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Technical Guidelines for Designing a Solar PV System with HeliaSol®

PLEASE NOTE

This document contains only some of the important notes that should be considered when planning a PV system with HeliaSol solar modules. All regional and international standards must be observed when planning a solar installation.

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Introduction

HeliaSol is an innovative organic solar film for the generation of electrical energy from sunlight, designed and tested according to IEC 61730:2016 class II, for an ambient temperature range from -40°C to 85°C. It is a ready-to-install product, already equipped with a junction box and connectors on the front and an integrated backside adhesive on the backside for quick and easy installation. In the following, HeliaSol is referred to as solar film and describes the entire product.

HeliaSol has significant differences from conventional solar modules (Si-based), including:

- Ultra-light

  Weight of less than 2 kg/m² makes it perfect for lightweight buildings with low rooftop load-bearing capacity. In addition, makes it easy to carry on the roof and installation surfaces.

- Flexible

  Ideal for all curved or non-straight surfaces with minimum bending radius of 50 cm.

- Ultra-thin

  Thickness of less than 2 mm with seamless integration into the application surface.

- Truly green

  With an ultra-low carbon footprint, OPV is the greenest of all solar technologies and amongst the greenest of all power generating technologies. This is achieved using low material input, the abundance of heavy metal use such as Cadmium or Lead, by not using rare earths or other scarce raw materials.

- Easy and fast installation

  Integrated backside adhesive makes it simply gluing on various surfaces without requiring any special tools. There is no need for any mounting structure and penetration of the roof. Fast installation with less than 2 min/m².

- Temperature independent

  No performance loss at high temperatures up to >65 °C. (+/- 0 temperature coefficient from 25°C to 65 °C and -0.11 %/°C, from 65°C to 85 °C).

It is recommended to proceed in the following phases when designing a solar system with HeliaSol.

1 Pre-Feasibility Study

The pre-feasibility study provides a preliminary systematic assessment of all critical elements of the project and evaluates the feasibility of the project in general.

1.1 Fire Safety

As the first step, ensure that all relevant local and national laws, ordinances, and regulations related to fire resistance are met. The solar films have been tested and rated in accordance with the following standards, in combination with metal, concrete or polymeric waterproofing membranes with Fire class E acc. EN 13501-1 (resistance to other external fire sources not evaluated).

This means that HeliaSol is a normal flammable material, and some countermeasures should be taken to prevent the spread of flames. For example, you can keep a distance of 10 cm between the modules, use metallic cable ducts between the modules and provide the roof with a fire barrier, etc.

It is also recommended to discuss with the building owner or fire office for any restrictions. In addition, local regulations should be considered before designing, for example, PV installation is permit-free up to a certain building height in Berlin. In general, it should be noticed that façade installation is more relevant for fire safety.

1.2 Mounting Location & Substrate Feasibility

Since the power generated by the PV system varies significantly depending on the time and geographical location, the choice of installation site for the PV system is of utmost importance.

HeliaSol can be installed on structures with low static load capacity because it is very light. It can also be easily installed on the facade of buildings. Due to its flexibility, HeliaSol can be installed on curved buildings, and it can be installed without penetrating the building, as it does not require a mounting structure.

It should be considered that HeliaSol requires more area than conventional solar panels to give the same installed system power, so determining the right location is the first step.

Therefore, the following points must be considered when evaluating and selecting the installation site.

- Available area
  Firstly, determine the area available for the installation of the solar system. This area can be selected on the roof or facade of the building or on open spaces. Access to the site for installation of the system and for operation and maintenance should be considered. If selling electricity is the main goal of the solar system, the distance to grid access point should be considered. In addition, solar panels should not be installed near sources of dust generation to prevent soiling issue.

Finally, the dimensions of the available space should be taken to determine the area that will allow the installation of PV systems such as HeliaSol, DC /AC cable ducts, inverters, and combiner boxes.

- Mounting tilt
  The mounting surface on which HeliaSol is fixed, must have an inclination of min. 1° and max. 90° (façade). Choose the location of the installation in accordance to avoid HeliaSol being immersed in water or exposed to water streams. HeliaSol is IP67 certified but it must be ensured that water (e.g., rainwater) can run off the solar film. The orientation of the solar film must be such that rainwater or snowdrifts do not collect around the junction boxes.

- Mounting orientation (azimuth)
  For the best results, the solar panels should be oriented towards the equator. If the site is in the northern hemisphere, the panels should face south; if the site is in the southern hemisphere, they should face north. To install HeliaSol on the facade, it should not be installed on the walls facing north.

- Shading objects
  Specific shading patterns can cause reverse-bias conditions in the solar film which may affect its performance and in extreme cases it can cause local burns on the solar film surface. To avoid this, shading from stable and mobile objects near the project location should be checked. For this purpose, use simulation softwares like PVSyst or Google Sketchup to check shading at several days and times throughout the year.
  Most importantly, shading parallel to the long sides of the modules must be always avoided. For more information, please see the HeliaSol User Guide, chapter §4.3.

- Substrate type

  HeliaSol comes with an integrated backside adhesive (peel & stick) and can be installed directly on a wide range of materials e.g., glass, concrete, fiber cement, uncoated aluminum, stainless steel, copper, metal substrates coated with polyethylene (PE) or polyvinyl fluoride (PVF), acrylic glass (polymethyl methacrylate, PMMA).

  It is also possible to install HeliaSol on some surfaces using a primer, such as Bitumen or selected membrane materials. For them and other substrates, Heliatek offers adhesion test kits to check the compatibility of HeliaSol adhesive tape with the desired substrate. For more information, please see the HeliaSol User Guide, appendices 2 and 3.

1.3 Nominal Power - Rough Estimation

As a rough estimate, each 1 kWp HeliaSol requires about 15 m^2 surface area (the area may be less for crystalline silicon solar modules). Each 1 kWp PV module installation can generate about 1000 kWh per year in Germany and about 2000 kWh per year in the Middle East.

Remember that the access area around the modules can account for up to 20 percent of the required area.

Use the following formula to estimate approximately the nominal capacity of the solar system:

$$P_{nominal}[kWp] = Active\ area\ [m^2]\ \div 15$$

2 Feasibility Study

There are several factors to consider when selecting a solar system. To keep it simple, the two main components of a solar system are the solar module and the inverter. Each device is selected with the other in mind, and each has its own manufacturer that guarantees it. The preferences of the customer or installer play a role in the selection of equipment, as do site-specific concerns. There are several ways to design and build a system, as equipment preferences and pricing vary from company to company.

2.1 Number of Modules

The exact number of solar modules can be calculated based on the energy demand, the possibility of using batteries or connecting to the grid, the available area for the construction of a solar power plant and taking into account the following parameters:

- Calculation of horizontal and vertical distance between modules
  Leaving a distance of at least 5 mm between the modules to compensate for slight tilts after fixing the first part of the module is recommended. The space between the modules should be selected in such a way that the minimum bending radius for the cables is adhered to 40 mm. Also, the arrangement of the modules should be considered in such a way that the minimum cabling route is required.

- Removal of shaded spaces
  Remove the obstacles that cause shading, especially those that create shadow parallel to the long side of the modules. If this is not possible, do not install HeliaSol in shaded areas.

- Consideration limitations about the substrate
  Leave out substrate areas that do not meet the requirements of HeliaSol installation, such as the minimum bending radius (>50cm), surface slope (min 1°) and bending in two axes.
  HeliaSol has a projected power production service life of 20 years. Please ensure that the mounting roof substrate has a remaining service life of at least 20 years. In addition, the substrate must be able to withstand the forces that occur during the installation of HeliaSol, and it must not crack or break during this process.

2.2 Select Inverters

First make sure that the extreme (minimum/maximum) parameters of the inverter are not exceeded.

For installation on non-grounded substrates (e.g., membranes, concrete, bitumen), a wide range of string, central, transformer and transformerless inverters can be used with HeliaSol.

For installation on grounded conductive substrates (e.g., metal), Heliatek recommends the use of inverters with transformers and galvanic isolation or three-phase inverters. If available, the use of inverters with H5 or HERIC topology would be beneficial. The maximum capacity of the inverter must be taken from the operating instructions of the inverter.

The following points should be considered to select an inverter:

- Power range
  Oversized and undersized inverters can cause energy loss in the system. The highest power generation of a year can be the basis for selecting the correct inverter size.

- Electrical limitation
  Consider the electrical limitations of the inverter, such as maximum voltage and current for the input strings, and number of MPPT. To consider these limitations, you should always pay attention to the changes in voltage and current as a function of temperature. For example, when the temperature decreases, the voltage increases.

- The maximum number of modules n that can be connected in series within the specified maximum system voltage V_{sys} can be calculated as:
  $$n = V_{sys} / (1.25 \times V_{OC})$$

- The maximum number of strings n that can be connected in parallel within the specified maximum Overcurrent Protection Rating (OCR) and without additional safety measures (i.e., fuses or blocking diodes) can be calculated as:
  $$n < OCR / (1.25 \times I_{SC}) + 1$$

- Parasitic capacitance
  For HeliaSol, a dry state parasitic capacitance of 15 nF/m^2 must be assumed in connection with a conductive underground surface under unfavorable conditions.
  If the coupling capacitance for one inverter is X µF and the area of one HeliaSol module is Y m^2 then the number n of HeliaSol that can be installed with this inverter should be less than:
  $$n < X \times 1000 / (15 \times Y)$$

- Grid code
  When the system is connected to the power grid, select an inverter that meets the grid connection requirements and local connection standards.

- IP Code

Solar inverters have different IP codes, which indicates how well a device is protected against water and dust. Select an inverter based on indoor/outdoor installation location.

- Market availability and delivery time
  It should always be checked whether the selected inverter is available in the market. Delivery time is also an important consideration, as it must be coordinated with the installation time of the project.

2.3 Simulation

There are some solar simulation softwares that can help designers to estimate electricity generation and improve design. They also provide economic evaluation, CO_2 savings, and other options. PVsyst and PVSOL are two examples of these solar softwares. They are useful for understanding different aspects of a system and determining where additional efforts should be made.

The most important results which are calculated are:

- Yearly Yield [kWh]:
  PV energy generation in one year

- Specific Annual Yield [kWh/kWp]:
  PV energy generation in one year for the unit of system power

- LCOE (Levelized Cost of Electricity) [€/kWh]:
  The average electricity price generated by the PV system over its lifetime, including all costs (installation, maintenance, and financing)

- ROI (Return on Investment) [Year]:
  The time in years needed to at least earn the amount of money back from e.g. PV power direct sales or grid power replacement that was invested in the full installation

- GHG Emissions Avoided/CO_2e savings [kg CO_2e/year]:
  By displacing more emission-intensive energy sources from the grid mix or directly replacing electricity from the grid mix, greenhouse gas emissions can be avoided and thus saved.

Simulation software also provides you with relevant data in an easily digestible format, so you can start designing your system right away. At the end, users have access to several simulation features, including a daily overview of all system energy levels and reports on selected areas during operation. This software uses advanced simulation algorithms to visualize how the system operates in real time.

HeliaSol simulation files are available for import into the software to accurately simulate the solar system in PVSOL and PVsyst.

3 String Design

A PV system can be designed in different ways, but the important thing is that it should be optimized. Optimization can be achieved by reducing electrical losses, cable lengths and system costs. Reducing the risk of failure and making the maintenance process easier could also be considered.

3.1 Physical arrangement

The physical arrangement of the solar modules can have a significant impact on the cost of the system. As HeliaSol has the junction box and cables on the frontside and is directly glued onto the substrate, DC cables cannot be hidden below the modules. Instead, cable channels should be used to collect DC cables and protect them from environmental hazards. The placement of these cable channels, along with the arrangement of the modules must therefore be optimized, as shown in the following.

- Module Layout

  A good module layout can maximize the use of available space. By minimizing the gaps between modules and choosing a face-to-face installation method, more panels can be placed in the available area, maximizing the overall capacity of the PV system. This is particularly important in areas where space is limited, such as urban environments or rooftop installations.

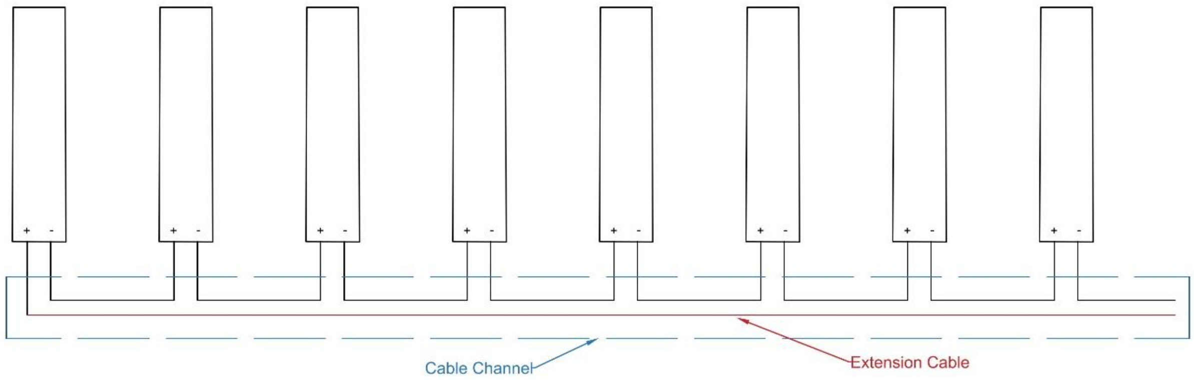
  In addition, shorter distances between modules and face-to-face design can reduce the amount of cabling and cable channels required, reducing material costs and electrical losses.

  The following example shows that the length of the cable channel in face-to-face layout is half that of the linear layout.

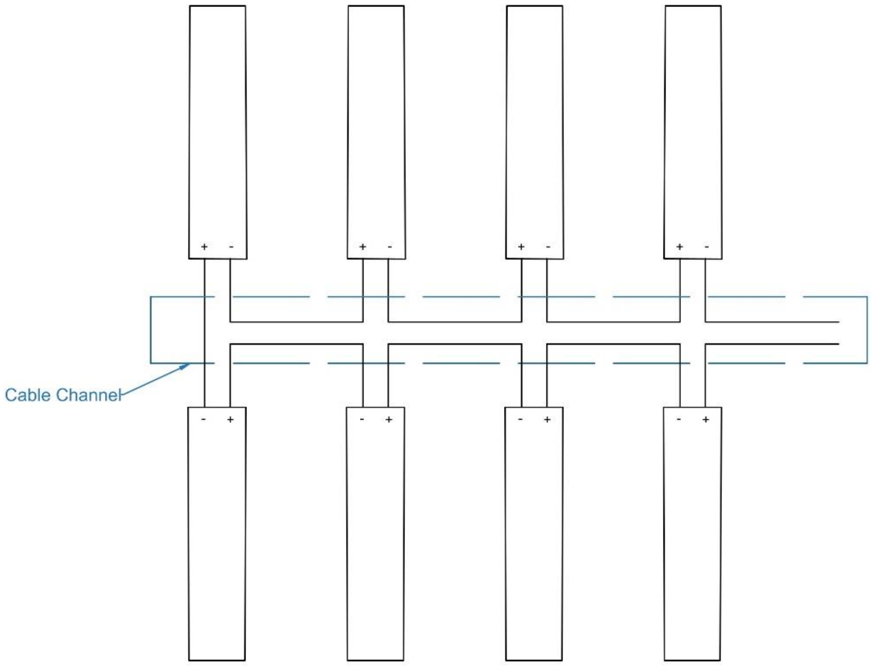
  In addition, Option A requires an extension cable to create a string, whereas Option B does not.

  We therefore always recommend arranging the modules face-to-face, with the cable channel in between.

Linear Layout (Option A)



Face-To-Face Layout (Option B)



- Cable Channel orientation for façade installation

  For the facade installation process, it is usually easier to put the cables into the cable channels in the vertical design of the cable channel compared to the horizontal one. As there is usually more than one string which goes into the same cable channel, the number of cables in one cable channel can become quite large. In vertical orientation, cable insertion is in-line with gravity, so they will stay in the cable channel naturally. In horizontal orientation, cables tend to fall out of the cable channel, caused by gravity, making the installation more cumbersome.

  We therefore recommend using the vertical configuration as much as possible.

3.2 DC combiner box

Once the strings are designed (see previous chapter), they need to be wired to the inverter to generate electricity at the end. For HeliaSol, the string current is typically lower than for conventional Si-based string systems. This means, you will have more strings at the end to be collected to one MPPT of the inverter. This is achieved by using a so-called DC combiner box.

A DC combiner box, also known as a photovoltaic (PV) combiner box, is an important component in solar PV systems. It serves several critical functions that contribute to the overall efficiency, safety, and ease of installation and maintenance of the system. Here are the key advantages of using a DC combiner box in solar PV systems:

- Simplifying Wiring and Installation:

  A combiner box can collect the inputs from multiple solar strings into a single output, simplifying wiring and reducing system complexity. It also simplifies the installation process by centralizing connections, saving time and reducing the probability of wiring errors.

- Enhancing Safety:

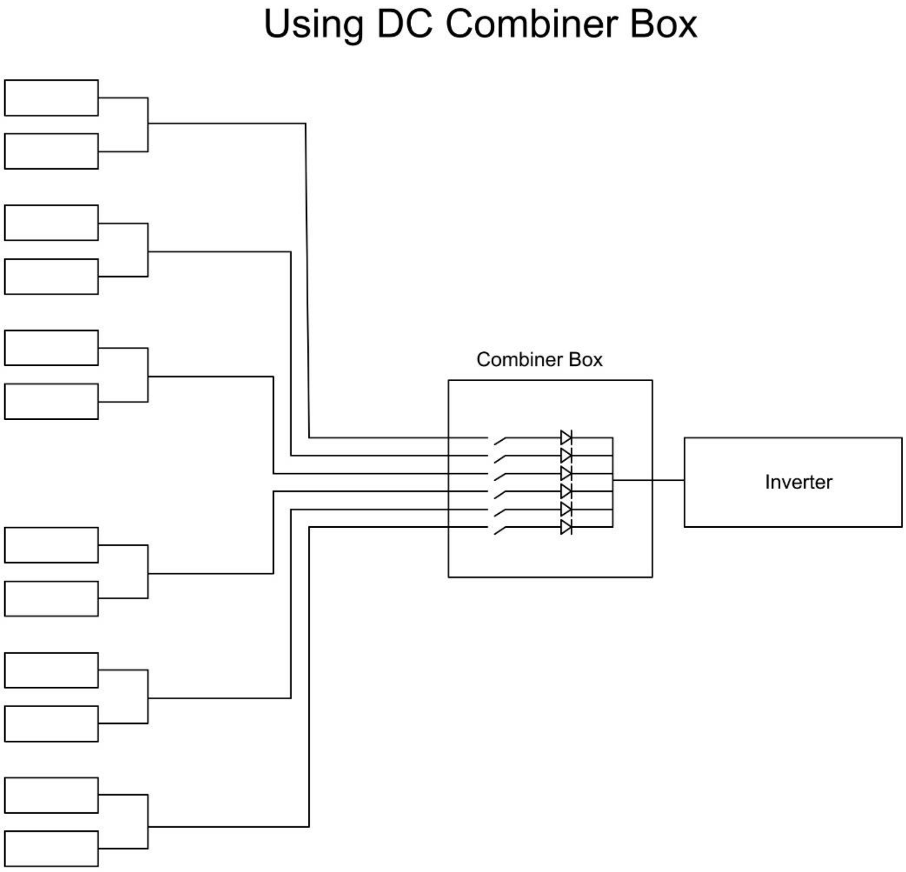
  Combiner boxes typically contain fuses or circuit breakers for each string, providing overcurrent protection and reducing the risk of electrical fires. It could be a great solution for making more than two strings parallel. Many combiner boxes are equipped with surge protection devices (SPDs) to protect the system from voltage spikes caused by lightning or other electrical disturbances. Built-in isolators allow the array to be safely disconnected from the rest of the system for maintenance or emergency purposes.

- System Monitoring:

  Some combiner boxes come with integrated monitoring systems that allow real-time tracking of individual string performance, helping to identify and troubleshoot problems quickly.

An example picture of a DC combiner box as well as a typical configuration of strings wired to the inverter via DC combiner box is shown in the following figure.

DC Combiner Box

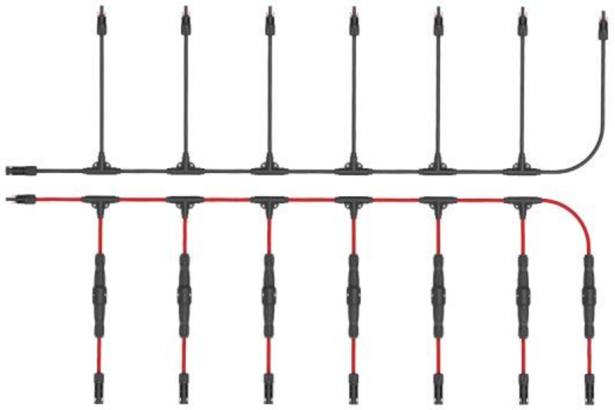


3.3 Minimizing DC cable length

Minimizing cable length in a solar PV system primarily enhances performance by reducing electrical losses, maintaining higher efficiency, and ensuring better voltage regulation. Additionally, it can lead to cost savings, improved system reliability, and increased safety. The following solutions are recommended to be considered in a system design of a HeliaSol installation:

- Y-Connector (Splitter)
  It is possible to reduce the DC cable length by using Y-connectors. Two strings could be parallel together with Y-connectors. It can reduce the number of cables from string locations to DC-combiner boxes. Making more than two strings parallel together can increase the current rate higher than OCR, then the modules should be protected (see below).

- Harness
  Solar PV wiring harnesses can improve the performance, safety, and reliability of solar PV systems. By providing pre-assembled wiring solutions, they simplify installation, improve system organization, and reduce the potential for errors and maintenance issues.
  These harnesses are particularly useful for small installations without combiner boxes, making some parallel connections much easier with inline diodes.



For all cases of parallel connections, overcurrent protection measures must be considered in case the installation has a fault and is not working properly. Here are several methods and devices used to protect against overcurrent in solar PV strings:

- Using blocking diodes (inline or in combiner boxes) to block the reverse current. It should be considered that the diode should be selected based on the different parameters such as Safety Margin, Temperature and Environmental Factors, Efficiency and Forward Voltage Drop.
  The operation electrical condition should meet the following rules and considering the safety factor:

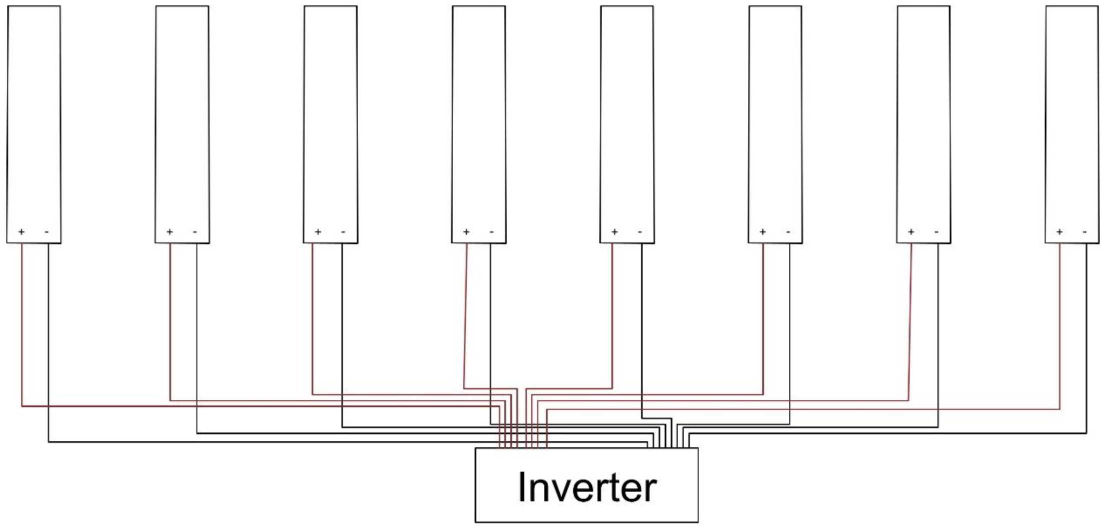
$$I_{SC} < \text{Diode rating}$$
$$\text{maximum voltage expected in PV string} < \text{Diode Voltage Rating}$$

- Using fuses to break the circuit when the current is higher than the overcurrent protection rating (OCR) of the modules.
  It should be considered that the fuses should be selected based on the different parameters such as Fuse Type, Voltage Rating, Temperature and Environmental Conditions.
  The operation electrical condition should meet the following rules and considering the safety factor:

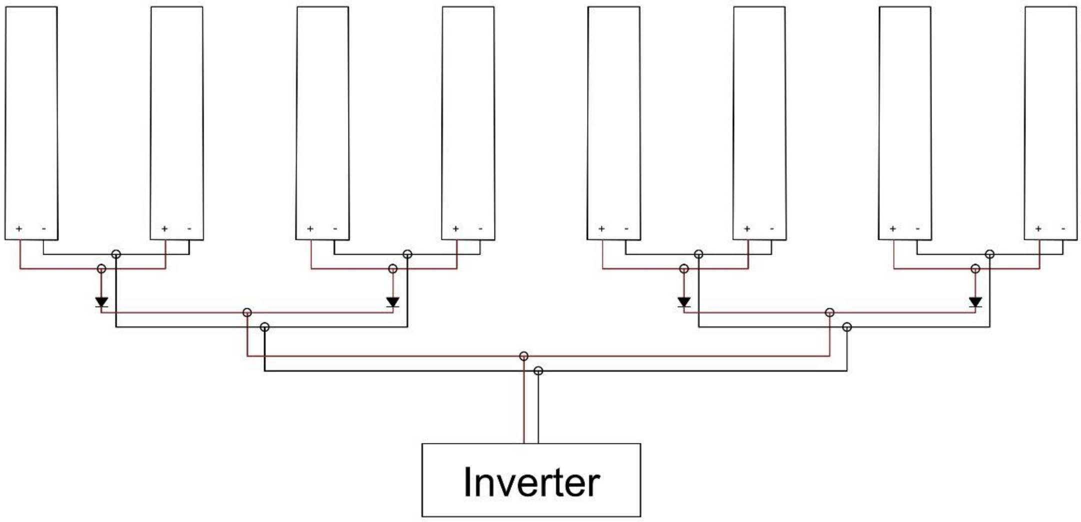
$$I_{SC} < \text{Fuse operation current} < \text{OCR}$$

Following sample shows how using Y-connectors and inline diodes can reduce the cable length:

Cabling Without Y-Connectors and Inline Diodes



Cabling Using Y-Connectors and Inline Diodes



We recommend placing all components for overcurrent protection together in the DC combiner box (see above), if possible. That way, safety components are collected at an easily accessible central place and can be replaced quickly in case of errors.

3.4 Finalizing the design

Check the design for optimal material requirements, accessibility, and other parameters. For example, find the best route for the cable ducts so that they are as short as possible, have a good shape especially when installed on the facade, and are easy to install.

If the monitoring of the data goes beyond the parameters accessed by the solar inverter, some sensors and a monitoring system are required, e.g., irradiation, ambient or module temperature, and wind speed sensor.

Consideration should always be given to installing devices that protect the solar array, the electrical grid, and the people working with the array from potential risks (e.g., AC / DC fuse, reverse current blocking diode, lighting, and surge protection). Some protections are optional, others are mandatory and should be included in the project.

Now it's time to consider all the points in your design and make the execution plans for the installation team.

4 Installation

Please follow the instructions in the “User Guide” and use the “Installation Checklist” during this process.

5 Commissioning

After installation, the PV system must be commissioned by an on-site visit to verify that all items have been delivered, e.g.:

- All project documents including as built documents
- Proof of correct working (string measurement protocols, system producing energy, monitoring system, …)
- Photos of installation progress
- Allowance of feed-in from local power supplier
- Warranty terms
- Operation & Maintenance contracts (if applicable)

6 Operation and Maintenance

To ensure the safe and effective operation of the installation, the solar films must be carefully and properly inspected, cleaned, and maintained at regular intervals or after special conditions have been met (e.g., extreme weather conditions).

All activity relating to inspection, cleaning, and maintenance work must only be carried out while the system is switched off (open-circuit condition) and at low irradiation levels.

If you have any questions, please contact us sayhello@heliatek.com before proceeding with your actions.

You can find more information about us on our website: www.heliatek.com

Appendix

Calculation of GHG Emissions Avoided/CO_2e savings

By displacing more emission-intensive energy sources from the grid mix or directly replacing the electricity from the grid mix, greenhouse gas emissions (GHG) can be avoided and thus saved.

The following formula can be used to calculate the amount of saved CO_2e:

$$CO_2e\ saving\ potential_x = CF_x\ \left[\frac{g\ CO_2e}{kWh}\right] - CF_{PV}\ \left[\frac{g\ CO_2e}{kWh}\right]$$

$$Annual\ CO_2e\ savings\ =\ CO_2e\ saving\ potential_x\ \left[\frac{g\ CO_2e}{kWh}\right] * E_{PV,a}\ [kWh]$$

CF_x: Country-specific Carbon Footprint of non-renewable grid mix

CF_{PV}: Carbon Footprint of PV solution

$E_{PV,a}$: Electricity generation annual

TÜV Rheinland has evaluated the environmental impact of HeliaSol with 15.95 kg CO_2e/m^2 through a life cycle assessment - certified towards end of 2023. Thereby, all environmental impacts were evaluated from acquisition of raw materials over the production and use up to end of life treatment including all transport/delivery routes. The exact value depends on location, inclination and orientation and can be calculated using softwares like PVsyst or PVSOL (see below). Click here to learn more about our truly green solar films.

In addition, the International Renewable Energy Agency (IRENA) has published the greenhouse gas emissions avoided by renewable electricity generation in a country in 2020 [IRENA: Avoided Emissions Calculator], which is used as a reference. CF_x for some countries in g CO_2e/kWh can be found in table 1.

CF_x based on IRENA 2020

Country	g CO_2e/kWh
Germany	636
United States of America	492
GB	353
France	75
China	906
UAE	469
South Korea	534
Japan	674
South Africa	950

Calculation of GHG Emissions Avoided/CO_2e savings in PVsyst

To calculate the CO_2e savings with HeliaSol in PVsyst software, these steps should be followed in order:

- Simulate a solar PV system with HeliaSol
- Select "economic evaluation" in "optional calculations"
- Select "carbon balance" tab
- Put these numbers in overview tab:
    - Project lifetime = 20 years
    - Annual degradation = 0 % (The degradation of the modules is already taken into account in the generation simulation part.)
    - LCE Grid = Find the correct number based on the location (country) in the table 1 or calculate for other locations based on IRENA source
- Select "detailed system LCE" tab
- Put these numbers in the items:
    - For PV Module select m^2 for unit and put 15.95 kg CO_2e/m^2 in the LCE box
    - Put 0 for transport, supports/trackers, concrete, and DC wiring (This is all included in the carbon footprint of 15.95 kg CO_2e/m^2.)

Calculation of GHG Emissions Avoided/CO_2e savings in PVSOL

To calculate the CO_2e savings with HeliaSol in PVSOL software, these steps should be followed in order:

- In designing a project, in the "System Type, Climate and Grid" step, click on "simulation parameters"
- Select tab "Project Option", then "AC Mains"
- Find the correct number based on the location (country) in table 1 or calculate for other locations based on IRENA source. Then write it manually in the box of "Specific CO_2 saving through the use of PV energy"[1]
- Click "OK" and continue simulation process

[1] It should be noted that in PVSOL, only CO_2e saving in the operation of the power plant is calculated, and the pollution caused by the production of equipment and construction of the PV system is ignored.