| Water use | m3 depriv. | **9,14E-03** | 7,60E-03 | 5,06E-05 | 1,40E-03 | 9,28E-05 |

***Table 8. LCA results of RSM144-10-xxxBNDG module on environmental impact per DU***

## 5.2. LCA Results – Resource use per functional unit

| Impact category | Unit | Total | Upstream Module | Core-infrastructure | Core process | Dowstream |
|---|---|---|---|---|---|---|
| Non renewable primary energy used as RM | MJ, net CV | **1,87E-03** | 1,87E-03 | 0,00E+00 | 0,00E+00 | 0,00E+00 |
| Renewable primary energy used as RM | MJ, net CV | **9,36E-04** | 9,36E-04 | 0,00E+00 | 0,00E+00 | 0,00E+00 |
| Non renewable primary energy excl. RM | MJ, net CV | **2,44E-01** | 1,26E-01 | 2,17E-02 | 7,89E-02 | 1,72E-02 |
| Renewable primary energy excl. RM | MJ, net CV | **2,42E-02** | 1,60E-02 | 7,77E-04 | 6,88E-03 | 5,10E-04 |
| Total non renewable primary energy | MJ, net CV | **2,44E-01** | 1,27E-01 | 2,17E-02 | 7,89E-02 | 1,72E-02 |
| Total renewable primary energy | MJ, net CV | **2,58E-02** | 1,77E-02 | 7,77E-04 | 6,88E-03 | 5,10E-04 |
| Net use of fresh water | m3 | **-4,72E-05** | 6,94E-05 | -2,60E-05 | -7,88E-05 | -1,18E-05 |
| Use of secondary material | Kg | **6,09E-05** | 6,09E-05 | 0,00E+00 | 0,00E+00 | 0,00E+00 |
| Use of renewable secondary fuels | MJ, net CV | **0,00E+00** | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 |
| Use of non renewable secondary fuels | MJ, net CV | **0,00E+00** | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 |

***Table 9. LCA results of RSM144-9-xxxBNDG module on resource use per DU***

| Impact category | Unit | Total | Upstream Module | Core-infrastructure | Core process | Dowstream |
|---|---|---|---|---|---|---|
| Non renewable primary energy used as RM | MJ, net CV | **3,95E-03** | 3,95E-03 | 0,00E+00 | 0,00E+00 | 0,00E+00 |
| Renewable primary energy used as RM | MJ, net CV | **9,50E-04** | 9,50E-04 | 0,00E+00 | 0,00E+00 | 0,00E+00 |
| Non renewable primary energy excl. RM | MJ, net CV | **2,46E-01** | 1,28E-01 | 2,16E-02 | 7,94E-02 | 1,66E-02 |
| Renewable primary energy excl. RM | MJ, net CV | **2,45E-02** | 1,64E-02 | 7,62E-04 | 6,92E-03 | 4,97E-04 |
| Total non renewable primary energy | MJ, net CV | **2,48E-01** | 1,31E-01 | 2,16E-02 | 7,94E-02 | 1,66E-02 |
| Total renewable primary energy | MJ, net CV | **2,62E-02** | 1,80E-02 | 7,62E-04 | 6,92E-03 | 4,97E-04 |
| Net use of fresh water | m3 | **-4,42E-05** | 7,18E-05 | -2,53E-05 | -7,92E-05 | -1,14E-05 |
| Use of secondary material | Kg | **6,17E-05** | 6,17E-05 | 0,00E+00 | 0,00E+00 | 0,00E+00 |
| Use of renewable secondary fuels | MJ, net CV | **0,00E+00** | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 |
| Use of non renewable secondary fuels | MJ, net CV | **0,00E+00** | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 |

***Table 10. LCA results of RSM144-10-xxxBNDG module on resource use per DU***

### 5.3. LCA Results – Output flows and waste categories per functional unit

| Impact category | Unit | Total | Upstream Module | Core-infrastructure | Core process | Dowstream |
|---|---|---|---|---|---|---|
| Hazardous waste disposed | kg | **1,83E-03** | 6,91E-04 | 5,65E-05 | 1,02E-03 | 5,87E-05 |
| Non hazardous waste disposed | kg | **2,94E-02** | 1,35E-02 | 1,15E-03 | 1,39E-02 | 9,05E-04 |
| Radioactive waste disposed | kg | **2,34E-07** | 1,31E-07 | 1,91E-08 | 7,04E-08 | 1,33E-08 |
| Materials for energy recovery | kg | **2,62E-04** | 0,00E+00 | 2,28E-04 | 3,47E-05 | 0,00E+00 |
| Materials for recycling | kg | **1,65E-03** | 0,00E+00 | 1,18E-03 | 1,92E-05 | 4,54E-04 |
| Components for re-use | kg | **0,00E+00** | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 |
| Exported thermal energy | MJ | **0,00E+00** | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 |
| Exported electricity energy | MJ | **0,00E+00** | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 |

***Table 11. LCA results of RSM144-9-xxxBNDG module on output flows and waste categories per DU***

| Impact category | Unit | Total | Upstream Module | Core-infrastructure | Core process | Dowstream |
|---|---|---|---|---|---|---|
| Hazardous waste disposed | kg | **1,84E-03** | 7,02E-04 | 5,58E-05 | 1,03E-03 | 5,60E-05 |
| Non hazardous waste disposed | kg | **2,97E-02** | 1,37E-02 | 1,14E-03 | 1,39E-02 | 8,63E-04 |
| Radioactive waste disposed | kg | **2,36E-07** | 1,34E-07 | 1,88E-08 | 7,08E-08 | 1,27E-08 |
| Materials for energy recovery | kg | **2,49E-04** | 0,00E+00 | 2,14E-04 | 3,52E-05 | 0,00E+00 |
| Materials for recycling | kg | **1,67E-03** | 0,00E+00 | 1,19E-03 | 1,94E-05 | 4,59E-04 |
| Components for re-use | kg | **0,00E+00** | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 |
| Exported thermal energy | MJ | **0,00E+00** | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 |
| Exported electricity energy | MJ | **0,00E+00** | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 |

***Table 12. LCA results of RSM144-10-xxxBNDG module on output flows and waste categories per DU***

Focusing on life cycle stages, the Raw Material supply (A1) stage contributes for a very large majority of most of the impact indicators for PV panel life cycle (approximately 55% in GWP total). The extraction of raw materials, especially solar-grade silicon for cells, and processes to obtain the cells are the most impacting activities on the life of a PV panel. Following, the second most impacting stage in most of the impact indicators is the Installation stage (A5), the mounting system (roof) is the highest contributor of impact. Disposal (A4) is the third most impacting stage, especially due to the lack of background data on disposal stage for PV panels as it is still a recent product and there is a need to take conservative assumptions.

Use (B1), Repair (B4), Refurbishment (B5) and Operational energy consumption (B6) stages are considered to be completely non-impacting, since the products do not require any type of modification. Moreover, except the Operational water use (B7) for manual cleaning, PV modules do not produce any other kind of emission during these phases.

Moreover, except for Maintenance **(B2)**, transport to the solar PV station, Replacement **(B4)** (in order to change the inverter after 15 years of use) and Operational water use **(B7)** (for manual cleaning), these stages are considered to be more conservative. PV modules do not produce any other type of emissions during these phases.

Waste processing and downstream stage represents the impacts of waste treatment process of the PV module and solar plant infrastructure.

# 6. Calculation rules

## *6.1. Declared unit*

In the EPD study, the declared unit is 1 kWh of electricity generated as output from the solar photovoltaic plant, from cradle-to-grave, with activities needed for a reference service of life (RSL) of 30 years. The environmental impact from this study was calculated and reported per declared unit.

To report the environmental impacts generated by each Risen photovoltaic (PV) module during its life cycle in the functional unit, the total energy produced by the solar PV plant during the reference service life (RSL) needs to be calculated. Once the total energy of the solar plant has been calculated, the overall environmental impacts generated throughout the entire life cycle are divided by this value to return the results in the individual kWh produced.

The total energy produced by the plant will therefore be equal to

$$\boldsymbol{Etot[kWh] = Eyear * RSL}$$

Where:

$E_{tot}$ represents the total energy produced by the plant (or, in an extreme case, by the individual module) during its entire life cycle;

$E_{year}$ represents the energy produced annually by the plant.

The present EPD study calculates the annual energy production in the case of plants under construction but not yet operational. Therefore, an estimate is provided of the annual production of the plant, which will be a function of various parameters (average irradiation, exposure, temperature, optical factors, etc.) however known at the design stage.

Following the EPDItaly PCR, the reference service life (RSL) of Risen modules is assumed to be 30 years.

The calculation of the total energy production of a PV plant during its reference service life was done with the following equation used by PINK Strategy's project developers:

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

Where:

n = year of operation, here 0<n<30

$E_1$ = energy produced during first year

RSL = reference service life = 30 years (according to PCR)

deg = yearly degradation rate = 0.40%

To get the most precise value, energy production in the first year of operation was modeled in PVGIS software using the scenario that the power plant is installed in Rome in Italy. The table below explains the characteristics of the power plant for each module.

| Parameter | Unit per module | RSM144-9-xxxBNDG | RSM144-10-xxxBNDG |
|---|---|---|---|
| Reference service life | Years | 30 | 30 |
| Peak power of the plant | KWp | 99,71 | 100,04 |
| Plant latitude & longitude | ° | 41.893 , 12.483 | 41.893 , 12.483 |
| Plant altitude | m | 42 | 42 |
| Nominal solar irradiance | kWh/m²/year | 1919,09 | 1919,09 |
| Number of modules | pcs | 169 | 164 |
| Module power | Wp | 590 | 610 |
| Specific production | Wh/kWp/year | 1 501 290 | 1 501 290 |

***Table 13. PV Plant characteristics***

## *6.2. LCI data origin and LCA period*

| Module type | Module factory | Cell factory | Wafer factory | Ingot factory |
|---|---|---|---|---|
| RSM144-9-xxxBNDG | Risen Solar (Ningbo) Technology Co., Ltd. | Risen Solar (Anhui) Technology Co., Ltd.<br><br>Tongwei Co., Ltd. | Tianjin Huanzhi New Energy Technology Co., Ltd. | Inner Mongolia Zhonghuan Crystal Material Co., Ltd. |
| RSM144-10-xxxBNDG | Risen Solar (Ningbo) Technology Co., Ltd. | Risen Solar (Anhui) Technology Co., Ltd.<br><br>Tongwei Co., Ltd. | Tianjin Huanzhi New Energy Technology Co., Ltd. | Inner Mongolia Zhonghuan Crystal Material Co., Ltd. |

***Table 14: Addresses of Risen module factories***

Data about product manufacturing is based on the Life Cycle Inventories (LCI) performed in the validated LCAs for Risen plants with an update on the period from March 1st, 2023 to February 29st, 2024.

## *6.3. System boundaries*

For each process step, all energy and material inputs and outputs are collected. The process inputs are energy consumption, material consumption, infrastructure, transport of materials to the factory, the transport of the PV modules to the installation site, and the transport of the wastes to the waste treatment center. The process outputs are products, waste to treatment, and emissions to water and air.

EPDItaly Regulations state that the life cycle stages must refer to segmentation in the following three modules:

1. Upstream module which includes all the processes upstream of the production of the photovoltaic module. In this EPD study, the upstream module includes the extraction and processing of raw materials covering silicon, ingot, wafer, PV cell, other raw materials, semi-finished goods, and packaging materials (A1). The transportation of the raw material and semi-finished products from suppliers to the manufacturing factory (A2) is also taking into account here as well as the production and disposal of waste associated with the processes;
2. Core module contains most of the environmental impacts related to the production of electricity by photovoltaic modules. The core module includes all the relevant processes managed by the Risen. The core module could be identified by two types of impact:
   - *Core - Process:* contains the maintenance (B2) of the module which considers the fuel needed to drive to the plant but also the production and use of the materials required for maintenance. It also contains Replacement (B4), and the electricity (B6) and water (b7) use in the factory while producing product.
   - *Core – Infrastructure:* The core module in the present study covers the manufacturing process of the photovoltaic modules (A3) including the consumption of energy and natural resources, like water; the treatment and emission of wastewater; the treatment, emission and transport of solid wastes generated during the PV module manufacturing as well as the packaging waste. Align with the EPDItaly PCR, the core module also includes the transportation of photovoltaic modules to solar plant (A4); the construction of the solar plant (A5) with all the auxiliary and infrastructure equipment needed to ensure that electricity is properly generated and fed into the grid, the transportation of auxiliary and infrastructure equipment, the treatment and emission of packaging wastes during the solar plant construction; the de-construction and demolition of the solar plant (C1), the transport of PV modules to waste processing (C2), waste processing (C3) and disposal (C4).
3. Downstream module which includes all the relevant processes that are outside of the control of Risen. It needs to be presented the electricity dissipation between PV installation on feeding them with grid electricity and, the environmental impacts related to the construction, maintenance and disposal of electricity infrastructure.

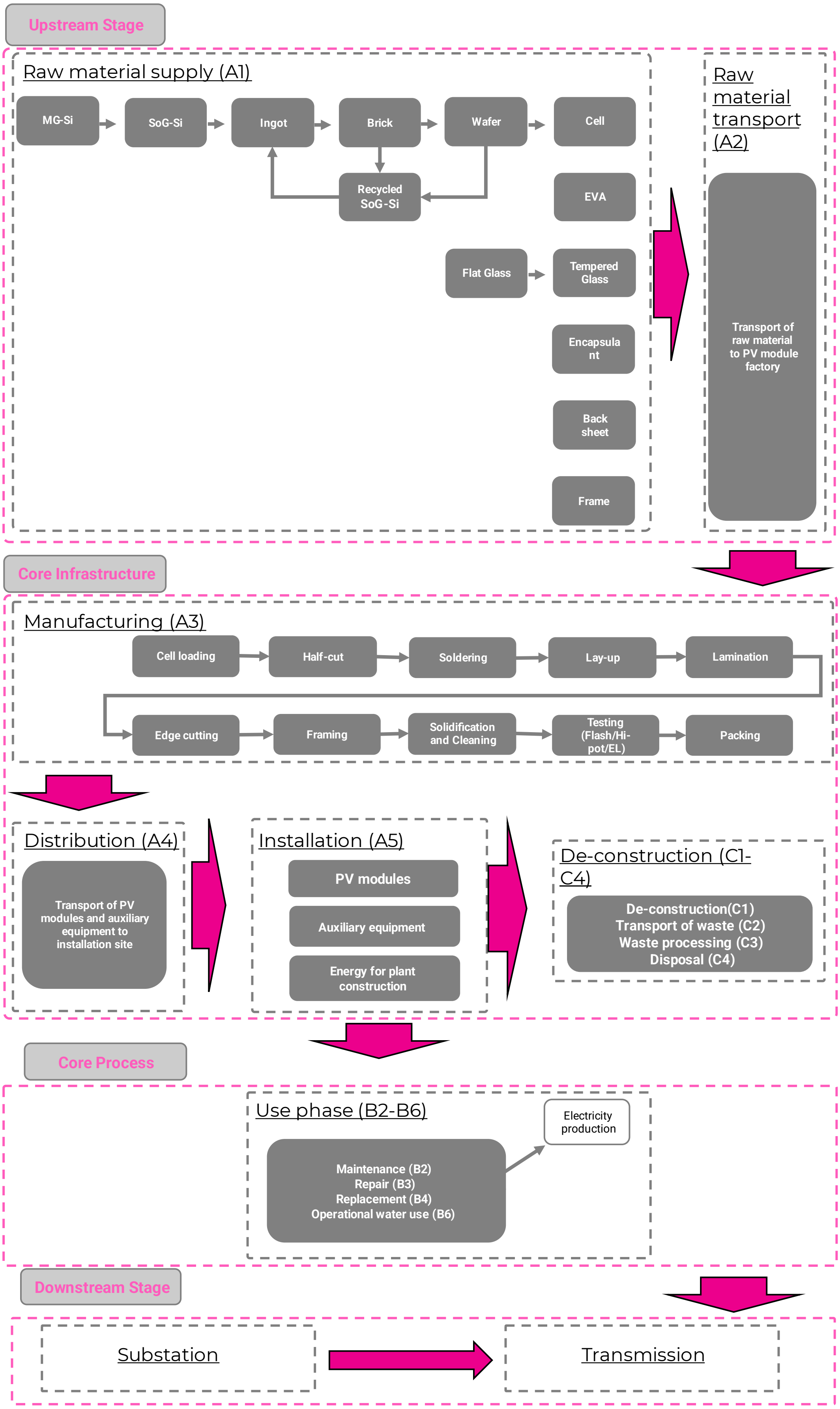

Upstream Stage
Raw material supply (A1)
MG-Si
SoG-Si
Ingot
Brick
Wafer
Cell
Recycled SoG-Si
EVA
Flat Glass
Tempered Glass
Encapsulant
Back sheet
Frame
Raw material transport (A2)
Transport of raw material to PV module factory
Core Infrastructure
Manufacturing (A3)
Cell loading
Half-cut
Soldering
Lay-up
Lamination
Edge cutting
Framing
Solidification and Cleaning
Testing (Flash/Hi-pot/EL)
Packing
Distribution (A4)
Transport of PV modules and auxiliary equipment to installation site
Installation (A5)
PV modules
Auxiliary equipment
Energy for plant construction
De-construction (C1-C4)
De-construction(C1)
Transport of waste (C2)
Waste processing (C3)
Disposal (C4)
Core Process
Use phase (B2-B6)
Electricity production
Maintenance (B2)
Repair (B3)
Replacement (B4)
Operational water use (B6)
Downstream Stage
Substation
Transmission

*Figure 5. Life cycle stages EPD (according to ISO 14025)*

## 6.4. Assumptions

The key assumptions of this LCA study are as listed below.

- This EPD study uses the scenario that the PV power plant of Risen modules is located in Rome in Italy. PVGIS simulations, transportation distances, and electricity mix have been chosen to be aligned with that assumption.
- Following the PCR EPDItaly 014, the reference service life (RSL) of Risen modules is assumed to be 30 years.
- Concerning the electricity generation by the PV power plant, linear annual degradation was assumed over reference service life (RSL). The current technology of PV modules with monocrystalline silicon cells, used in Risen photovoltaic panels, sees its power decrease at most of 0.40 % for bi-facial PV modules according to datasheets.
- As Risen is a module manufacturer, PINK Strategy has built a model for the impact of installation (auxiliary equipment and construction site) based on more than 10 years of Solstyce experience and multiple LCAs performed for other EPC and Photovoltaic developers (Over 50 LCAs performed on PV plants in the last two years).
- Energy is needed to dismantle the PV power plant. The energy consumption during the dismantling of the PV plant (C1) was assumed the same as the energy consumption during the construction stage (A5).
- The transport distance to end-of-life facilities for PV modules and packaging was considered in accordance with EN 15804:2021.
- Water consumption during the use phase for PV module cleaning was assessed using data from a peer-reviewed research paper. [Link]
- The distribution of PV module products is considered as the distance between the manufacturing plant in China (Ningbo) and the city of Rome in Italy.

## 6.5. Excluded processes

This study is a cradle-to-grave analysis from the extraction of raw materials (mining) up to the end-of-life of Risen's photovoltaic modules. Excluded in this analysis are:

- Transportation of workers.
- (EoL) treatment of packaging waste from module components like cells, aluminum frames, glass, etc.;
- Consumption of electricity, water, and heat by ancillary services not directly related to production.;

- Impacts of building halls and metalworking machinery, which are minimal due to large-scale production.;
- Recycling of defective products.;
- Storage phases of PV modules.;
- Operations management within distribution centers and retail outlets.;
- Use of small, rechargeable manual tools during installation.;
- Outcomes and benefits derived from recycling and energy recovery (module D).

## *6.6. Cut-off rules*

To determine which inputs and outputs to exclude, the following methodologies were applied:

- All inputs and outputs of a (unit) process were accounted for in the analysis when data was accessible. Where data was lacking, conservative estimates were used based on average or general data, and every such assumption was duly recorded.
- In cases where sufficient input data were unavailable or incomplete for a particular unit process, a cut-off criterion was established in accordance with the PCR guidelines. These criteria were set at 2% of the total mass and energy for that unit process, reflecting the specific weight of the photovoltaic module and the energy needed for its manufacture and assembly.

## *6.7. Data quality*

Data about product manufacturing is based on the Life Cycle Inventories (LCI) performed in the validated LCAs for Risen plants with an update on the period from March 1$^{st}$, 2023 to February 29$^{st}$, 2024

LCI data were compared with literature and other studies performed or reviewed by PINK Strategy. Data quality is assessed as follows:

- Technological representativeness: Rather conservative for silicon production. Good for the rest of the data. The scenarios represent the average technologies used at the time of data collection.
- Geographical representativeness: Good – Background data may be global data. LCI data linked to the geographical locations of the processes, such as electricity and transport data from China and Italy, were used.
- Time-related representativeness: Very good – very recent data. Data has been collected from March 1$^{st}$, 2023 to February 29$^{st}$, 2024
- Completeness: Good
- Precision/uncertainty: Good, some hypotheses are taken, as explained in Chapter 6.4.
- Methodological appropriateness and consistency: Good (substitution, etc.).

The overall data quality is good.

### 6.8. Allocations

Multi-input processes:

When data on energy usage was accessible from the LCI, featuring detailed meter readings (notably for lamination, which consumes the most energy in the module assembly), allocation was based on the number of lamination cycles per module and the energy required for each cycle. In instances lacking specific energy data, allocation was determined by the surface area of the PV panel, as it most accurately reflects energy consumption during manufacturing.

For all materials, the allocation accounted for an average breakage and loss ratio specific to each material, which was then applied to the quantity of the material listed in the BoM.

Multi-output processes:

Allocation for multiple outputs is determined by a quantitative analysis of resource usage and emissions, such as through the assignment of functions, physical properties, or economic factors. Physical attributes (such as mass and calorific value) are prioritized, but if these are not applicable, economic factors (like man-hours, operational hours, and production costs) are considered.

In this study, as there are no co-products, the sole multi-output process concerns waste produced during manufacturing. This waste is quantified based on the surface area (square meters) of the PV modules.

*Allocation for recovery processes:*

The allocation key for recovery processes specifies the proportion of each input and emission attributed to the main product and any by-products with economic value. The Ecoinvent database primarily uses economic allocation (for instance, based on market value) but makes exceptions for energy, where allocation is based on energy.

The allocation method for recovery processes utilized in this context is the Ecoinvent cut-off system model (Allocation, cut-off by classification). Under this system, waste responsibility remains with the producer, promoting the use of recyclable materials that are provided without associated environmental burdens (cut-off).

The core philosophy of this model is that the initial production of materials is always charged to the first user of the material. When a material is recycled, the original producer does not gain any benefit from the availability of the recyclable material. Consequently, recyclable materials enter the recycling process without any environmental debt, and the impacts associated with secondary (recycled) materials are limited to those from the recycling process itself. Additionally, waste producers do not receive any benefits for the recycling or reuse of products derived from their waste treatments.

# 7.LCA scenarios

Risen's bi-facial photovoltaic modules are produced in Ningbo factory in China. All models are manufactured with the same technics and machinery. The processes covered by modules A1-A3 are explained in Chapter 4.

The following tables summarize the LCA scenarios included within system boundaries for the downstream module (A4 - C4).

## *7.1. Distribution (A4)*

This assessment is promoted using Risen panels for the Italian market.

Therefore, the transport distribution of this product is considered like the average distance between the production plant in Ningbo, China and the city of Rome in Italy. In this study, we took greater distances to be conservative. In this way,

- Transport in lorry represents 188 km from Ningbo factory to Ningbo port in China
- Transport in ship represents 18 260 km from Ningbo port to Genoa port in Italy
- Transport in lorry represents 520 km from Genoa port to Rome
-

The following table explains the transportation from factories to Rome, Italy.

| **Gate to site transport** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Origin/Factory** | **China Port** | **Europe Port** | **Project site Location** | **Factory to port (Road)** | **Port to port (Ship)** | **Port to site (Road)** | **TOTAL Lorry (km)** | **TOTAL Ship (km)** |
| Ningbo | Ningbo | Genoa | Rome | 188 | 18 260 | 520 | 708 | 18 260 |

***Table 15. Gate to project location site transport***

## *7.2. Installation (A5)*

For roof mounted PV plants, the following design was taken into consideration:

- String inverters are employed at the PV plant and are replaced once during the reference service life (RSL).
- Transformers are not utilized in roof-mounted PV plants as the system connects directly to low-voltage switchgear.
- The module support consists of aluminum structures designed for flat roofs, which are welded onto the roofing membrane.

- According to the International Energy Agency's Task 12 report from 2020, materials such as copper, brass, zinc, and steel used in the installation are taken into account.
- Transportation to the installation site is carried out using light commercial vehicles.

The construction impact for a roof-mounted PV plant is primarily due to the use of large lifting equipment to hoist materials to the rooftop, while the remaining tasks are handled with manual tools, which are also considered in the study.

Another impact to be considered in this module is the waste disposal of the packaging materials. The following table shows the quantity and allocation of the packaging waste.

| Waste from packaging | Unit | Bi-facial | |
|---|---|---|---|
| | | RSM144-9-xxxBNDG | RSM144-10-xxxBNDG |
| Plastic | Kg/pcs | 0,088 | 0,089 |
| Paper/Cardboard | Kg/pcs | 0,263 | 0,276 |
| Wood | Kg/pcs | 1,000 | 1,048 |

***Table 16. Packaging waste disposal share***

## *7.3. USE phase (B1-B7)*

**Use stage description for RSM144-9-xxxBNDG**

| USE Stage | Consideration | Value | Ecoinvent 3.9 module |
|---|---|---|---|
| B1. Use | Not concerned; for water, air or soil emissions | | |
| B2. Maintenance | Transport with a commercial vehicle to the plant | 20 km to the PV plant | Transport, freight, light commercial vehicle {Europe without Switzerland}\| market for transport, freight, light commercial vehicle \| Cut-off, U |
| B3. Repair | Not concerned | | |
| B4. Replacement | Inverter replacement | 1,06E-03 | Inverter, 500kW {GLO}\| market for inverter, 500kW \| Cut-off, U |
| B5. Refurbishment | Not concerned | | |
| B6. Operational energy use | No energy consumption; but energy | Energy production during reference service life (30 | |

| | | | |
|---|---|---|---|
| | production according to DU | years) is explained below. | |
| B7. Operational water use | Water is used to clean PV panels. | 1,17E+01 kg/pcs | Tap water {Europe without Switzerland}\| market for \| Cut-off, U |

**Use stage description for RSM144-10-xxxBNDG**

| USE Stage | Consider ation | Value | Ecoinvent 3.9 module |
|---|---|---|---|
| B1. Use | Not concerned; for water, air or soil emissions | | |
| B2. Maintenance | Transport with a commercial vehicle to the plant | 20 km to the PV plant | Transport, freight, light commercial vehicle {Europe without Switzerland}\| market for transport, freight, light commercial vehicle \| Cut-off, U |
| B3. Repair | Not concerned | | |
| | | | |
| B5. Refurbishment | Not concerned | | |
| B6. Operational energy use | No energy consumption; but energy production according to DU | Energy production during reference service life (30 years) is explained below. | |
| B7. Operational water use | Water is used to clean PV panels. | 1,23E+01 kg/pcs | Tap water {Europe without Switzerland}\| market for \| Cut-off, U |

***Table 17: Use stage description for RSM144-9-xxxBNDG and RSM144-10-xxxBNDG***

### *7.4. End-of-Life phases (C1-C4)*

| | Unit | Value | Comment |
|---|---|---|---|
| ***De-construction (C1)*** | | | |
| Energy is needed to de-construct the PV power plant. The electricity consumption during deconstruction of PV plant (C1) was assumed the same as the electricity consumption of construction stage (A5). | | | |
| ***Waste transport (C2)*** | | | |
| Total mass of module waste | | | Explained in Table 39 |
| Road transport | km | 50 | lorry >32 metric ton, EURO5 |

The total mass of the product uninstalled is:

| PV module | Unit | Total mass (kg) |
|---|---|---|
| RSM144-9-xxxBNDG | Kg | 31 |
| RSM144-10-xxxBNDG | Kg | 32 |

***Table 18. Weight of total mass***

Waste processing (C3) and disposal (C4):

| Mean of transport | EoL | Unit [per module] | Bi-facial | |
|---|---|---|---|---|
| | | | RSM144-9-xxxBNDG | RSM144-10-xxxBNDG |
| Glass | Recycling | Kg | 2,56E+01 | 2,68E+01 |
| Aluminium frame | Recycling | Kg | 2,49E+00 | 2,57E+00 |
| Cells | Delamination | Kg | 7,23E-01 | 7,61E-01 |
| Junction box (set) | Landfill | Kg | 9,00E-03 | 9,00E-03 |
| Non ferrous metals (cooper, tin) | Recycling | Kg | 2,82E-01 | 2,93E-01 |
| Plastic | Energy recovery | Kg | 2,44E+00 | 2,55E+00 |
| Silicone | Energy recovery | Kg | 3,01E-01 | 2,80E-01 |

***Table 19. EoL treatment of PV module parts***

# 8.Additional environmental information

An additional indicator is the Return on Energy (RoE). This parameter gives an estimate of the efficiency of the photovoltaic park's solar energy production.

Following the PCR, the calculation is done using the following formula:

$$RoE\ [years] = \frac{E_{iinvested}}{E_{produced,annual}}$$

Where:

$E_{invested}$ = total amount of energy (thermal and electrical) required to produce the photovoltaic module (or solar park).

This number is the sum of the indicators PENRT + PERT.

$E_{produced,annual}$ = total amount of electricity generated in a year by the photovoltaic module (or solar park).

The results are explained by the following table:

| | RSM144-9-xxxBNDG | RSM144-10-xxxBNDG |
|---|---|---|
| **RoE** | 2,33 | 2,21 |

***Table 20. RoE results of Risen's PV modules in Ningbo factory***

# 9.Reference

**EPDItaly:**

Regulations of the EPDItaly Programme, version 6.0 (Issue date: 30th October 2023)

PCR for PV Panel: EPDItaly014 ELECTRICITY PRODUCED BY PHOTOVOLTAIC MODULES - Rev. 1.2 valid until 15/03/2026

**Sustainability reporting standards:**

European Standards. (2019). EN 15804:2012+A2:2019 Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products.

European Standards. (2019). EN 50693:2019 Product category rules for life cycle assessments of electronic and electrical products and systems

ISO. (2006). ISO 14044: Environmental management - Life cycle assessment - Requirements and guidelines.

ISO. (2009). ISO 14040: Environmental management - Life cycle assessment - principles and frameworks.

ISO. (2011). ISO 14025: Environmental labels and declarations - Type III environmental declarations - principles and procedures.

**Literature:**

IBP, Fraunhofer. *LCA screening of a recycling process for silicon based PV modules.* Fraunhofer : Fraunhofer, 2012.

ADEME: Packaging recovery in France: https://www.actu-environnement.com/media/pdf/news-28108-emballages-ademe-chiffres-2014.pdf

TASK 2020: LCI for PV; https://iea-pvps.org/wp-content/uploads/2020/12/IEA-PVPS-LCI-report-2020.pdf

Report water use in the PV plant during use phase; [https://solarpost.in/om/role-water-long-term-performance-solar-pv-plants/](https://solarpost.in/om/role-water-long-term-performance-solar-pv-plants/)

**LCA report:**

LCA report of Risen Energy Co., Ltd. For Environmental Product Declaration (EPD): Environmental Product Declaration of Mono-crystalline silicon photovoltaic (PV) modules. V1.2 dated April 18, 2025.