

PVSYST 7


Grid-connected



INTRODUCTION

This document is a first step of a series of tutorials which explain the use of PVsyst Version 7 and may be understood as a PVsyst user's manual. It contains three different tutorials describing the basic aspects of the simulation:

- Creation of a grid-connected project
- Construction and use of 3D shadings scenes
- Meteorological data in PVsyst

More tutorials are in preparation and will be added in the future. They will explain in more detail the different features of PVsyst. The complete reference manual for PVsyst is the online help, which is accessible from the program through the “Help” entries in the menus, by pressing the F1 key or by clicking on the help icons  inside the windows and dialogs.

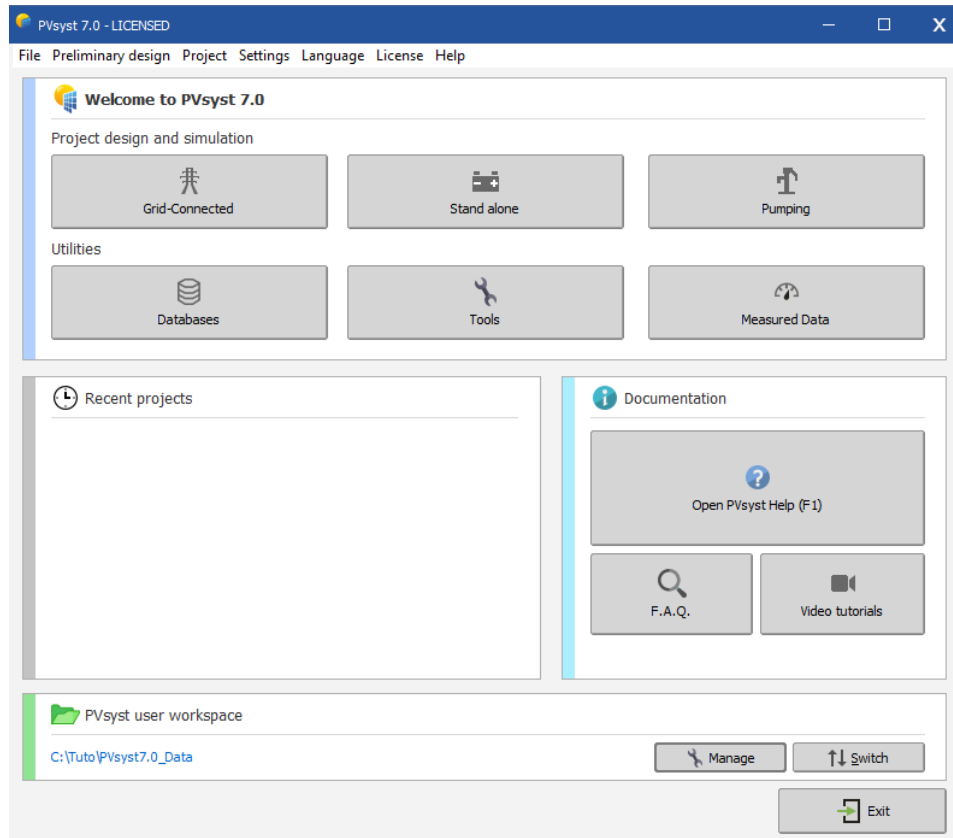
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Part 1: Basic Approach - My First Project

1- First contact with PVsyst

When opening PVsyst you get to the main page:



This gives access to the four main parts of the program:

“Project design and simulation” is the main part of the software and is used for the complete study of a project. It involves the choice of meteorological data, system design, shading studies, losses determination, and economic evaluation. The simulation is performed over a full year in hourly steps and provides a complete report and many additional results.

“Recent projects” allows you to quickly find and modify your recent projects

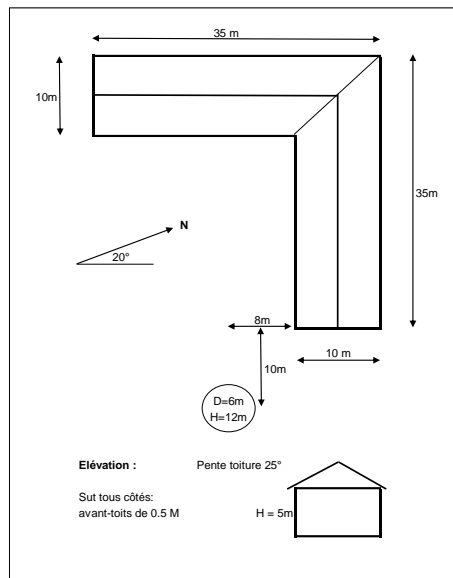
“Documentation” will help you in the realization of your different simulations with the help of PDF tutorials, Videos and a FAQ.

“Pvsyst user Workspace” contains all data created by the user. The default place is C:\Users\<username>\Pvsyst7.0_Data but this can be changed by the user

2- Full study of a sample project

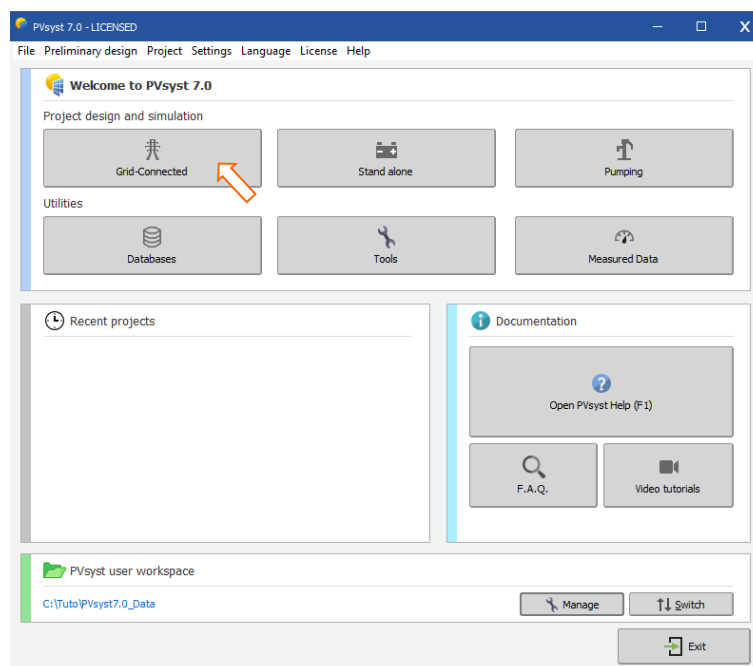
Project specifications and general procedure

For an introduction to the development of a project design in PVsyst, we will walk through a full project step-by-step. As an example, we will consider a farm located in Switzerland close to Geneva. The building in question is shown on the following sketch:

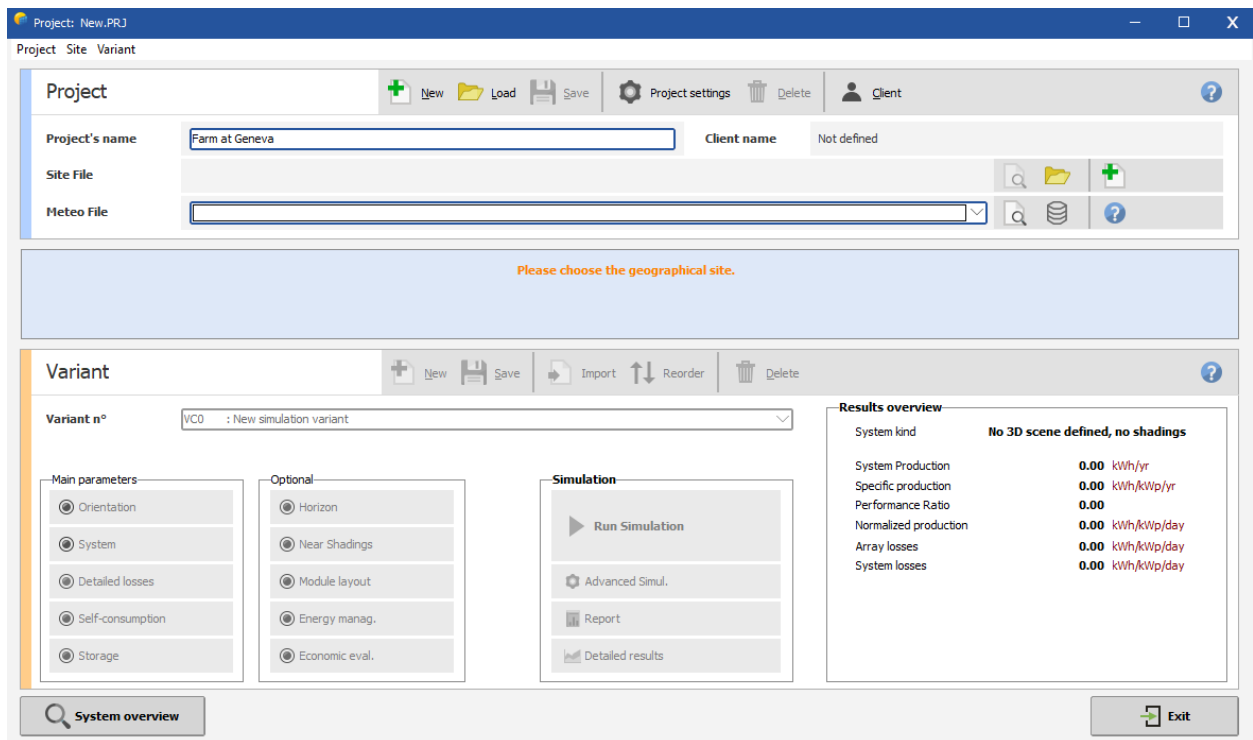


The roof of the farm is facing south. A roof surface of 125 m² is available, and we plan to cover 50 m² of them with mono-crystalline PV modules.

As explained before, we will not use the “Preliminary Design” for a grid-connected project, but rather start the complete “Project design”.



When you choose "Grid connected" project, you will get the following dashboard for the management of a project:



The dashboard has two parts: The Project basic definitions and the System variant management.

The 'Project' in PVsyst, is just a central object for which you will construct different variants (also called system configurations or calculation variants) of your system. The Project contains the geographical site of your system, the reference to a file with the meteorological data, and some general parameters like the Albedo definition, some sizing conditions and parameters specific to this project. In the PVsyst workspace it will get a filename with the extension *.PRJ.


Each System Variant contains all the detailed definitions of your system, which will result in a simulation calculation. These definitions include the choice of solar panels and inverters, the number of panels and inverters, geometrical layout and possible shadings, electrical connections, different economic scenarios, etc. In the database, the files with the Variants of a project will have the Project's file name, with extensions VC0, VC1, VCA, etc. You can define up to 936 Variants per project.

Steps in the development of a project

When developing a project in PVsyst, you are advised to proceed in small incremental steps:

- Create a project by specifying the geographical location and the meteorological data.
- Define a basic system variant, including only the orientation of the PV modules, the required power or available area and the type of PV modules and inverters that you would like to use. PVsyst will propose a basic configuration for this choice and set reasonable default values for all parameters that are required for a first calculation. Then you can simulate this variant and save it. It will be the first rough approximation that will be refined in successive iterations.
- Define successive variants by progressively adding perturbations to this first system, e.g., far shadings, near shadings, specific loss parameters, economic evaluation, etc. You should simulate and save each variant so that you can compare them and understand the impact of all the details you are adding to the simulation.

Tips - Help

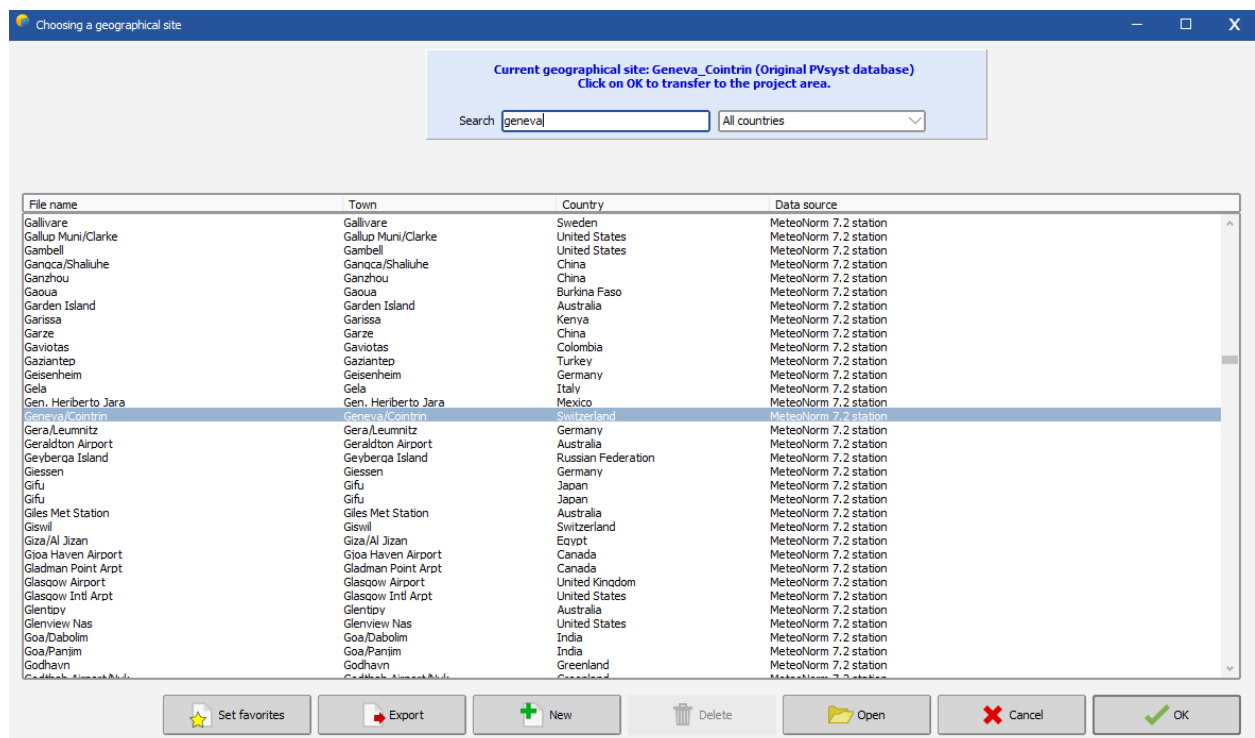
In PVsyst, you can always get to the context Help by pressing F1. Sometimes you will also see little blue question mark buttons . Clicking on them will lead to more detailed information on the topic in the Help section.

When PVsyst displays messages in red, you are advised to carefully read them! They may be either warnings or error messages, or they can be procedures that should be followed to get a correct result.

Defining the Project

In the project dashboard click on «New project» and define the project's name.

Then click on “Site and Meteo”.



You can either choose a site from the built-in database, which holds around 2,550 sites from Meteonorm, or you can define a new site that can be located anywhere on the globe. Please refer to the

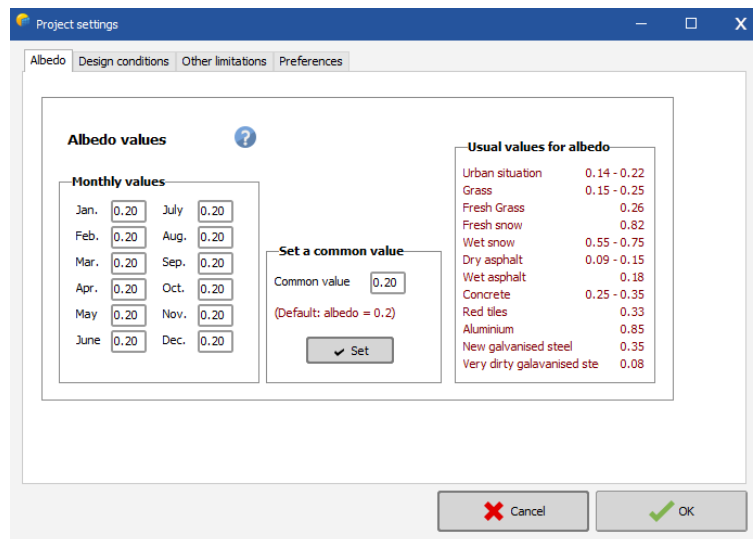
tutorial "Meteorological Data management" if you want to create or import a site other than those available in the database.

The project's site defines the coordinates (Latitude, Longitude, Altitude and Time zone), and contains monthly meteorological data.

The simulation will be based on a Meteo file with hourly data. If a near meteo file exists in the vicinity (less than 20 km), it will be proposed. Otherwise PVsyst will create a synthetic hourly data set based on the monthly meteo values of your site. However, you can always choose another Meteo file in the database. A warning will be issued if it is too far from your site.

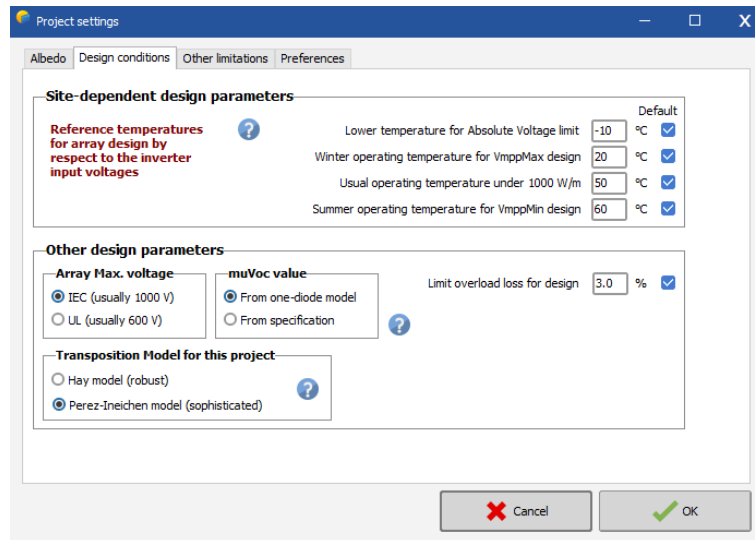
NB: If you start by choosing a meteo file, you have the possibility of copying the site associated with this file to the Project's site.

In the project dashboard you can click on the button "Project settings" which will give you access to the common project parameters, namely the albedo values, the design conditions, design limitations and interface preferences.



Usually you will never modify the albedo factor. The value of 0.2 is a standard adopted by most people. Nevertheless, if for example your site is located in the mountains, you can define in this table a higher albedo factor like 0.8 for the months with significant snow cover.

The second tab in the project parameters dialog contains the "Design Conditions" page.

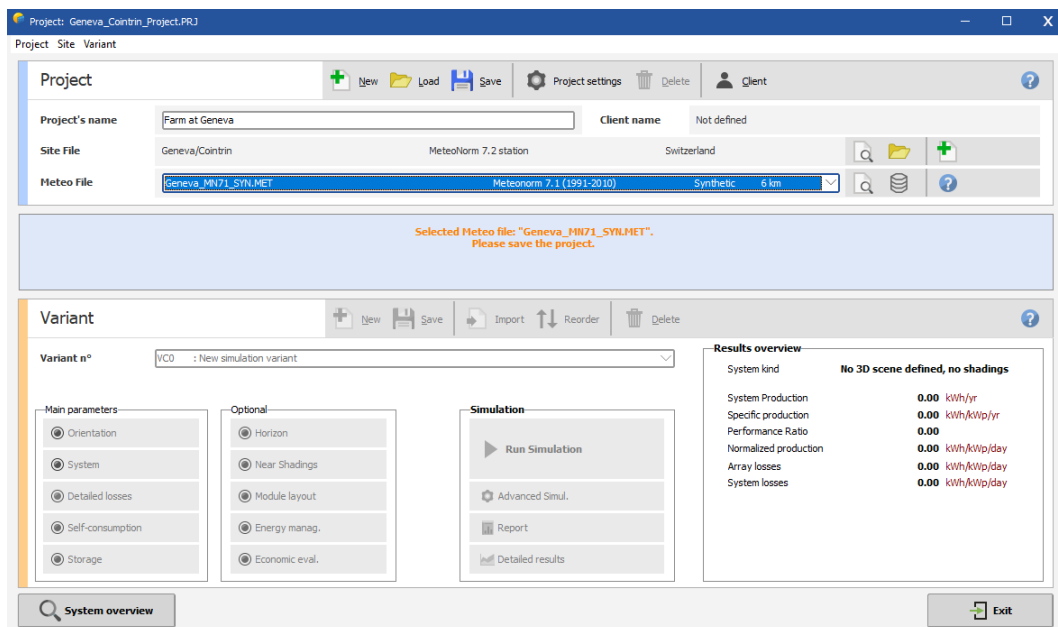


This page defines sizing temperatures, which may be site-dependent. These are only used during the sizing of your system; they are not involved in the simulation.

The "Lower temperature for Absolute Voltage Limit" is an important site-dependent value, as it is related to the safety of your system (it determines the maximum array voltage in any conditions). Ideally, it should be the minimum temperature ever measured during daylight at this location. In Central Europe the common practice is to choose -10°C (lower in mountain climates).

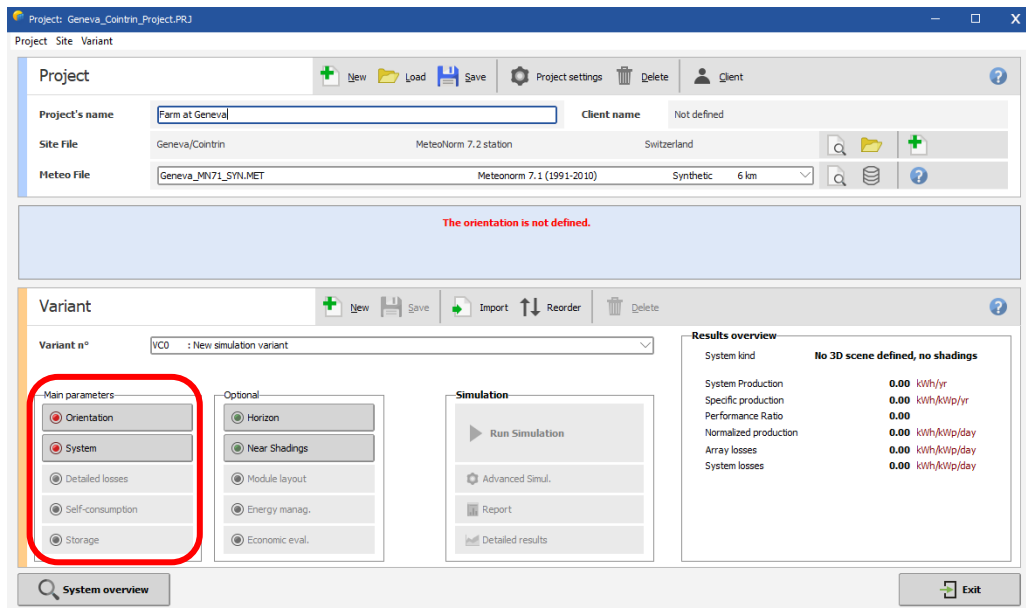
3- Saving the Project

When you are finished (i.e. you have gone to the Variant choices), you will be prompted to save the project. The dialog that comes up allows you to rename the project. We recommend that you use a simple filename, since it will be used as a label for all the Variants.

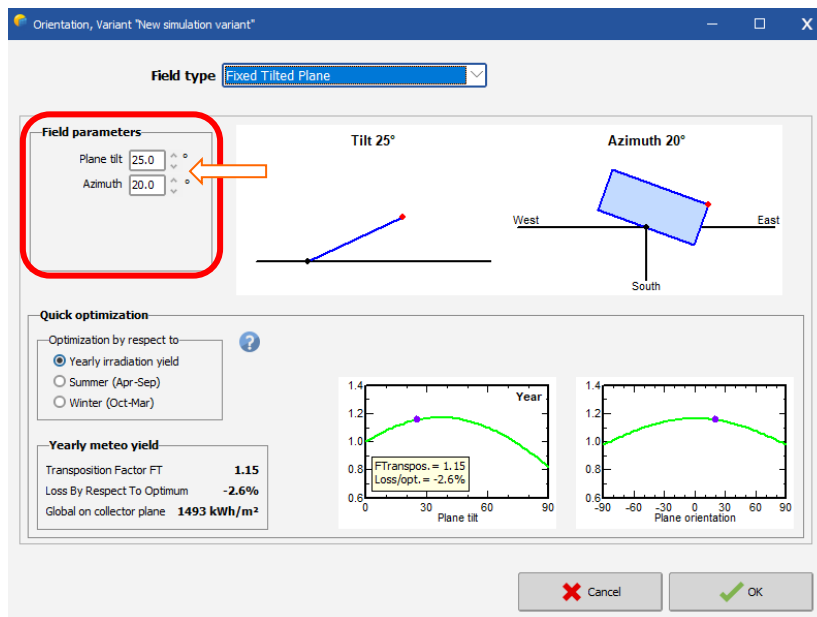


Creating the first (basic) variant for this project

After having defined the site and the meteorological input of the project, you can proceed to create the first Variant. You will notice, that in the beginning there are 2 buttons marked in red: "Orientation" and "System". The red color means that this variant of the project is not yet ready for the simulation, additional input is required. The basic parameters that have to be defined for any variant, and that we have not specified yet, are the orientation of the solar panels, the type and number of PV modules and the type and number of inverters that will be used.



First, click on "Orientation". You will get the orientation dialog where you have to supply values for the type of field for the solar installation and tilt and azimuth angles.



The solar panels in our example will be installed on a fixed tilted plane. From the project's drawing (page 5) we get the Plane Tilt and Azimuth angles (25° and 20° west respectively). The azimuth is defined as the angle between the South direction and the direction where the panels are facing. Angles to the west are counted positive, while angles to the east are counted negative.

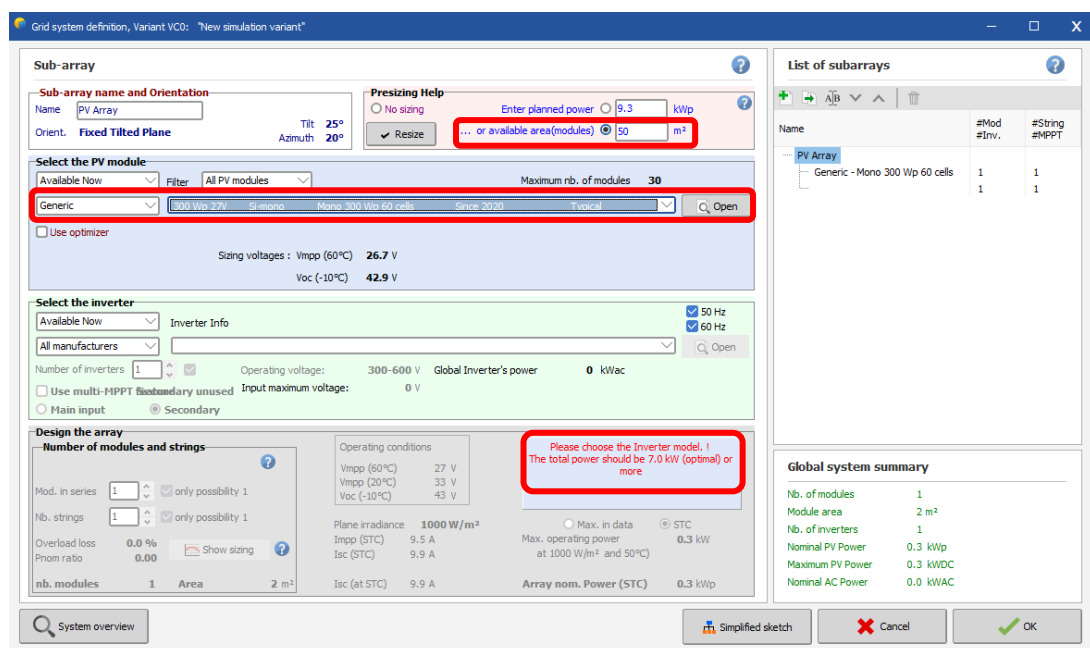
After setting the correct values for tilt and azimuth, you click on "OK" and the "Orientation" button will turn green. Next click on "System".

Presizing Help

From the system description, we remember that we have an available area of around 50 m². It is not mandatory to define a value here, but doing so will simplify our first approach as it will allow PVsyst to propose a suitable configuration.

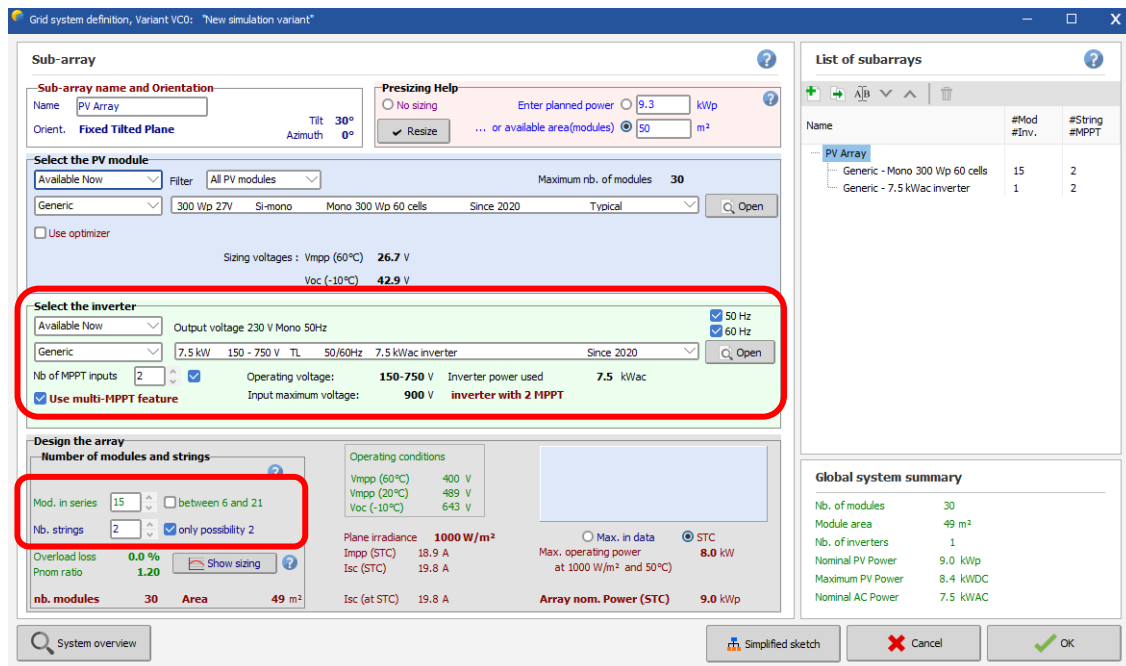
Select a PV module

Choose a PV module in the database. Among "All modules", select "Generic" as manufacturer and select the 300 W model. In the bottom right part of the dialog PVsyst will display a hint for choosing the inverter: "Please choose the Inverter model, the total power should be 7 kW or more."



Select the Inverter

For the installation in our example we can choose a monophased inverter of around 7 kW. We choose the Generic 7.5 kW inverter, and PVsyst proposes a complete configuration for the system: 1 inverter, 2 strings, each with 15 modules connected in series.



After the module type, the inverter and the design of the array have been defined, the blue panel in the bottom right part of the dialog should be either empty or orange. If you get a red error message, check all choices you made and correct them to the values described above (it may take a short moment for the message to adapt to the changes you make).

We have now defined all mandatory elements that are needed for a first simulation. We will go through more details of this very important dialog later in this tutorial. For now, you can click on "OK" to validate the choices. You will get a message box with the warning: "The inverter power is slightly undersized". For the time being we will ignore it and just acknowledge with the OK button.

Message colors in PVsyst

In many of the PVsyst dialogs you will be prompted with messages that are meant to guide you through the different steps of the definition and execution of a simulation. The color of the text gives you a clue on how important the message is:

- Messages in black are additional information or instructions on how to proceed.
- Warnings in orange indicate design imperfections, but the system is still acceptable.
- Errors in red mean serious mistakes, which will prevent the execution of the simulation.

A similar color code is also valid for the buttons on the project's dashboard (in addition a greyed-out button means "has not been defined").

4- Executing the first simulation

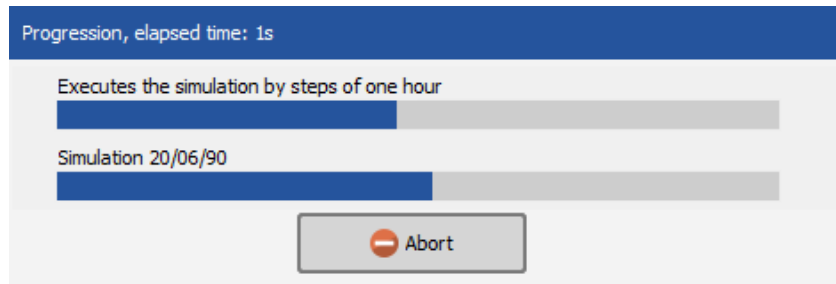
On the Project's dashboard, all buttons are now green (possibly orange) or Off.

The "Run Simulation" button is activated, and we can click on it.

The screenshot displays the simulation software interface. On the left, a 'Simulation' sidebar contains a green 'Run Simulation' button, along with 'Advanced Simul.', 'Report', and 'Detailed results' buttons. The main window shows simulation parameters for a 'DEMO Residential system at Geneva' and 'Main results' including System Production (10993 kWh/yr), Specific prod. (1221 kWh/kWh/yr), Performance Ratio (6.871), Normalized prod. (3.35 kWh/kWh/day), Array losses (0.43 kWh/kWh/day), and System losses (6.87 kWh/kWh/day). Four graphs are visible: 'Array Temperature vs. Effective Irradiance', 'System Output Power Distribution', 'Daily Input/Output diagram', and 'Array Voltage Distribution'. A 'Simulation ended successfully' dialog box is open on the right, asking 'Do you want to save the simulation variant?' with 'Yes' and 'No' buttons, and a checkbox for 'Don't ask me again (I can save later)'. Below this, another window shows the 'Simulation parameters' section with fields for 'Variant' (First simulation), 'Project', 'Site', 'Horizon', and 'System', along with 'Preliminary definitions' and 'Simulation dates' (from 01/01/1990 to 31/12/1990).

The simulation dates are those of the underlying meteo data file. Don't modify them (you cannot perform a simulation outside of the available meteo data).

The preliminary definitions are additional features which may be defined for advanced purposes. We will skip them for now, and click right away on "Simulation".

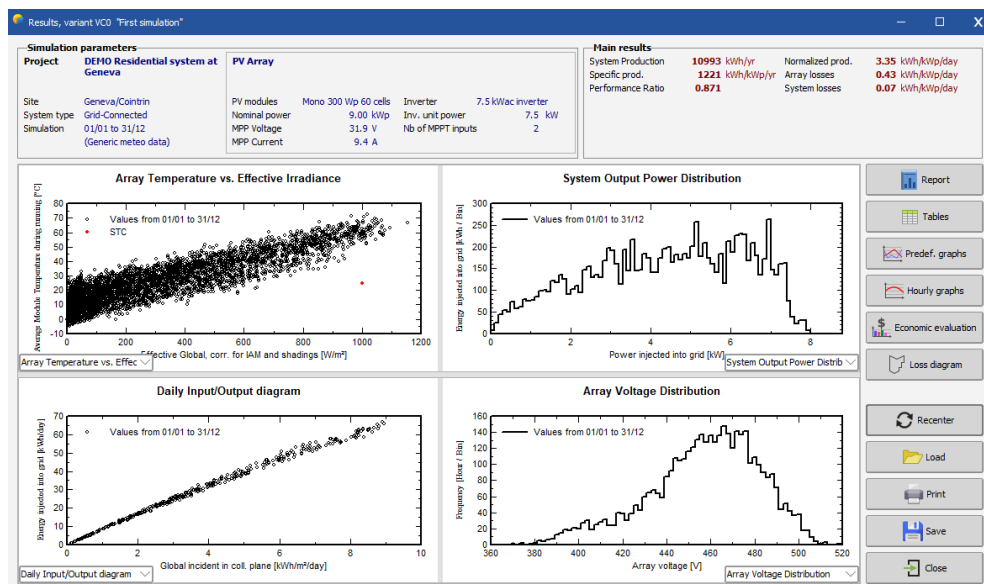


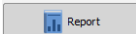
A progress bar will appear, indicating how much of the simulation is still to be performed. Upon completion, the "OK" button will get active. When you click on it, you will get directly to the "Results" dialog.

Analyzing the results

This dialog shows on the top a short summary of the simulation parameters that you should quickly check to make sure that you made no obvious mistake in the input parameters. To the right is a frame with six values that summarize at one glance the main results of the simulation. They only give a very coarse picture of the results and are there to quickly spot obvious mistakes or to get a first impression of a change or a comparison between variants of the project.

In the bottom part of the dialog you will see several diagrams, which gives you already more detailed information about the general behavior of the system. The "Daily Input/Output diagram" displays for every day that was simulated, the energy that was injected to the grid as a function of the global incident irradiation in the collector plane. For a well dimensioned grid-connected system, this should be roughly a straight line that slightly saturates for large irradiation values. This slight curvature is a temperature effect. If some points (days) deviate at high irradiances, this is an indication of overload conditions. For stand-alone systems, a plateau indicates overload (full battery) operation.



The main information of the simulation results is gathered in the report. The other buttons give access to complementary tables and graphs for a deeper analysis of the simulation results. For now we will ignore them. When you click on  you will get the complete report, which for this first simple

variant consists of only three pages (for simulations with more detail you can get up to 11 pages of report). In this report you will find:

First page: All the parameters underlying this simulation: Geographic situation and Meteo data used, plane orientation, general information about shadings (horizon and near shadings), components used and array configuration, loss parameters, etc.

Second page: A reminder of the main parameters, and the main results of the simulation, with a monthly table and graphs of normalized values.

Third page: The PVsyst arrow loss diagram, showing an energy balance and all losses along the system. This is a powerful indicator of the quality of your system, and will immediately indicate the sizing errors, if they exist.

Analyzing the report

Second page: main results

For our first system: three relevant quantities are now defined:

Produced Energy: The basic result of our simulation.

Specific production: The produced energy divided by the Nominal power of the array (P_{nom} at STC). This is an indicator of the potential of the system, taking into account irradiance conditions (orientation, site location, meteorological conditions).

Performance ratio: An indicator of the quality of the system itself, independently of the incoming irradiance. We will give its definition below.

Main simulation results				
System Production	Produced Energy	10.99 MWh/year	Specific prod.	1221 kWh/kWp/year
	Performance Ratio PR	87.08 %		

The bottom of the second page contains a table with the main variables, given as monthly values and the overall yearly value. The yearly value can be an average like the temperature, or a sum, like the irradiation or energies. The meaning of the different variables is the following:

GlobHor: Global irradiation in the horizontal plane. This is our meteo input value.

T_{amb}: Ambient (dry-bulb) average temperature. This is also our meteo input value.

GlobInc: Global irradiation in the collector plane, after transposition, but without any optical corrections (often named POA for Plane of Array).

GlobEff: "Effective" global irradiation on the collectors, i.e. after optical losses (far and near shadings, IAM, soiling losses).

E_{Array}: Energy produced by the PV array (input of the inverters).

E_{Grid}: Energy injected into the grid, after inverter and AC wiring losses.

Eff_{ArrR}: PV array efficiency E_{Array} related to the irradiance on the Collector's total area.

Eff_{SysR}: System efficiency E_{Grid} related to the irradiance on the Collector's total area.

**First simulation
Balances and main results**

	GlobHor kWh/m ²	DiffHor kWh/m ²	T_Amb °C	GlobInc kWh/m ²	GlobEff kWh/m ²	EArray MWh	E_Grid MWh	PR ratio
January	32.1	17.94	1.92	49.4	47.7	0.425	0.414	0.932
February	53.9	32.18	3.16	72.7	70.3	0.623	0.610	0.932
March	101.1	50.53	6.67	124.5	120.7	1.036	1.017	0.907
April	133.3	67.46	10.38	147.0	142.3	1.193	1.170	0.885
May	163.8	79.63	15.16	165.3	160.0	1.297	1.272	0.855
June	180.7	73.70	18.90	178.5	173.0	1.370	1.343	0.836
July	183.6	76.30	20.37	186.9	181.0	1.420	1.393	0.828
August	155.8	71.30	19.65	167.4	162.3	1.285	1.261	0.837
September	112.0	53.38	15.29	132.4	128.4	1.046	1.025	0.860
October	68.2	35.47	11.55	89.8	86.9	0.731	0.716	0.885
November	36.5	22.60	5.84	52.0	50.2	0.440	0.429	0.917
December	25.2	17.13	2.75	36.8	35.5	0.315	0.306	0.924
Year	1246.1	597.63	11.02	1402.7	1358.1	11.181	10.957	0.868

The monthly graphs on the second page of the report are given in units called «Normalized Performance Index». These variables have been specified by the "Joint Research Center" JRC (Ispra) for a standardized report of PV system performance, and they are now defined in the international IEC61836 norm. The PVsyst online help contains a full explanation of these values (you can directly access this section of the online help by pressing F1 when you are on this page of the report). In these units the values are expressed in [kW/kWp/day] and contain the following information:

Yr Reference Yield Energy production if the system were always running at "nominal" efficiency, as defined by the array P_{nom} (nameplate value) at STC.

 This is numerically equivalent to the GlobInc value expressed in [kWh/m²/day].

Ya Array yield Energy production of the array

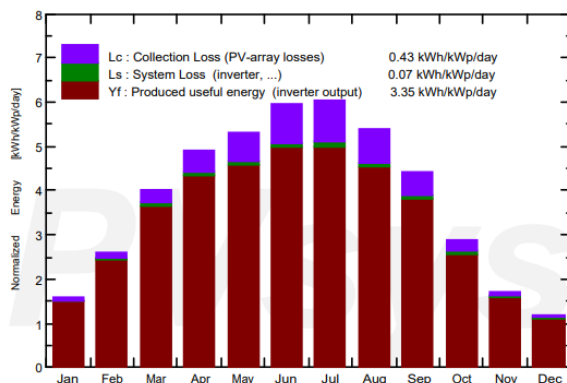
Yf Final System yield Energy to the grid

Lc = Yr – Ya Array capture losses

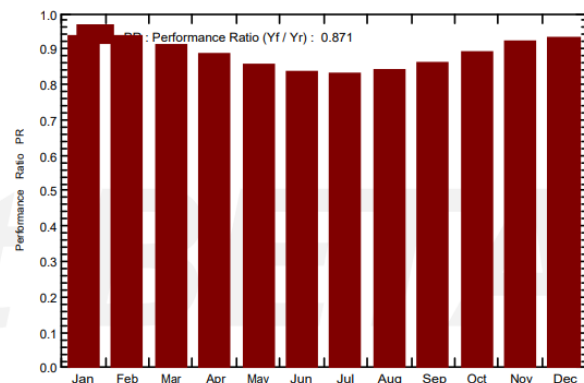
Ls = Ya – Yf System losses

PR = Yf / Yr Performance Ratio = E_Grid / (GlobInc P_{nom}(nameplate))

Normalized productions (per installed kWp): Nominal power 9.00 kWp



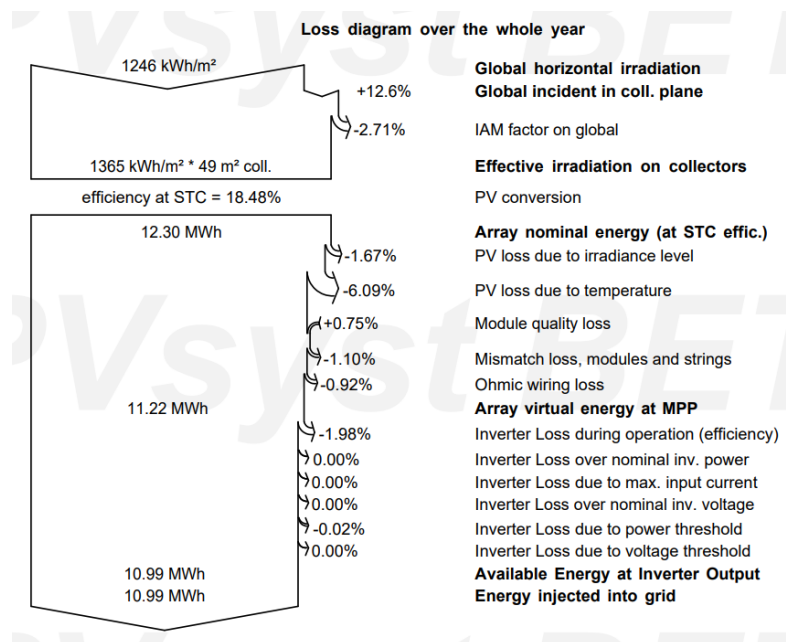
Performance Ratio PR




Third page: arrow loss diagram

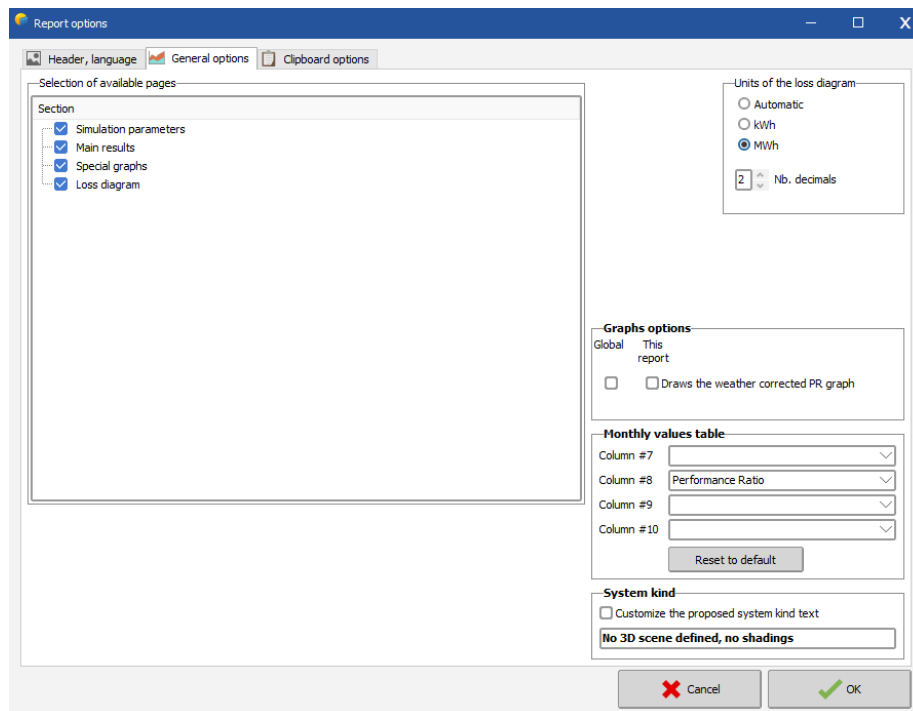
This is the PVsyst way of reporting the system's behavior, with all detailed losses. This diagram is very useful for the analysis of the design choices, and should be used when comparing systems or variants of the same project.

GlobHor	Horizontal irradiation (meteo value): starting point.
GlobInc	After transposition (reference for the calculation of PR, which includes the optical losses).
IAM	The optical losses. When adding further details to a variant, there will be additional arrows for far and near shadings, soiling, etc.
GlobEff · Coll. Area	Energy on the collectors.
EArrNom	Array nominal energy at STC (= GlobEff Effic. nom).
Array losses	Collection losses (irradiance, temperature, mismatch, module quality, wiring, etc.).
EArrMPP	Array available energy at MPP.
Inverter losses	Efficiency and eventual overload loss (all others are usually null).
EOutInv	Available energy at the output of the inverter.
AC losses	Eventual wiring, transformer losses between inverter and injection point, unavailability.
EGrid	Energy injected into the grid.



The report can be sent to a printer or copied to the clipboard. These options are accessible through the Print button .

Here you can select which parts of the report should be printed or copied and define comments that will show up in the header of the report. With the "Settings" button you can customize even more details for the header comments and the clipboard copy resolution.



Saving the simulation

Take the habit to "Save" your different variants for further comparisons. Choose a meaningful title to easily identify your variant in the future. This title will be mentioned on the report (it can also be defined in an earlier step, for example at the time of the simulation).

The first variant will be saved in the file "DEMO_Residential_Geneva_First Simulation.VC0". Later Variants will get the file endings VC1, VC2, etc. If you want to create a new Variant, make sure that you use "Save As" to avoid overwriting your previous variants. To open previous simulations of the project, you just select a variant in the drop-down list.

5- Adding further details to your variant

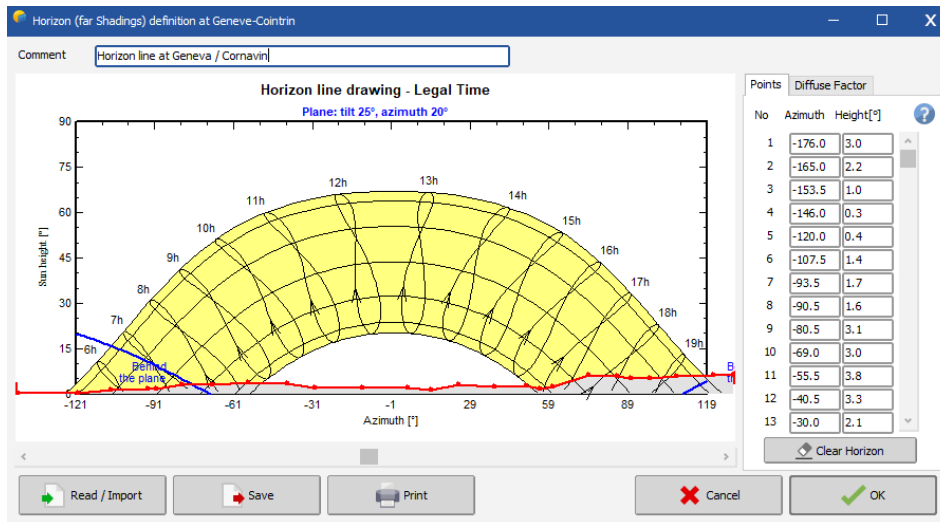
After this first "standard" simulation, you can progressively add the specific details to your project. You are advised to perform and save a new simulation at each step in order to check its effect and pertinence - especially by analyzing the "Loss diagram".

Far shadings, Horizon profile

The horizon profile is only suited for shading objects that are located sufficiently far away from your PV system, so that the shadings may be considered global on your array. This is the case when the distance to the shading object is more than about 10 times the PV system size. The Horizon Profile is a curve that is defined by a set of (Height, Azimuth) points.

The Far Shadings operate in an ON/OFF mode: i.e. at a given time, the sun is or is not present on the field. When the sun is behind the horizon the beam component becomes null. The effect on the diffuse component will be explained below.

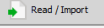
Clicking the "Horizon" button will open a graph of the sun paths for the site of the project.

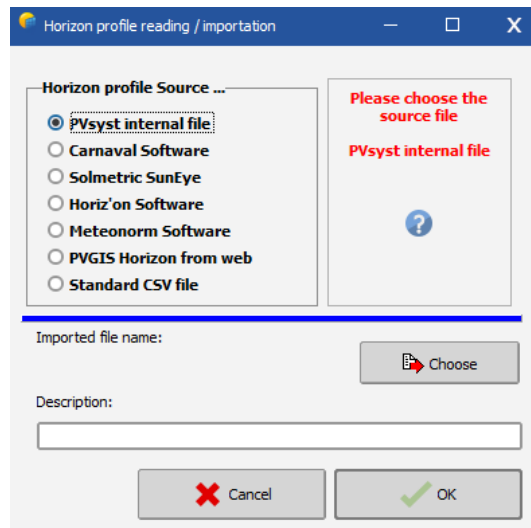


You can either define the horizon line manually. For this the values (Height, Azimuth set of points) have to be recorded on-site using a compass and a clinometer (measuring the height angles), a land surveyor or some specific instrument, photographs, etc. But you can also import a horizon line that has been generated with the “SunEye” device or some dedicated software as explained below.

Defining a horizon line by hand:

You can move any of the red points, by dragging it with the mouse, or define accurately its values in the edit boxes on the right. For creating a new point right-click anywhere. For deleting a point right-click on the point. You can save this horizon as a file for further use in other PVsyst projects.

When you click on the “Read / Import” button  you will get the “Horizon profile reading / importation” dialog. You can either read a horizon line that you have previously saved in PVsyst, or you can import a predefined format from sources external to PVsyst.



Importing Horizon from Solmetric "SunEye" instrument

The "SunEye" records the horizon line using a fisheye camera, and provides the result in several files. You should choose the file called "ObstructionElevation.csv". Do not use the "Sky0x_PVsystem.hor" file! This is an obsolete format, which was created by Solmetrics for the old versions 4.xx of PVsystem.

NB: If near objects are present on the pictures taken by the "SunEye", you should remove them from the data by editing the horizon line after importing it.

Importing Horizon from the "Carnaval" software

"Carnaval" is a georeferenced free software (including altimetry data), which is able to create a horizon line starting from geographical coordinates - Latitude and Longitude – of a site. It works only for locations in France and its neighboring countries.

NB: You should not use the 'near objects' option in this software when creating the far shadings for PVsystem. Carnaval produces a file named "YourProject.masque.txt". You will have to rename this file, removing the ".masque" characters, as PVsystem does not accept file names with 2 dots in them.

Importing Horizon from the «Horiz'ON" software

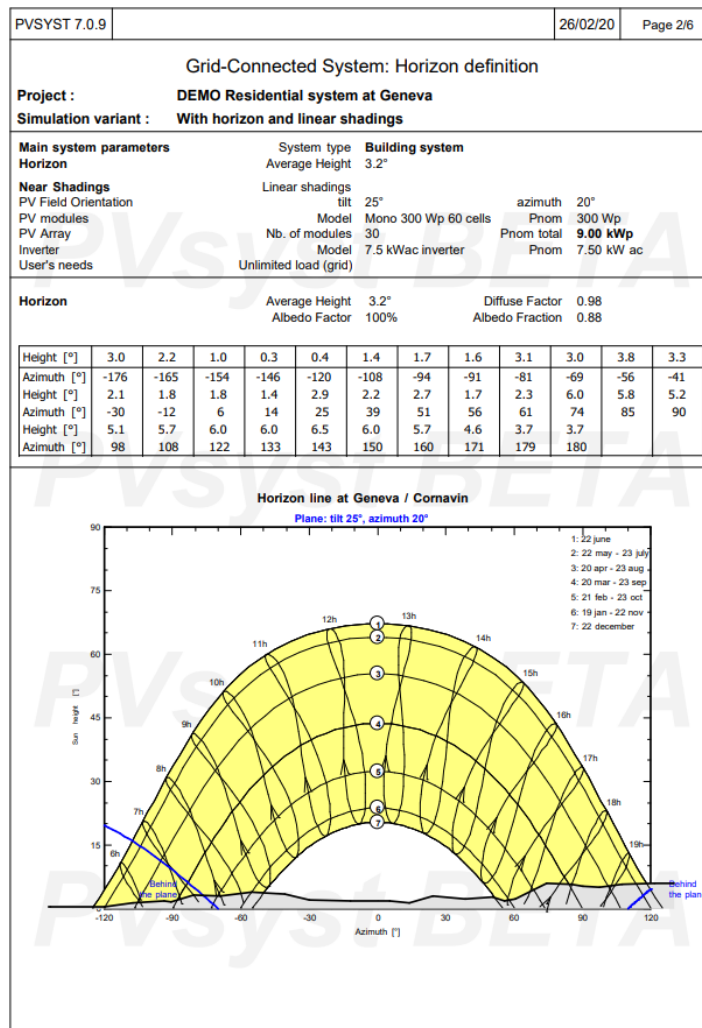
The "Camera Master" tool is a special support for photo cameras, which allows to take a series of pictures in precise horizontal rotation steps (every 20° in azimuth). The software "Horiz'ON" gathers these photographs in a single panorama picture, on which you can draw the horizon line by using the mouse. The software will produce a file format of the horizon line that is directly readable in PVsystem.

NB: When you want to create a horizon line starting from a geographical location (like in Carnaval or Meteonorm), the exact coordinates of your PV system have to be carefully defined. You may determine them using GoogleEarth or with a GPS instrument. Keep in mind that a degree in latitude corresponds to 111 km, a minute to 1850 m and a second to 31 m. For the longitude this is also valid for locations on the equator. As you move away from the equator these values will decrease.

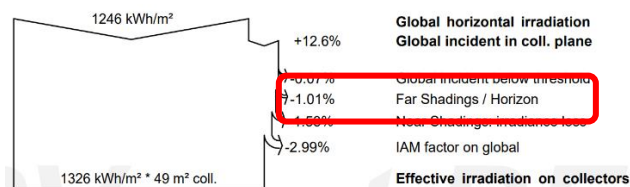
Using the horizon in the simulation

After defining a horizon line, the button in the project dashboard will turn from greyed-out to green. If we now perform again a simulation the shading of the horizon will be taken into account. The report will

now have an additional page. On the second page of the report you will find the horizon definition and the sun graph that includes the far shading effect:

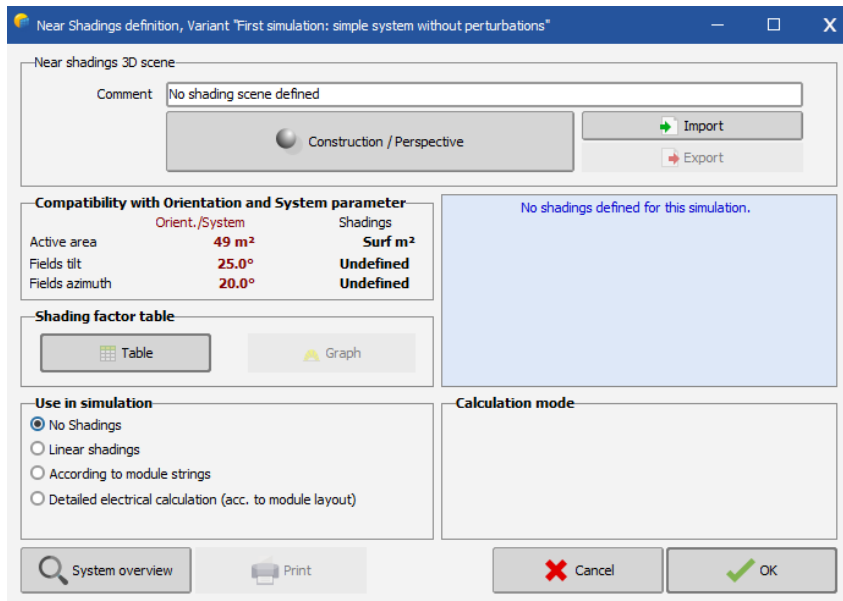


Also the loss diagram on the last page of the report will now include the effect of the far shadings:

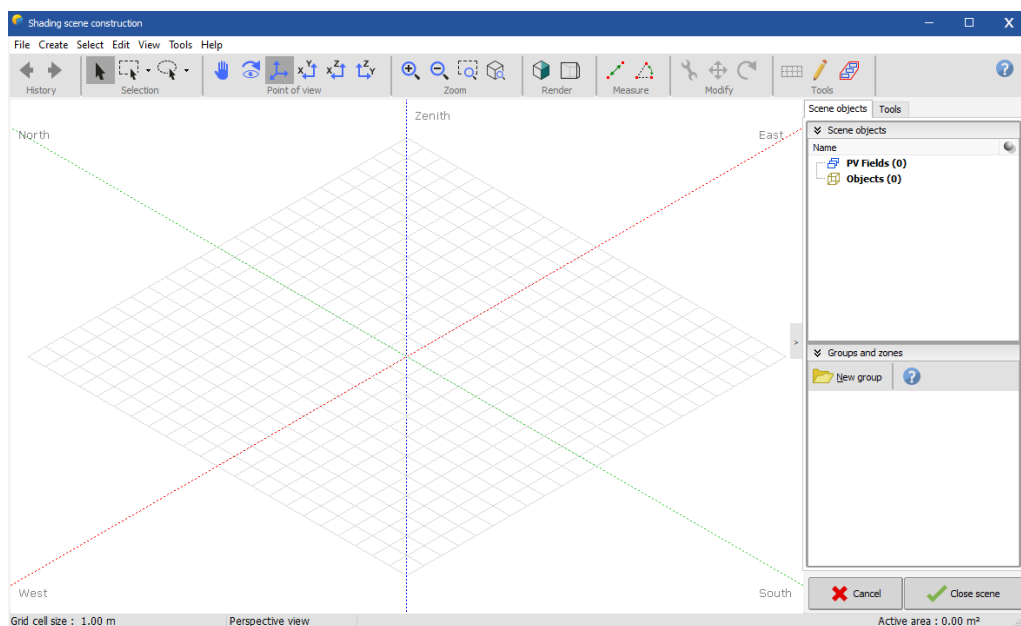


Near shadings, 3D construction

The construction of the near shadings is described in the dedicated chapter “3D Near Shadings Construction”. The near shadings treatment (shading of near objects) requires a full 3D representation of your PV system. This is managed from the following central dialog:



The construction of the 3D scene is performed in a 3D editor, which opens when you click on the button "Construction/Perspective"



If you have near shadings, you should construct your PV installation and its surroundings as a 3D scene (see the dedicated tutorial). The instruments described in the far shadings section (including SunEye) are not useful for this construction. The starting point should be the architect's drawings or anything equivalent, and they should include topological information to get the height of the objects right.

After constructing the 3D representation of the installation, you should perform the simulation in the "linear shadings" mode which takes into account only the irradiance deficit. This will give you a lower bound for the estimation of the shadings effect. Then you repeat the simulation once more in "according to module strings" mode, which also considers electrical effects resulting from the fact that the modules are arranged in groups (strings). The modules in each of these strings are assumed to be

connected in series. This will provide an upper bound for the estimation of the shading losses. For the final report that will be submitted to your customer, you choose an intermediate value for the electrical effect, taking the by-pass diode recovery into account. For this, you have to choose an intermediate fraction for the electrical effect, which will depend on your system geometry. There is no well-established value that would generally cover all possible situations. A rough estimate would be 60 to 80% (Higher for regular shading patterns like sheds).

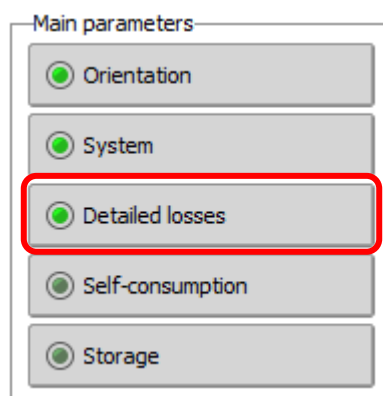
NB: The near shading loss does not cumulate with the far shadings. When the sun is behind the horizon, the beam component is null, and therefore there is no near shading contribution.

Final layout of the system

In PVsyst there is no direct link between the definition of the system (PV panels and inverters), and the definition of your 3D scene. But when you do modifications in either one of these parts, the program will check if they remain compatible, and issue warning or error messages if it detects any incoherence. Namely it will require that the plane orientations are identical in the two parts, and that you have defined a sufficiently large sensitive area in the 3D scene for installing the PV modules defined in the system. PVsyst will perform this test only on the total areas, it will not check the real physical (geometrical) compatibility. You need to check the arrangement of your modules on the sensitive area in the 3D scene and if you do not find a possible arrangement, you have to modify the system definitions (number of modules in series and parallel) or the 3D scene in order to make these two parts match. The "Module layout" section will help you in finding a consistent arrangement. This part of PVsyst will be described in a different tutorial. For the present example we only need to make sure that the PV sensitive area in the 3D scene is at least as large as the total PV module area from the system definitions. This will allow to perform the simulation.

Detailed losses

Finally there are several parameters which are initialized by PVsyst to reasonable default values for the first simulations, but that you should modify according to the specificities of your system to add more accuracy to the simulation. These parameters are accessed with the button "Detailed losses" in the project dashboard.

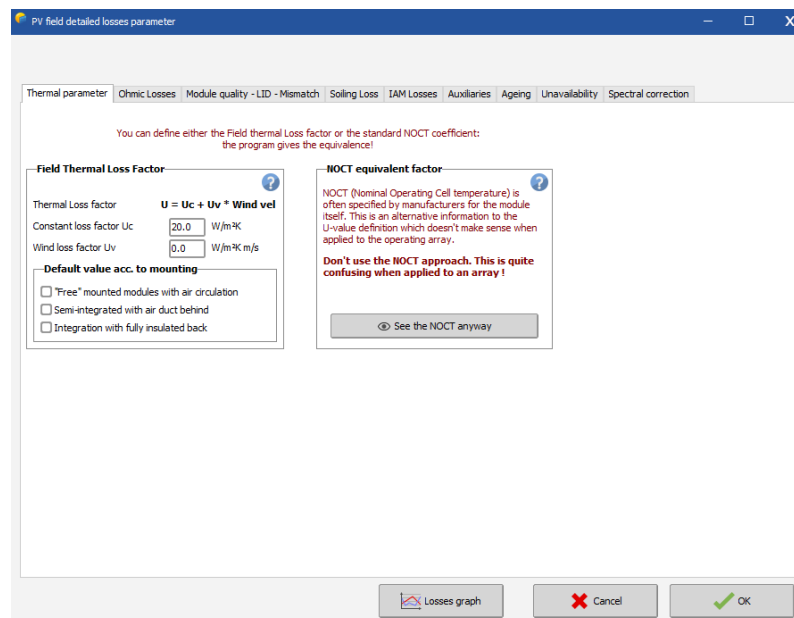


The Dialog “PV field detailed losses parameter” will pop up. It contains the following nine tabs:

- Thermal Parameters
- Ohmic Losses
- Module Quality – LID – Mismatch
- Soiling Loss
- IAM Losses
- Auxiliaries
- Ageing
- Unavailability
- Spectral correction

In the following we will go through all of them and give a brief explanation of the different parameters and options.

Thermal parameters



The thermal behavior of the array is computed in each simulation step, by a thermal balance. This establishes the instantaneous operating temperature, that is used by the PV modules modelling.

The thermal balance involves the "Heat loss factor" $U = U_c + U_v \cdot \text{WindSpeed}$ [W/m²·K]. In practice we advise not to use the wind dependency, as the wind speed is usually not well defined in the meteo data, and the parameter U_v is not well known. Therefore we put $U_v = 0$ and include an average wind effect in the constant term.

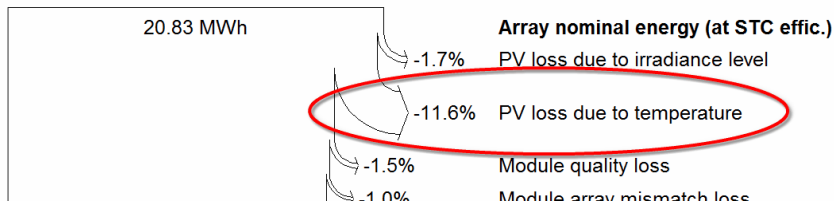
According to our own measurements on several systems, PVsyst proposes:

- $U_c = 29$ W/m²K for complete free air circulation around the collectors (free-standing collectors).
- $U_c = 20$ W/m²K for semi-integrated modules with an air duct on the back.
- $U_c = 15$ W/m²K for integration (back insulated), as only one surface participates to the convection/radiation cooling.

- There are no well-established values for intermediate situations with back air circulation. Our measurement on quasi-horizontal modules on a steel roof, 8 cm spacing and not joint collectors, gave 18 W/m²K;

NB: up to PVsyst version 5.1, the default value for U_c was 29 W/m² (free standing). From version 6 onwards the default is set to 20 W/m² since nowadays more and more installations are being built in an integrated way.

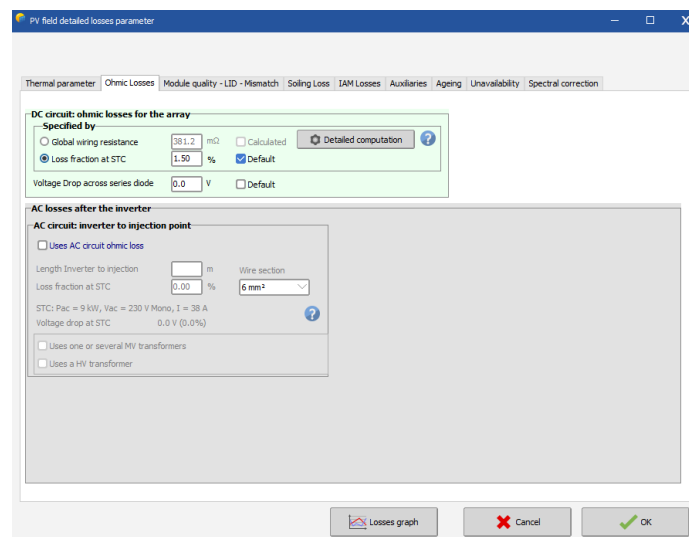
The thermal loss effect will show up on the array loss diagram in the final report.



The ‘Standard NOCT factor’ (Nominal Operating Cell Temperature) is the temperature that the module reaches in equilibrium for very specific surrounding and operation conditions. It can often be found together with the module specifications supplied by the manufacturers. It has no real relevance for the simulation, because the conditions for which it is specified are far away from a realistic module operation. PVsyst only mentions it for completeness and for comparison with the manufacturer’s specifications.

Wiring Losses

The wiring ohmic resistance induces losses ($R \cdot I^2$) between the power available from the modules and that at the terminals of the array. These losses can be characterized by just one parameter R defined for the global array.



The program proposes a default global wiring loss fraction of 1.5% with respect to the STC running conditions. But you have a specific tool for establishing and optimizing the ohmic losses (press "Detailed

Calculation" button). This tool asks for the average length of wires for the string loops, and between the intermediate junction boxes and the inverter, and helps the determination of the wire sections.

NB: remember that the wiring loss behaves as the square of the current. Therefore operating at half power (500 W/m²) will lead to only a quarter of the relative loss. The effective loss during a given period will be given as a simulation result and shown on the loss diagram. It is usually of the order of 50-60% of the above specified relative loss when operation at MPP.

It is also possible to include losses between the output of the inverter and the injection point (energy counter). You have just to define the distance and the loss will also appear in the loss diagram.

AC circuit: inverter to injection point

Uses AC circuit ohmic loss

Length Inverter to injection m Wire section

Loss fraction at STC %

STC: Pac = 9 kW, Vac = 230 V Mono, I = 38 A ?

Voltage drop at STC 2.4 V (1.0%)

Uses one or several MV transformers

Uses a HV transformer

In addition there is the option to include the losses due to an external transformer. If you select this option, you will get two radio buttons in the "AC circuit" frame, where you select if the AC losses to be accounted for are between the inverter and the transformer, or between the transformer and the injection point.

AC losses after the inverter

AC Wire loss Inverter to transfo

Uses AC circuit ohmic loss

Length Inverter to Transformer m Wire section

Loss fraction at STC %

STC: Pac = 9 kW, Vac = 230 V Mono, I = 38 A ?

Voltage drop at STC 2.4 V (1.0%)

Uses one or several MV transformers

Uses a HV transformer

Medium Voltage external transformer ?

MV Transformer(s), full system

Number of MV transfos night disconnect

Generic values

Reference Pac(STC) **8.8 kW**

Iron loss (constant value) % kW default

Copper (resistive) loss % at STC default

Transfo equivalent resistance 3 x 59.82 mΩ

Transformer from Datasheets

Uses datasheets data

Nominal power kVA

Iron losses (no load loss) kVA

Copper (resistive) loss at PNom kVA

Global loss at PNom kVA

Global efficiency at PNom %

Medium Voltage line

MV line voltage kV

Length MV Transfo to injection m Wire section

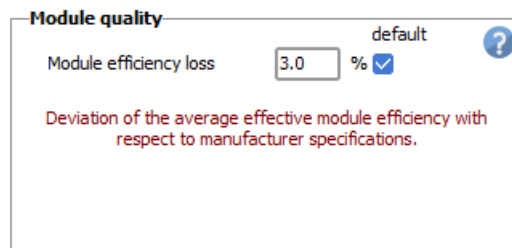
Loss fraction at STC %

STC: Pac = 9 kW, Vac = 20.0 V Mono, I = 0.4 A

Voltage drop at STC 0.4 V (0.00%)

Module quality loss

The aim of this parameter is to reflect the confidence that you put in the matching of your real module set performance, with respect to the manufacturer's specification. The default PVsyst value is half the lower tolerance of the modules.

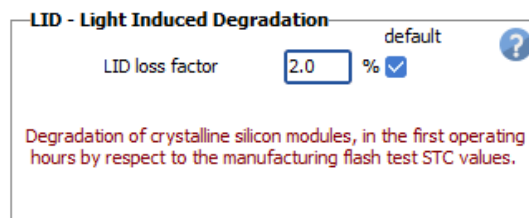


Module quality default ?
Module efficiency loss 3.0 % ✓
Deviation of the average effective module efficiency with respect to manufacturer specifications.

The value that is specified in this field might not be exactly the same as the one shown in the "Array loss diagram". The reason for this is, that this parameter is defined with respect to the Standard Test Conditions (STC) while the value in the diagram is given with respect to the previous energy.

LID – Light Induced Degradation

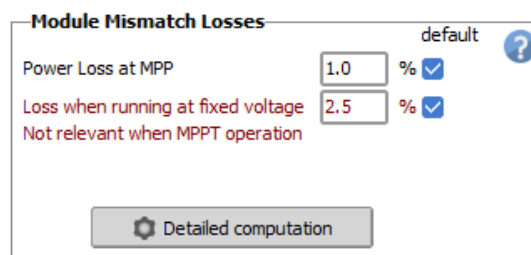
The light induces degradation happens in the first few hours of module operation. Typical values are around 2%, but you can define a different value in this field.



LID - Light Induced Degradation default ?
LID loss factor 2.0 % ✓
Degradation of crystalline silicon modules, in the first operating hours by respect to the manufacturing flash test STC values.

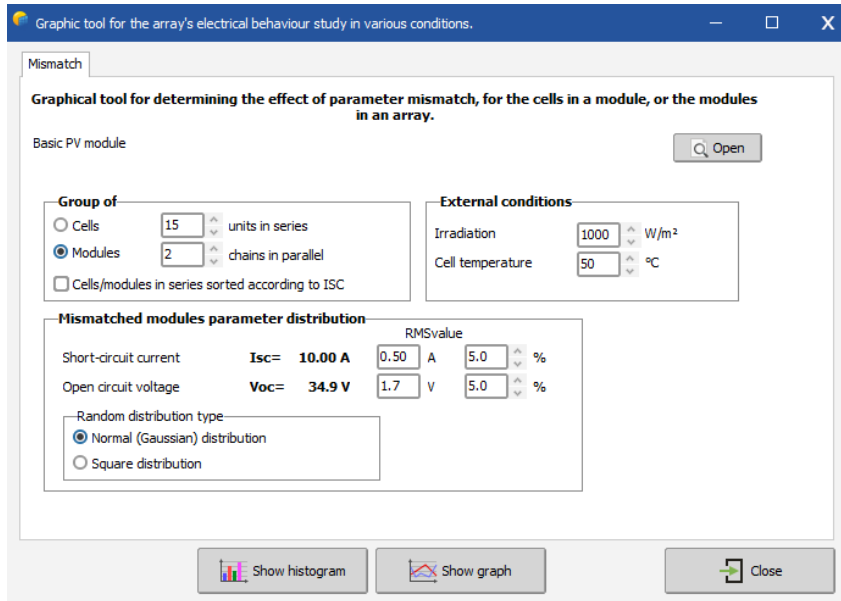
Mismatch loss

Losses due to "mismatch" are related to the fact that the modules in an array do not have exactly the same I/V characteristics. In a string of PV modules, the worst module drives the string's current.



Module Mismatch Losses default ?
Power Loss at MPP 1.0 % ✓
Loss when running at fixed voltage 2.5 % ✓
Not relevant when MPPT operation
Detailed computation

The button "Detailed computation" helps to understand this phenomenon and gives indications on the loss parameter to be set for the simulation, according to your estimation of the inhomogeneity of the set of modules.

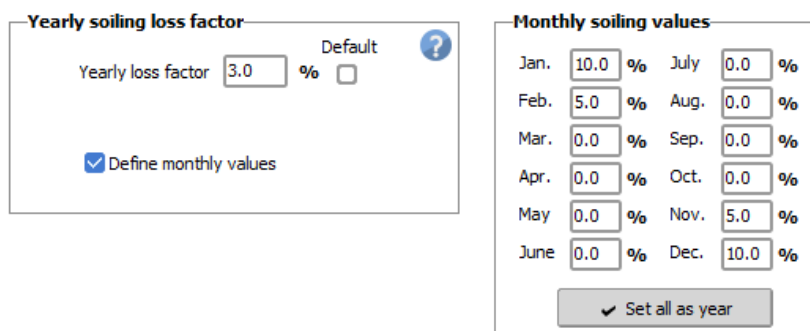


This parameter acts as a constant loss during the simulation. It is lower for thin film modules. It can become almost zero if the modules are well sorted according to their real performance (flash-test results provided by the manufacturer).

NB: There is probably a correlation between these last two parameters. The Module quality loss is rather related to the average of the module's distribution, while the mismatch refers to its width.

Soiling loss

According to our experience, the soiling effect is almost negligible in temperate-climate residential situations.



It may become significant in some industrial environments (for example near railway lines), or in desert climates. The soiling loss can be defined individually for each month to consider periodical cleaning or rainy periods.

This parameter may also be used for describing the effect of snow covering the panels (for example put 50% in winter months with 15 days of snow coverage).

Auxiliaries

The auxiliaries consumption is the energy used for managing the system. This may be fans, air conditioning, electronic devices, lights, or any other energy consumption which must be deducted from the generated PV energy that is injected into the grid.

Auxiliaries energy losses ?

Auxiliaries consumption defined

Auxiliaries during operation (day)

Continuous auxiliary loss (fans, etc.)	<input type="text" value="100"/>	W
... from inverter output power threshold	<input type="text" value="0.8"/>	kW
Proportional to the inverter output power	<input type="text" value="0.0"/>	W/kW
... from inverter output power threshold	<input type="text" value="0.0"/>	kW

Night auxiliaries losses

Night auxiliaries consumption excluding inverter night loss :	<input type="text" value="0.04"/>	kW
--	-----------------------------------	----

The auxiliary energy may be fans, air conditioning, monitoring or other electronics, lighting,, or any other energy which should be subtracted from the energy sold to the grid.

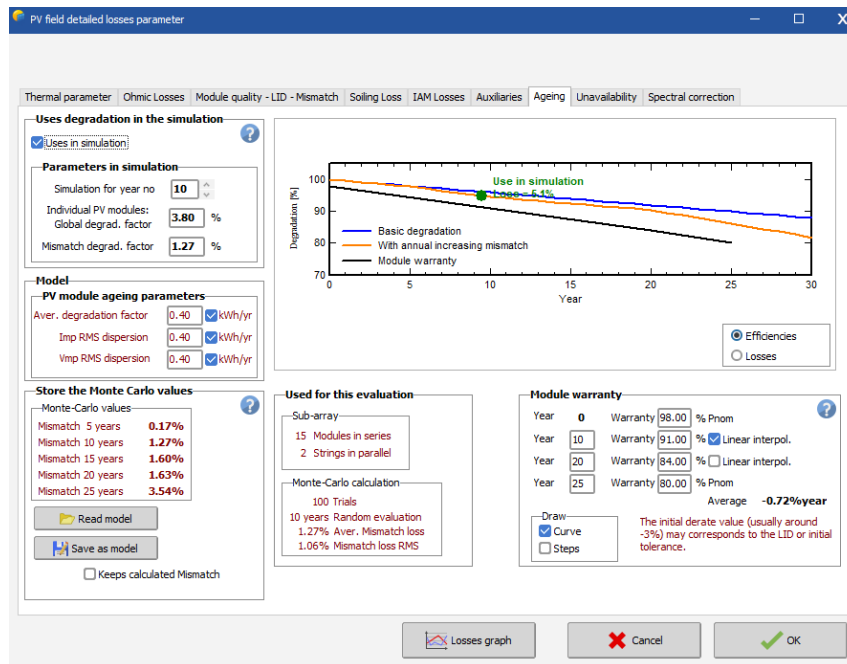
Aging

People often use the Manufacturer's warranty as loss reference when designing PV systems, which is usually a loss of efficiency of around 20% after 25 years.

However, the Manufacturer's warranty should be understood as a lower limit for any individual PV module.

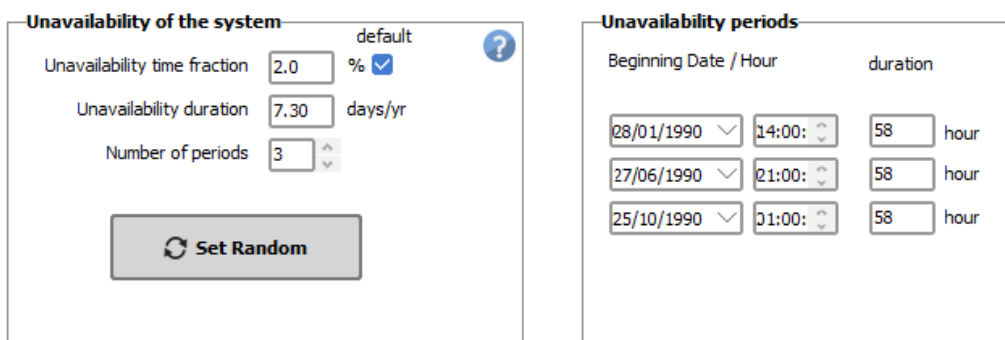
In this tool we define an average degradation rate (for a set of modules). This loss value may be much lower than this degradation limit. Some experimental studies mention degradation rates of the order of -0.3%/year measured as an average on several modules (and measured with very old modules

manufactured in the years 80-90, with old technologies). Long-term degradation rate measurements are relatively scarce.



Unavailability of the System

It is sometimes useful to foresee system failures or maintenance stops in the production expectations. You can define system unavailability as a fraction of time, or a number of days. As this is usually unpredictable, you have the possibility to define specific periods of unavailability of the system, and also to generate these periods in a random way. The effective energy loss is of course depending on the season and the weather during the unavailability periods. Therefore the unavailability loss has only a statistical meaning



Spectral correction

The spectral correction takes into account the changes in the solar spectrum due to scattering and absorption in the atmosphere. These changes depend on the water content in the atmosphere, the aerosols and the traveling distance of the light, expressed in Air Mass (AM). There are several models implemented in PVsyst to describe the spectral correction:

- 1.The CREST model that is used for amorphous silicon modules. This correction is applied automatically.
- 2.The spectral correction for PV modules in the Sandia database. This correction is applied automatically.
- 3.The FirstSolar spectral correction model that is disabled by default, and can be turned on by the user.

Use spectral correction in simulation

FirstSolar model

According to PV module technology

C0: Coefficient Set:

C1:

C2:

C3:

C4:

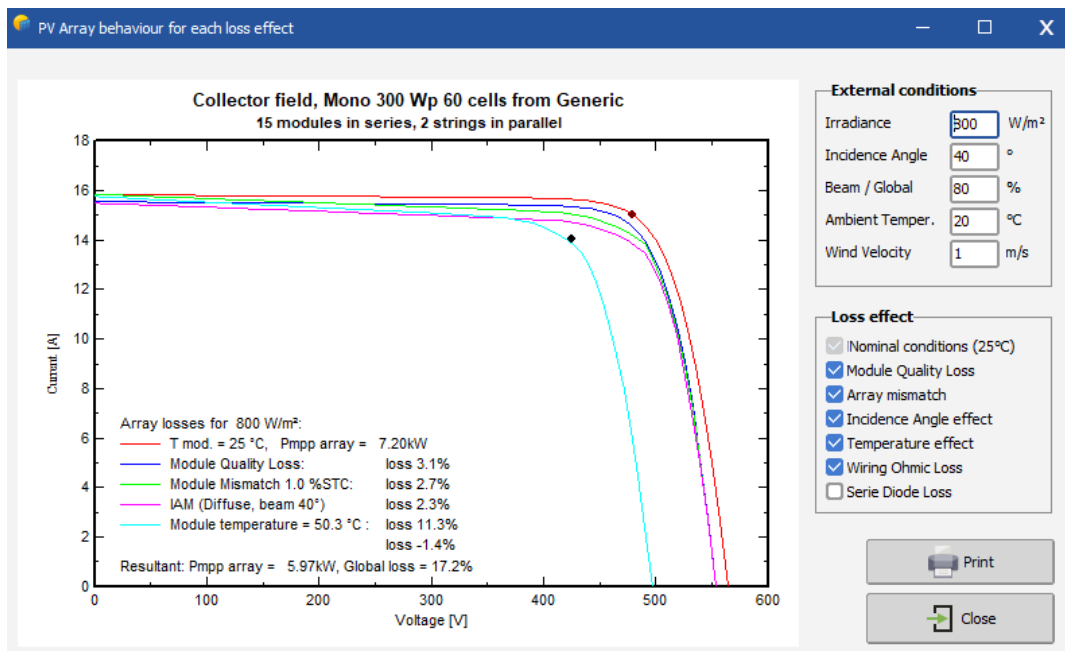
C5:

Meteo input: Precipitable water is not available in the Meteo variables

PV modules: PV module model: Mono 300 Wp 60 cells

Losses graph

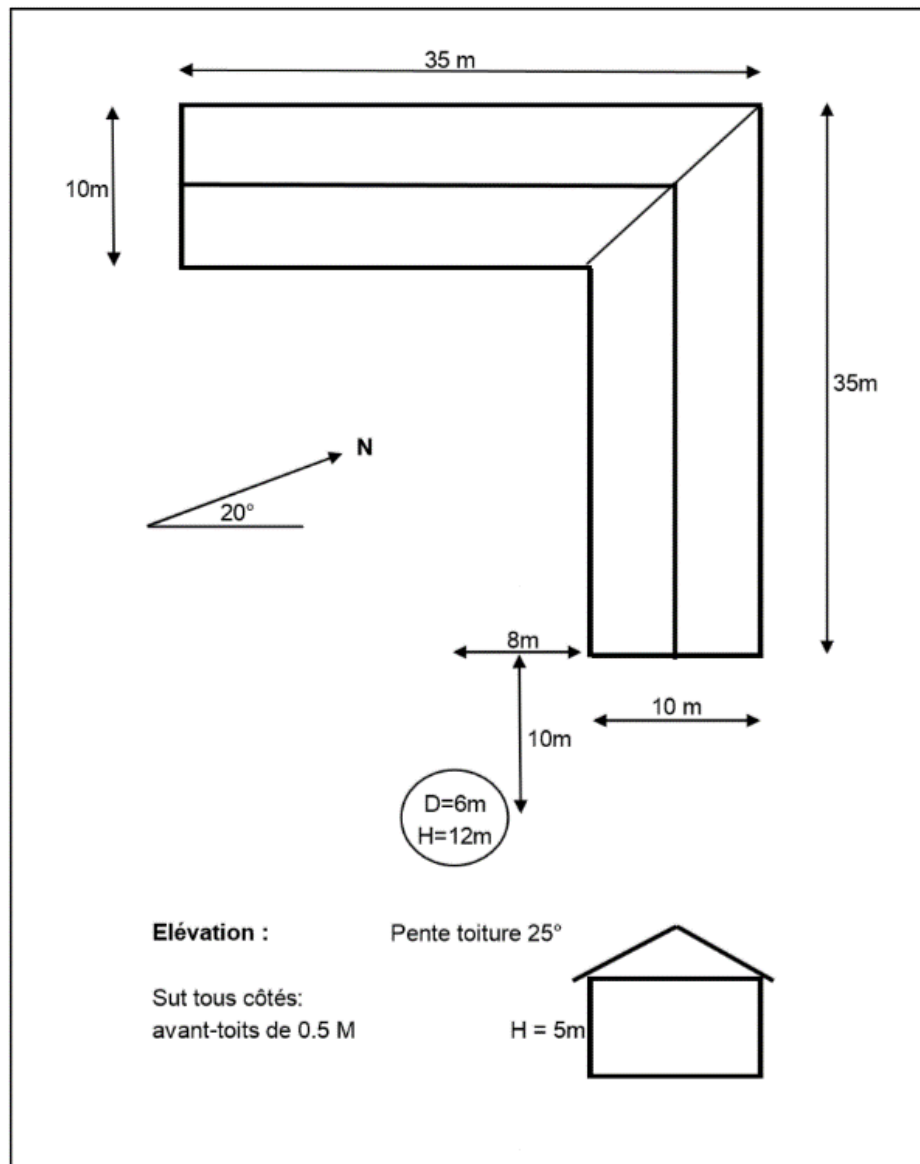
To visualize the impact that the losses have on the I/V-behavior of the array, you click on “Losses Graph” to get to the window “PV Array behavior for each loss effect”. In the top right field you can define the running conditions of the array. From the field below you select the kind of loss you want to display. The red curve gives the nominal conditions, which represent the upper limit of the system performance. For each selected loss you will get a curve in a different color.



Part 2: 3D Near Shadings Construction Basics

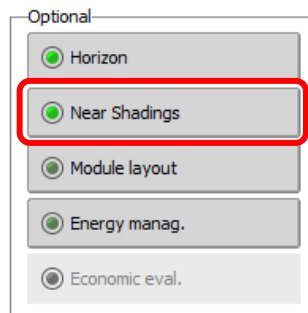
The construction of the near shadings are a part of PVsyst that requires some time and exercise to be fully mastered and take advantage of all available options and features. Therefore we present here a complete example as an exercise to explain the main steps, and give tips and advices for an easier use of this tool.

For the present example, we will create the farm that is used in the "DEMO Geneva" project that is distributed with every PVsyst installation. The starting point for the tutorial will be the following sketch:

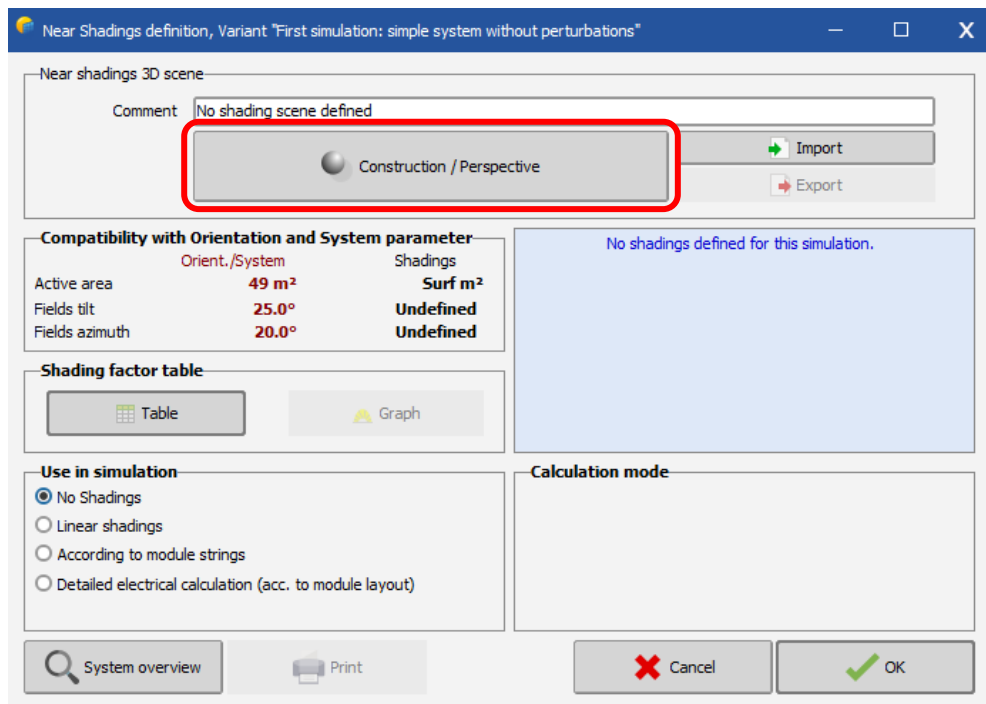


1- Defining the 3D scene:

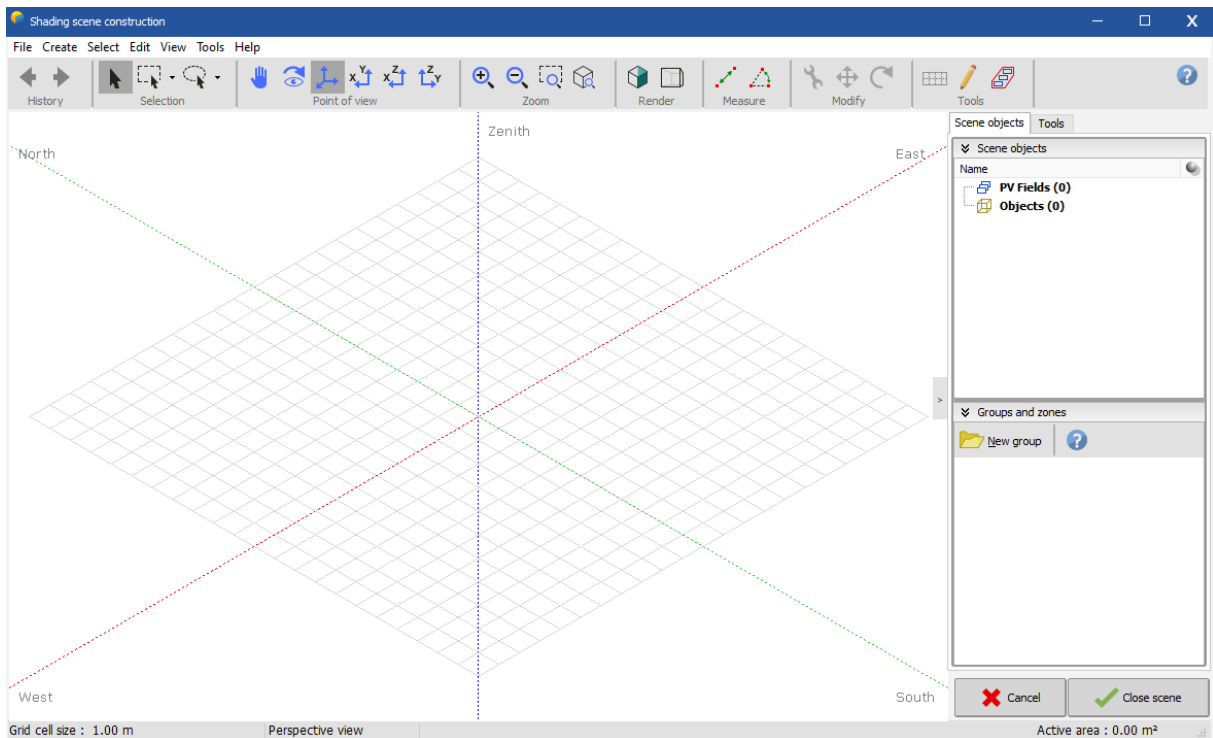
In the "Project Design" window click on the button "Near Shadings"



The "Near Shadings definition" dialog will open, and here you click on "Construction/Perspective".



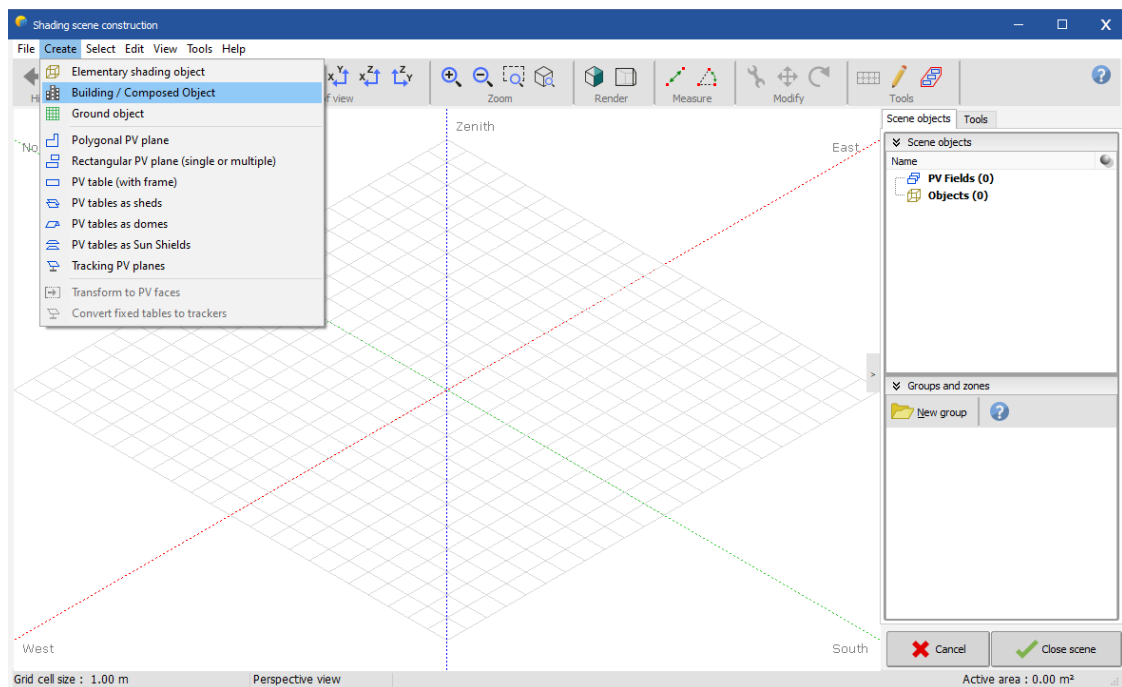
You obtain the main 3D window where you will construct the "scene".



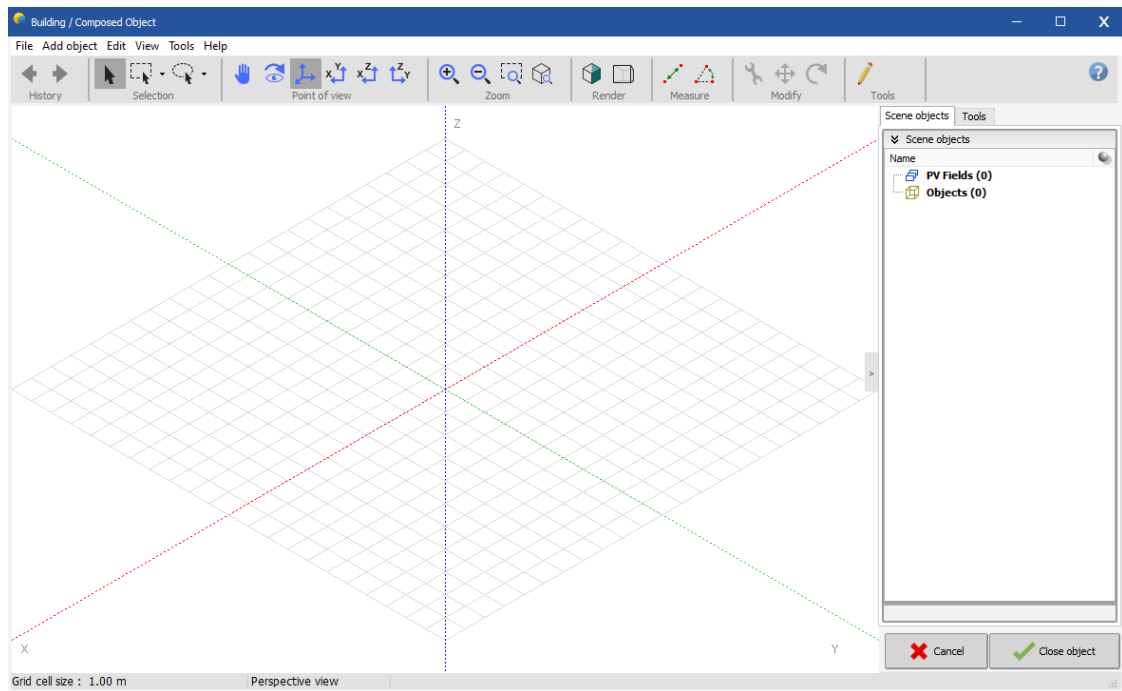
Constructing a building.

The building in our example will be an assembly of elementary objects that will be grouped afterwards and used as one single object in the main 3D scene.

From the menu, choose "Create" - "Building / Composed object"

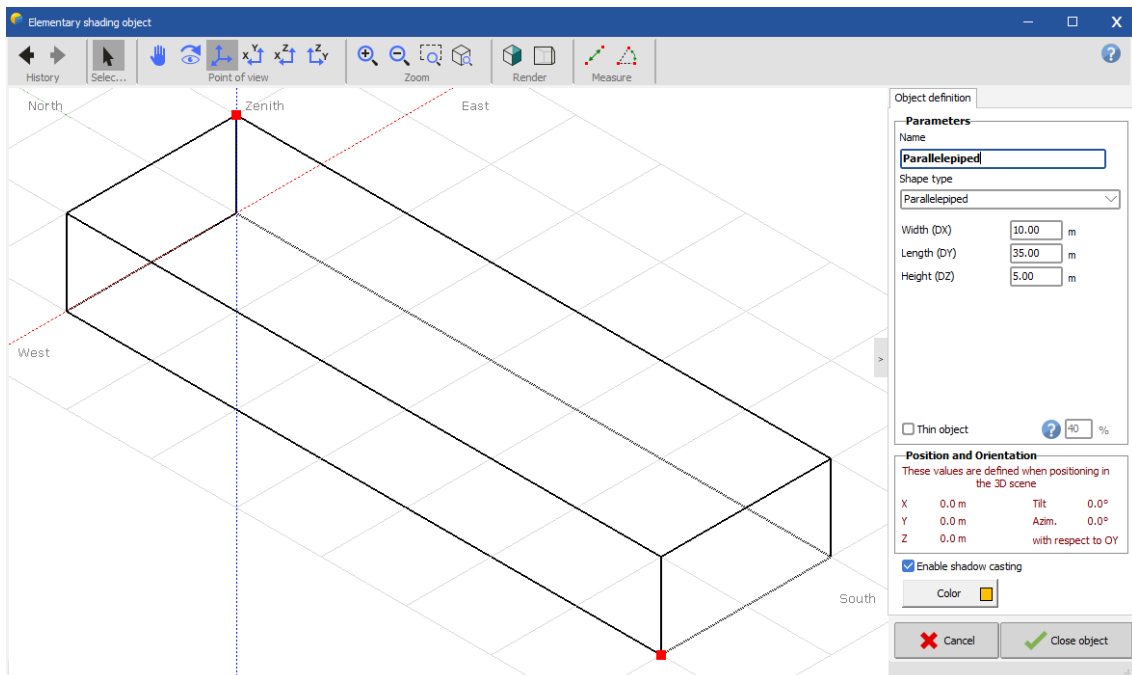


This will open a secondary 3D window in the reference coordinate system of the new building object.



- From the menu, choose "Add Object". It will open a new window where you can choose the type of your object and its properties.

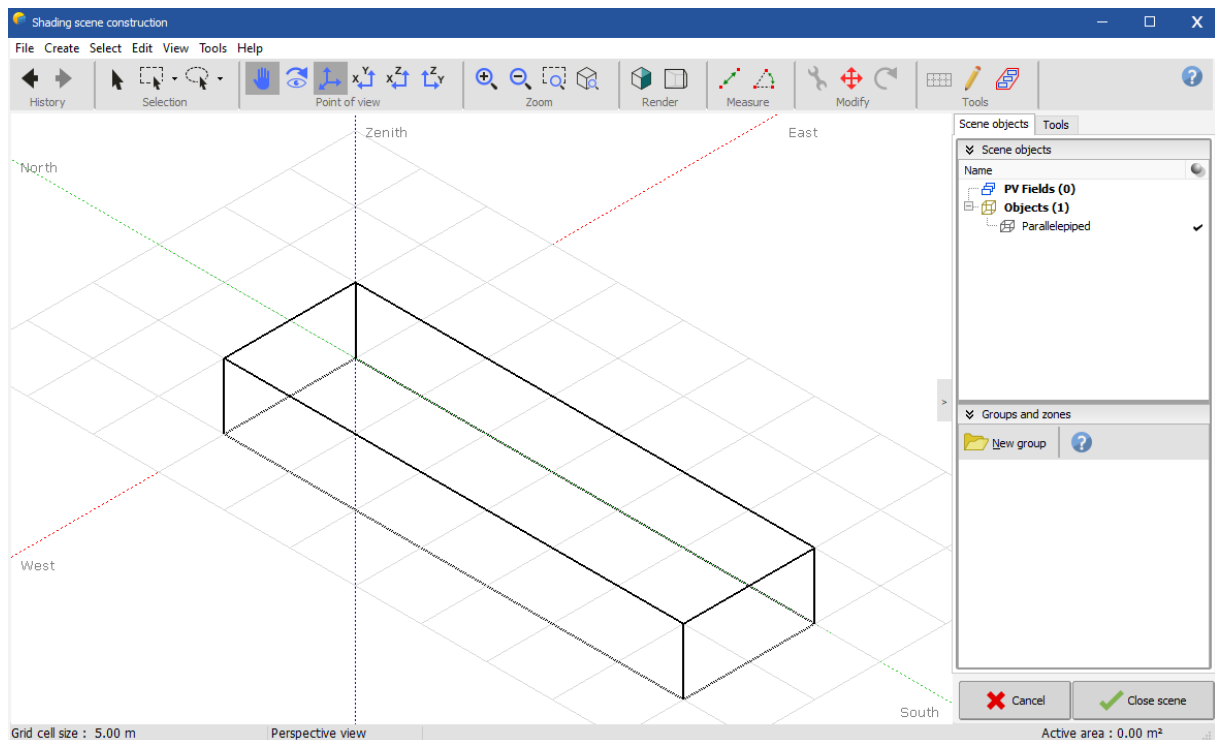
Here choose "Parallelepiped" and define the sizes (Width = 10m, Length = 35m, Height = 5m).



- Click "Close", this will place the parallelepiped in the coordinate system of the buildings' object
From the menu, choose again "Add Object".

Now choose "Parallelepiped" and define the sizes of the second wing of the farm (Width = 10m, Length = 25m, Height = 5m).


Click "Close", this will place the parallelepiped in the coordinate system of the buildings' object, again positioned at the origin.

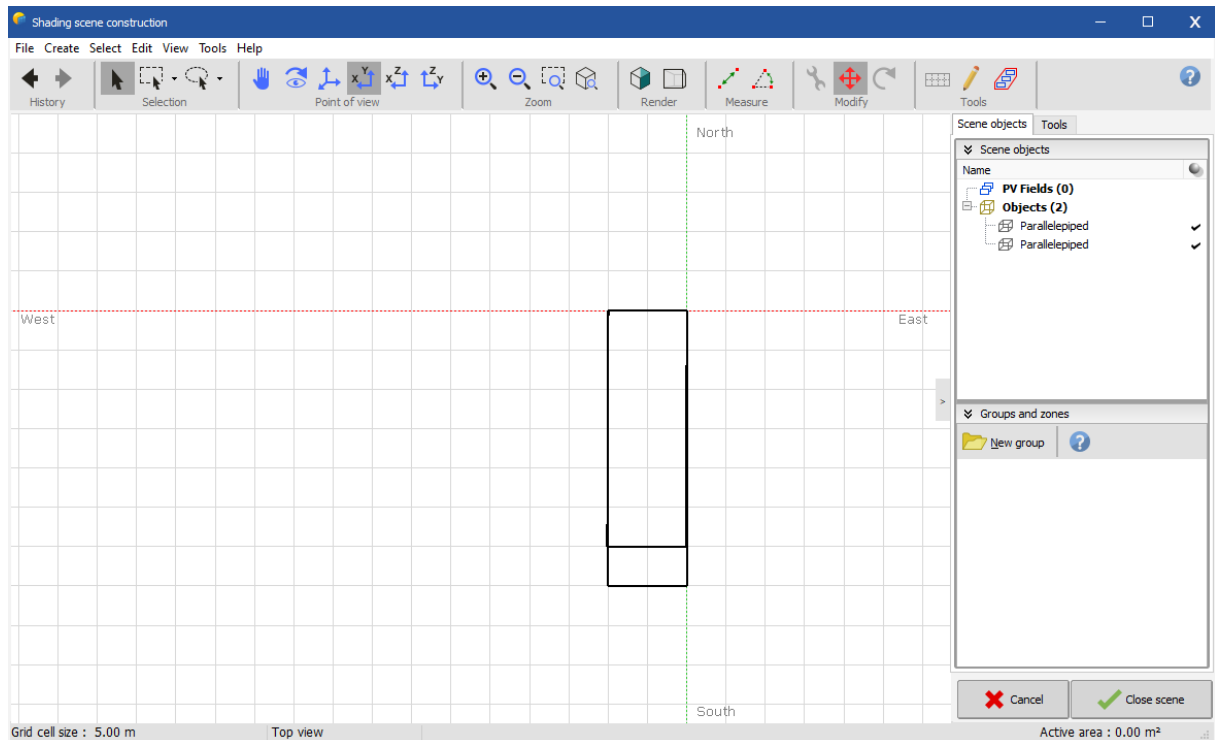



Positioning in the 3D scene

You have now to position this second wing inside the buildings' object.

Please note that for selecting an object, you have to click on its borders (remember: the objects don't "know" their interior!). The selected object becomes carmine red.

Click the "Top View" button  (the five buttons top left are for the positioning of the observer).

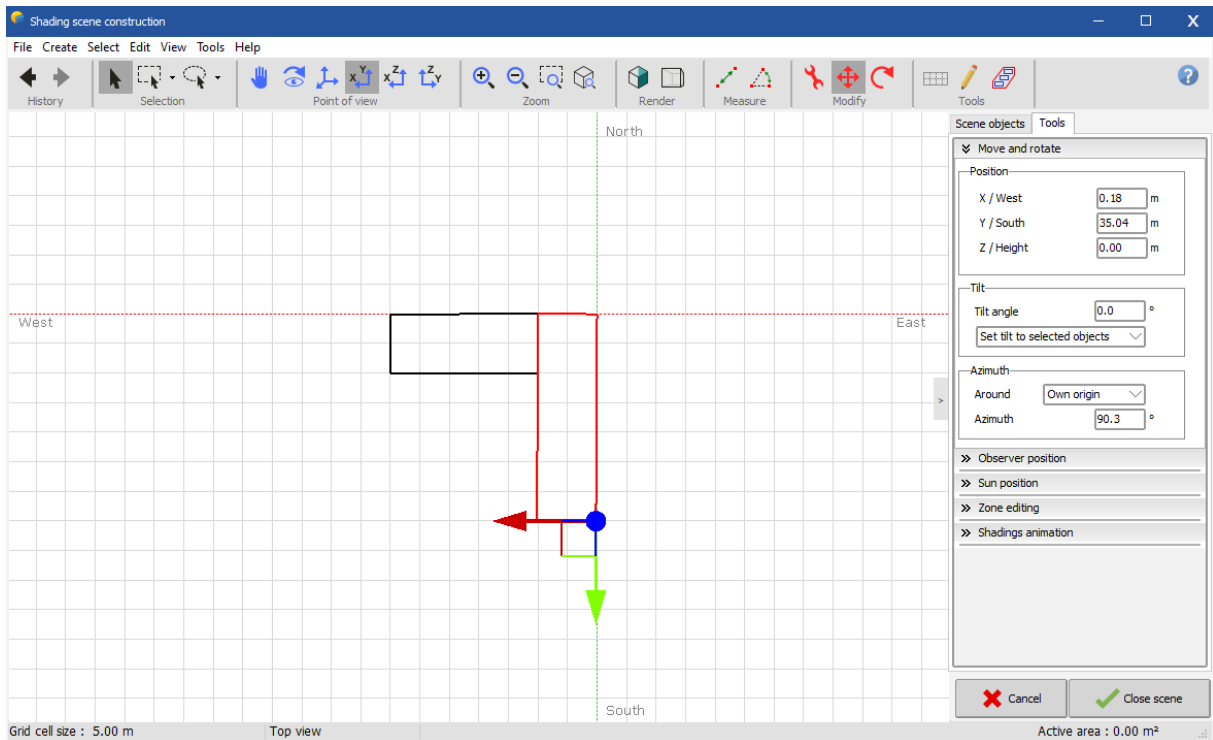


You can zoom in or out with the two "Zoom" buttons .

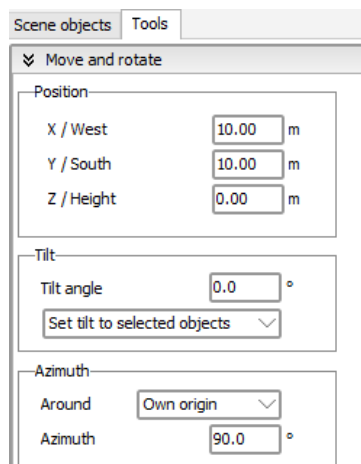
You can also re-center the scene, by clicking anywhere on the scene - but not on an object - and drag the scene's plane.

Click on the positioning tool button  to toggle the "Object positioning" panel.

Now, you can click and drag the red point and displace the selected object with the mouse, and the violet point for rotating it. Move and rotate the object coarsely to its place as second wing, perpendicular to the first parallelepiped.

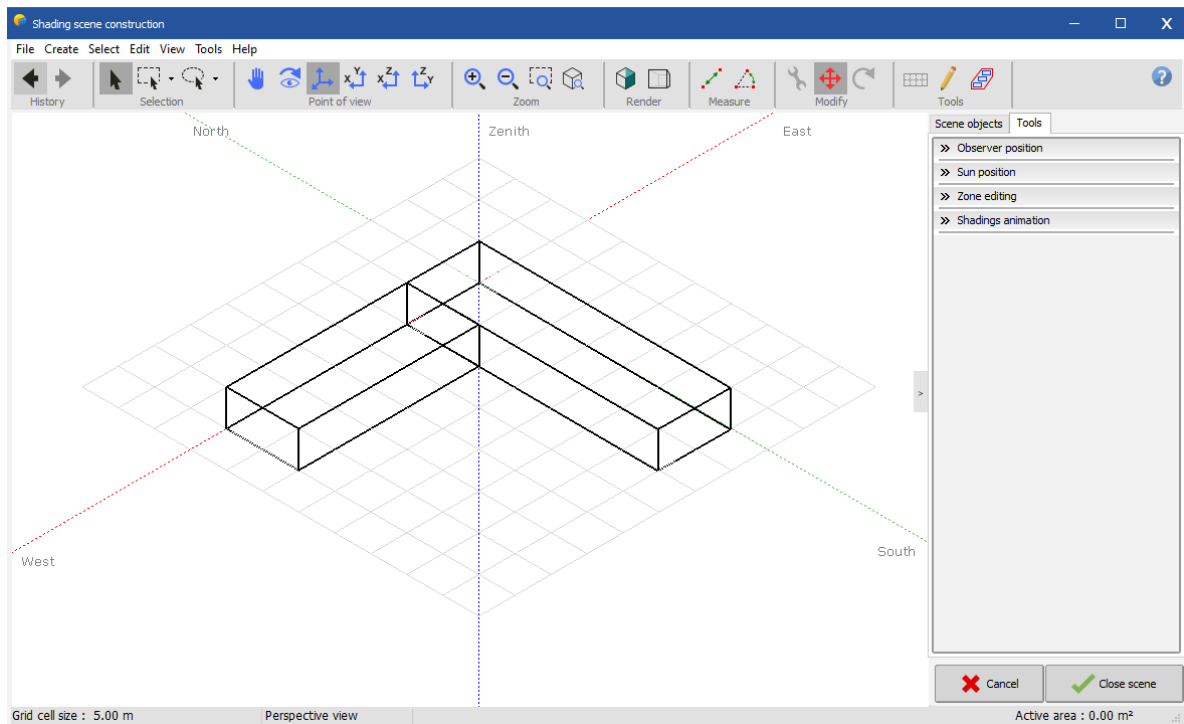


The mouse will not allow you to get precise positioning. But after the object has been placed coarsely, the “Object Positioning” dialog will display the approximate displacement and rotation, and now you can finely adjust the exact values according to the drawing. In our case you will put X = 10.00m, Y = 10.00m, and don't forget Azimuth = 90.0°



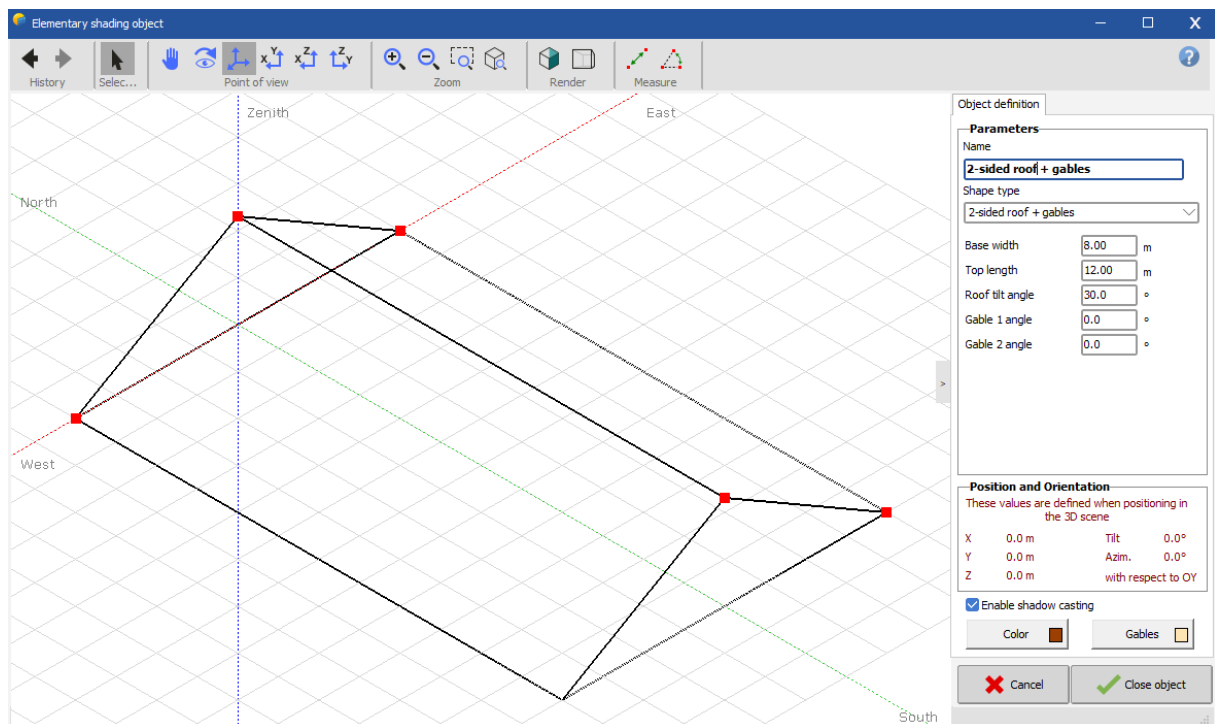
NB: Avoid the interpenetration of objects. This often creates problems for the calculation of the shades.

If you click on the 'Standard Perspective' button  or press F2, the building should now look like this:

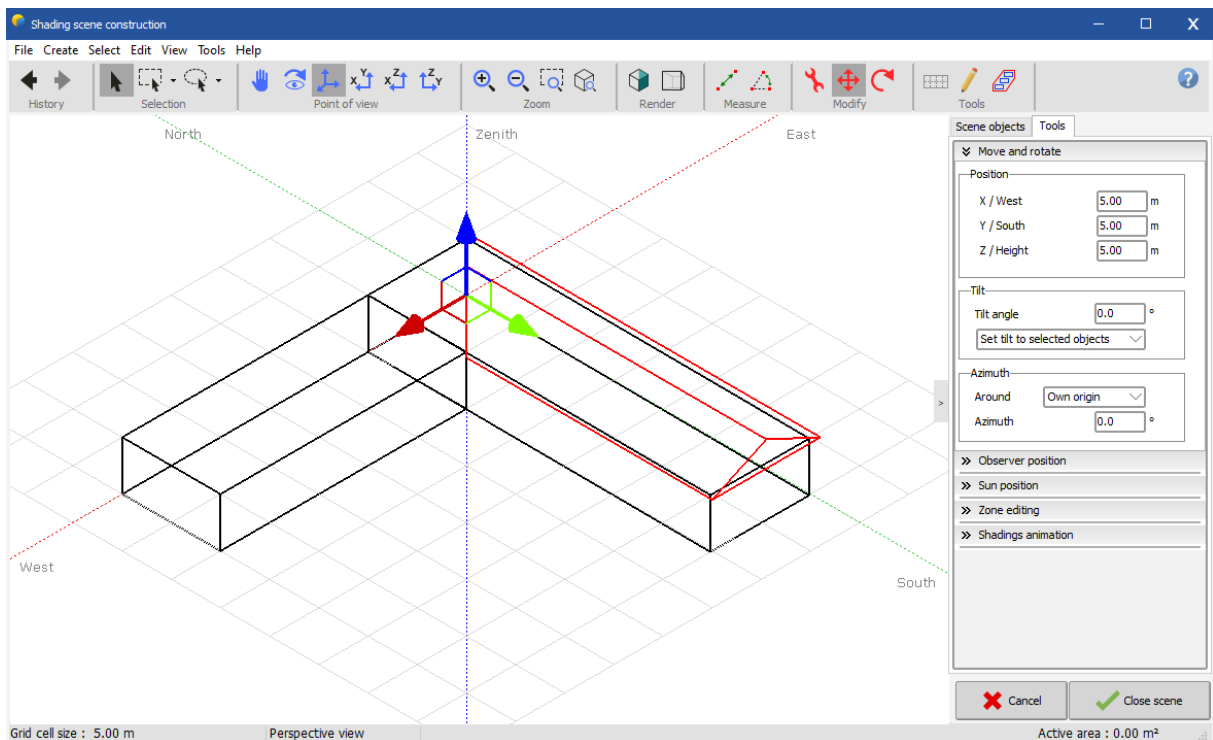


Adding the roof.

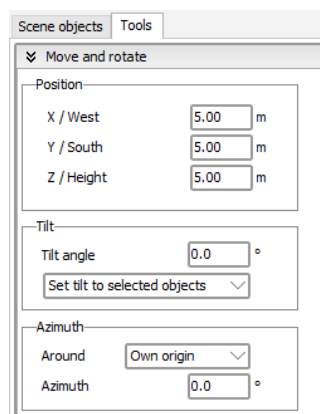
- Click on the menu "Add Object" and choose "Two-sided roof + Gables" in the new window.



- Define the sizes: "Base width" = 11m, "Top length" = 30.5 m (for eaves), "Roof tilt" = 25°, and "Gable 1 angle" = -45° and click "Close"



- This will put the roof in the buildings' scene. First position it with the mouse and then supply the exact values as before (X = 5m, Y = 5m, and Z = 5m, building height).

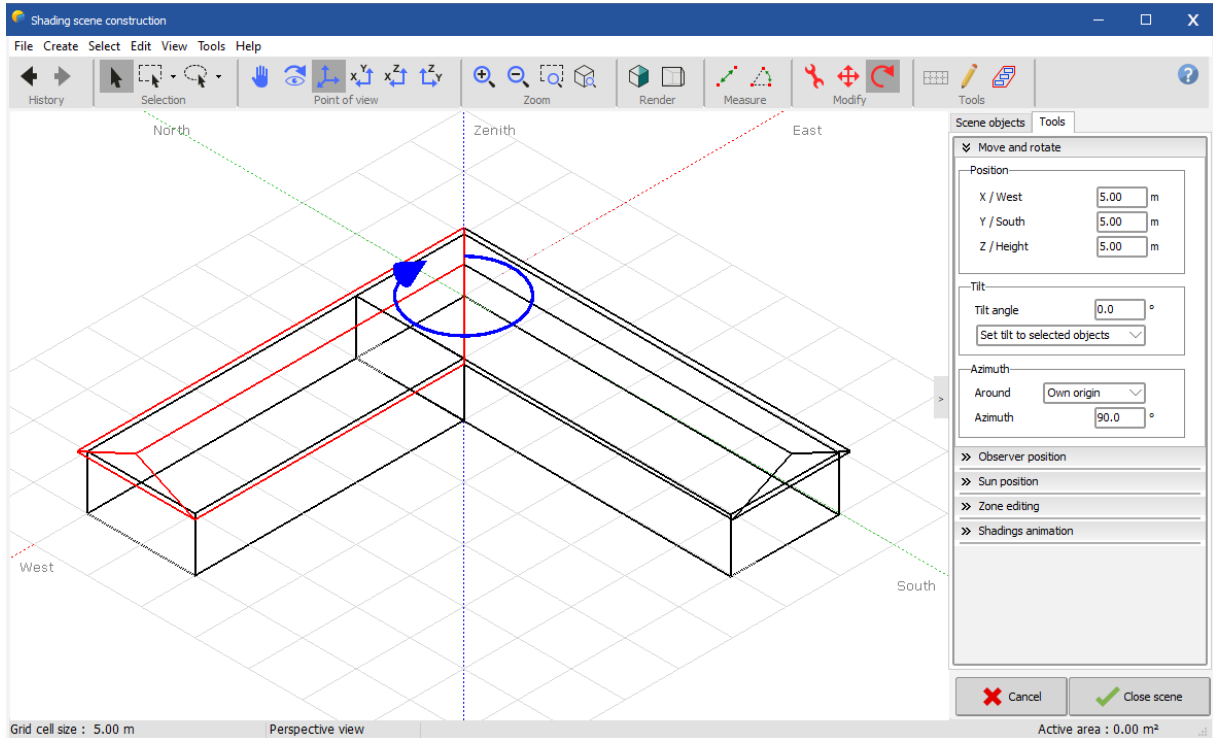


- For the second wing of the roof you could proceed in the same way. You can also reuse the roof you just created: "Edit" / "Copy", and "Edit" / "Paste". You will obtain a second instance of the selected object.

- Position this object using again first the mouse and then entering the exact values in the "Object Positioning" dialog (make sure that the new azimuth is exactly 90°).

Now the 45° cut gable is still not correct. For modifying the selected object, you can:

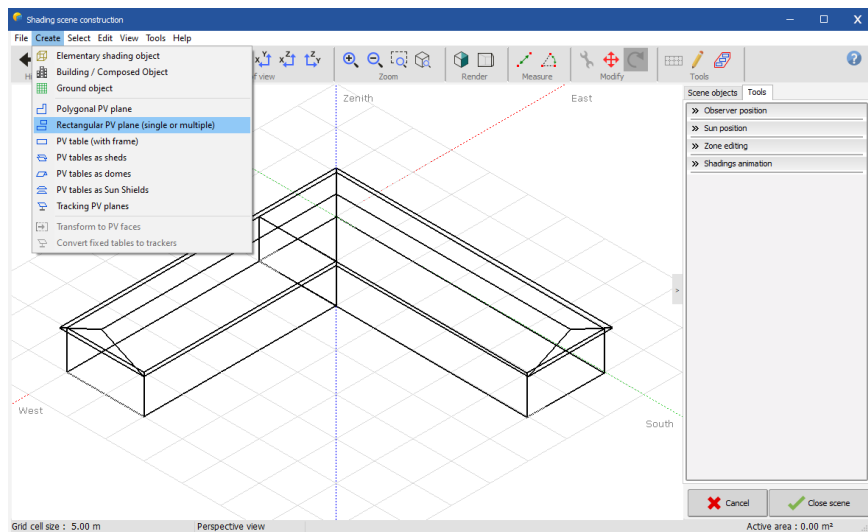
- Either choose "Elementary Object" / "Modify",
- Or, more easily, double-click the object on its border.
- Change -45° to $+45^\circ$ and click Close.



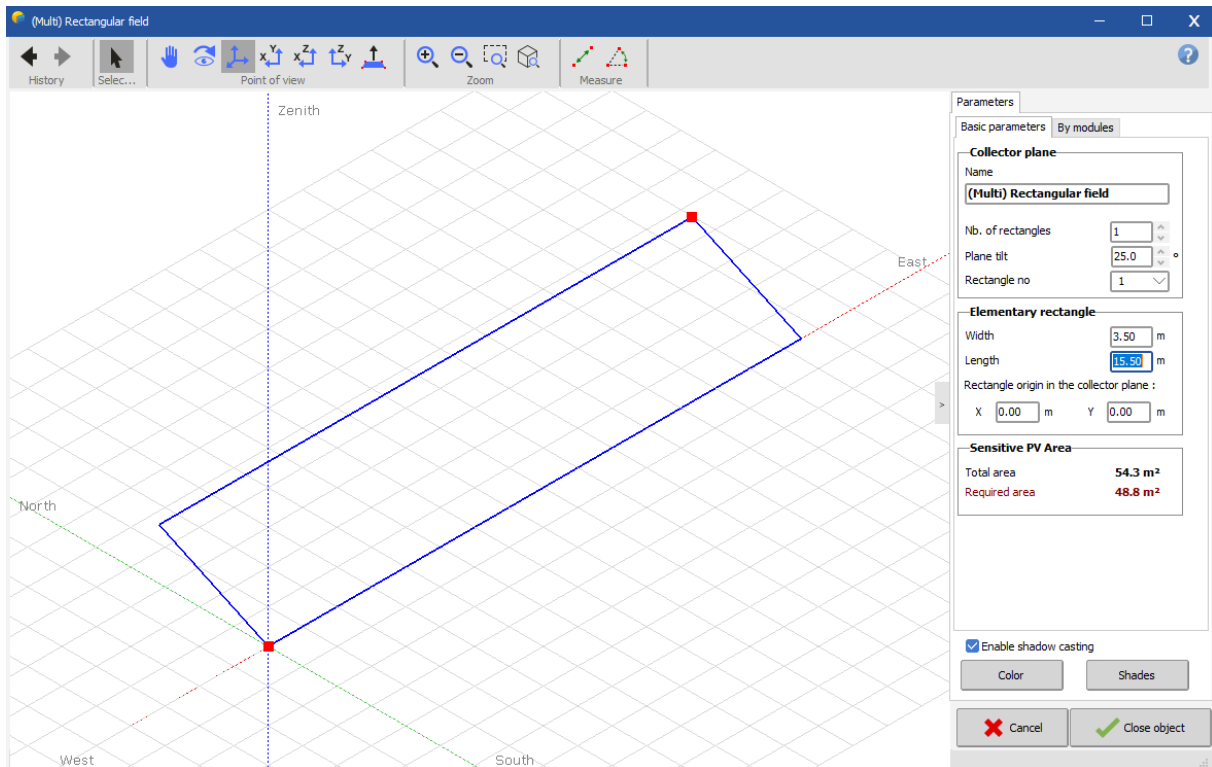
Adding the PV plane

PV planes cannot be integrated in building objects, as the PV planes elements (sensitive areas) are treated differently by the program. They have to be positioned on the buildings within the main 3D scene.

- In the main 3D scene, choose: "Object" / "New..." / "Rectangular PV plane".

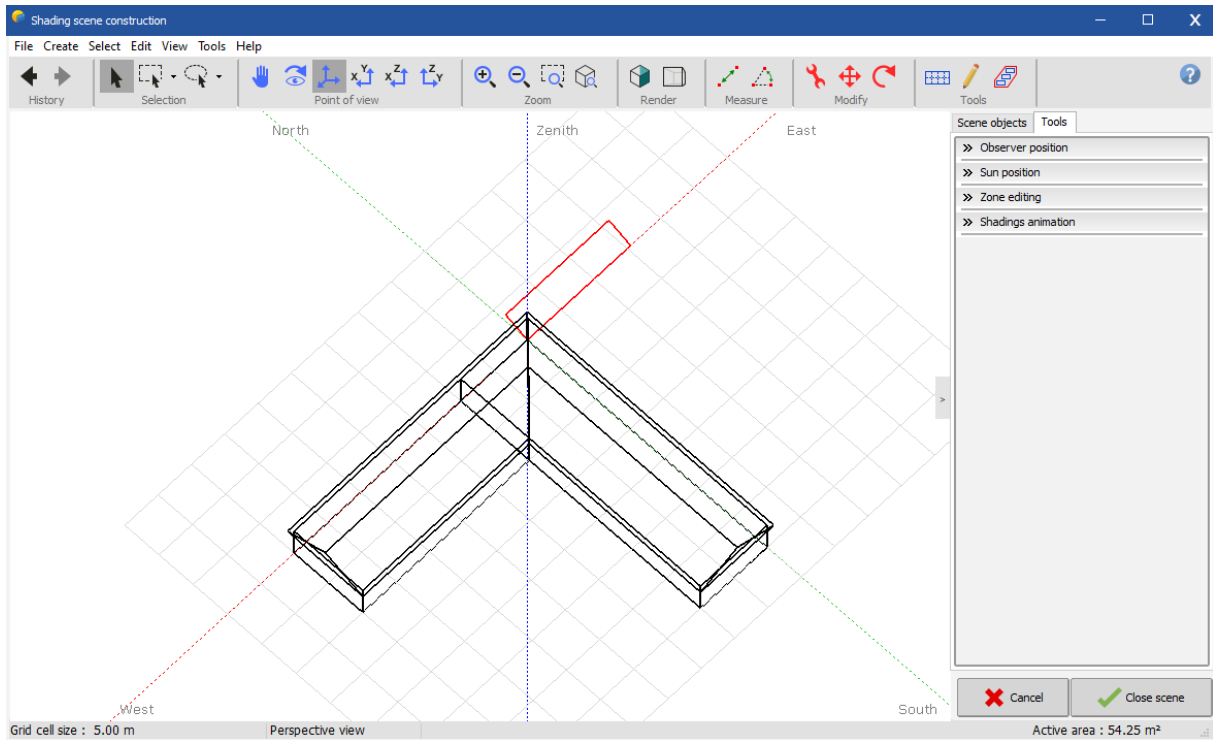



- You have to define the sizes: "Nb of rectangles" = 1 (you could define several non-interpenetrating rectangles in the same plane), "Tilt" = 25°, «Width" = 3.5 m, «Length" = 15.5 m.





NB: At this stage, there is no relation with the real size of the PV modules in your system definition. The program will just check at the end of the 3D construction that the PV sensitive area in the scene is larger than the area of the PV modules defined in "System". No check is made to verify that the panels can be arranged such that they fit into the sensitive area in the 3D scene. The detailed arrangement of the modules has to be defined in the "Module Layout" part of the project. Please refer to the online help for instructions.

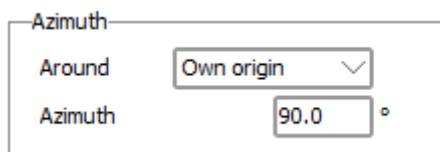
- Click "OK". The plane will be aligned to the origin of the 3D scene.



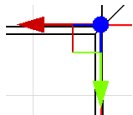
- For positioning it, again click "Top view" , position it globally with the mouse. Now you don't have rigorous references and you don't need to adjust the values, but be careful not to interpenetrate the other roof! Check the azimuth value (should be exactly 90°).

Use Rotate and move buttons to position the PV Plane 

First rotate the plane and have it parallel to the roof axis using the rotate button  or the azimuth

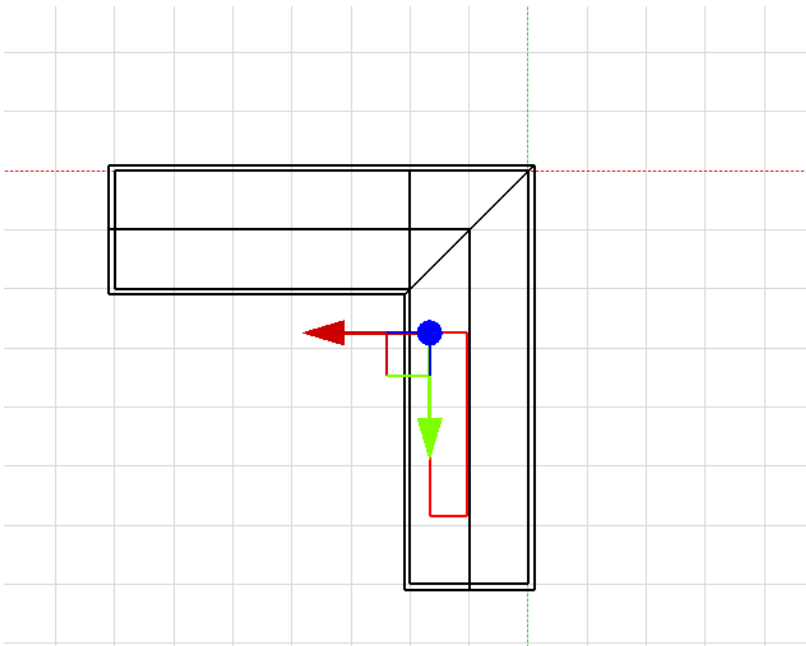
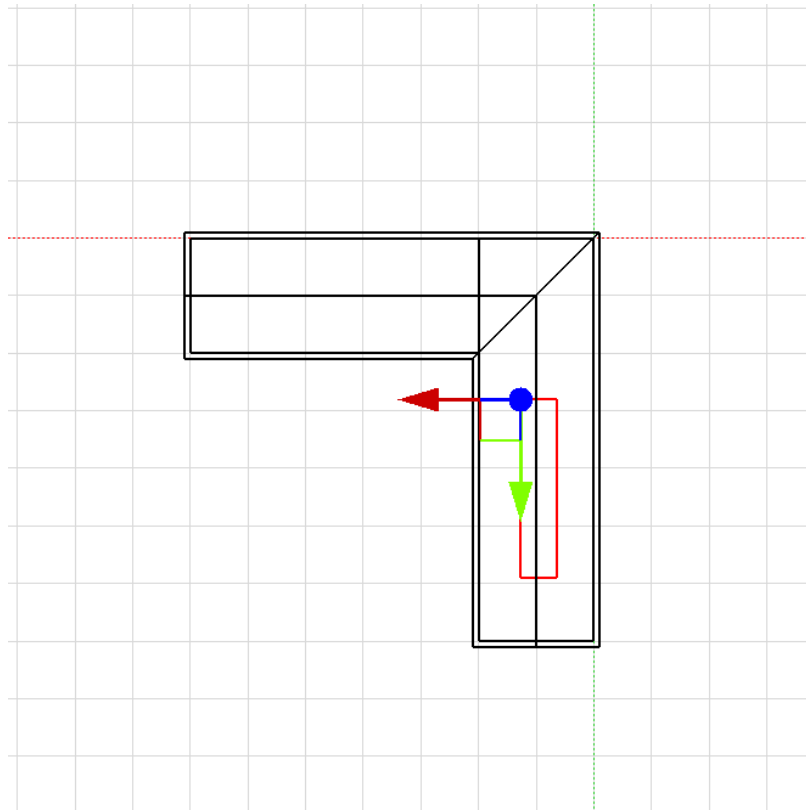



Then click the move button  and slide by dragging the green and red arrows to position correctly.




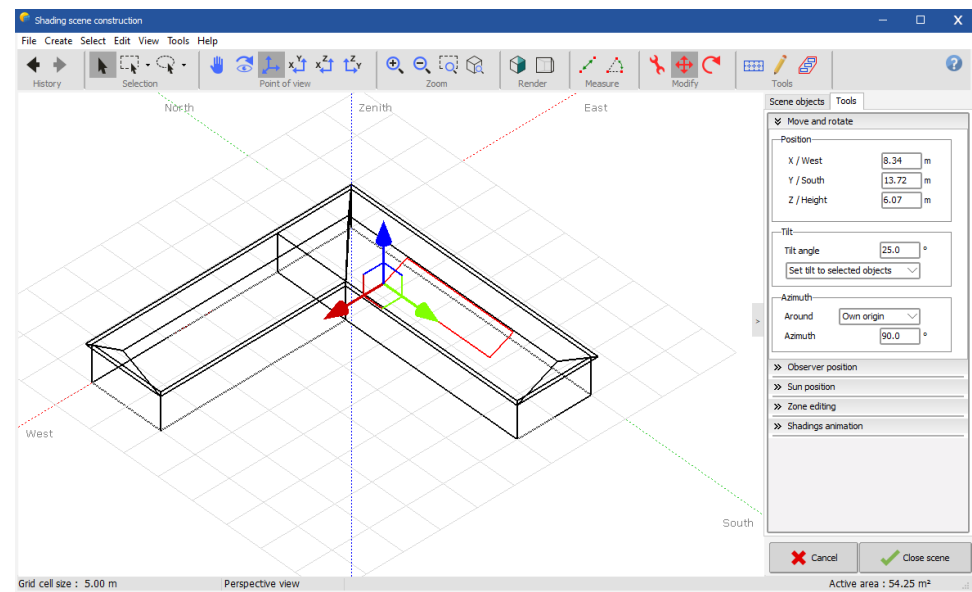
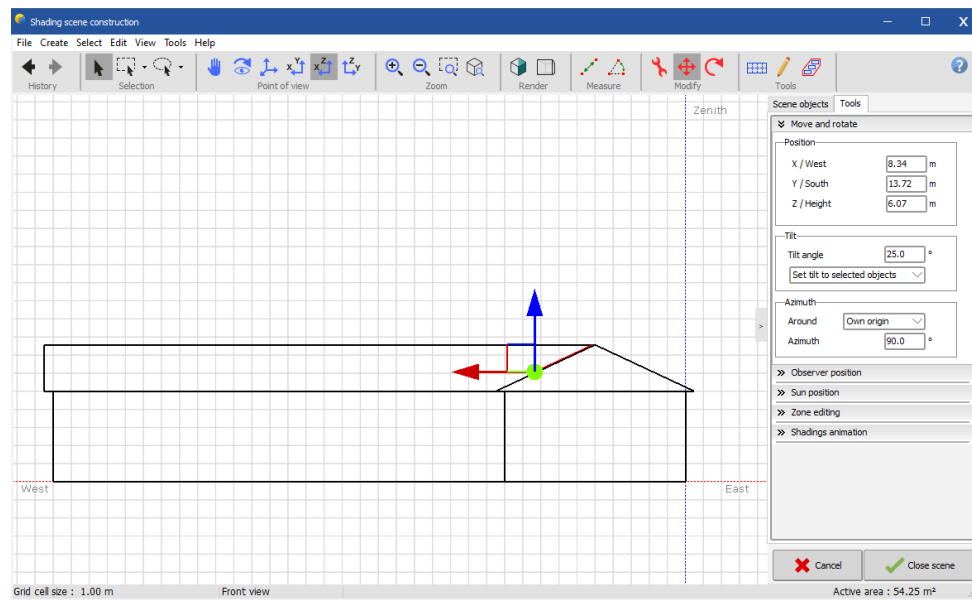
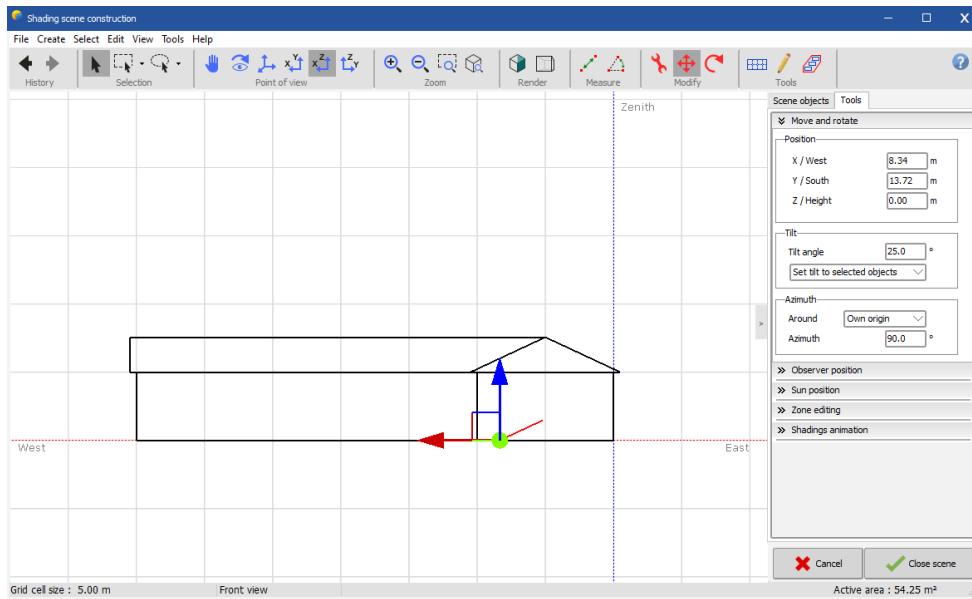
When hovering the different arrows, they will change to yellow color and indicate along which axis you'll be moving





- Vertical positioning: now your field is on the ground. Click the observer's "Front View"  button, and position your plane on the roof by dragging the red arrow with the mouse along Z Axis (vertically blue arrow below). Always remember to let some spacing between any active area and other objects. If you put the plane below the roof, it will be permanently shaded!

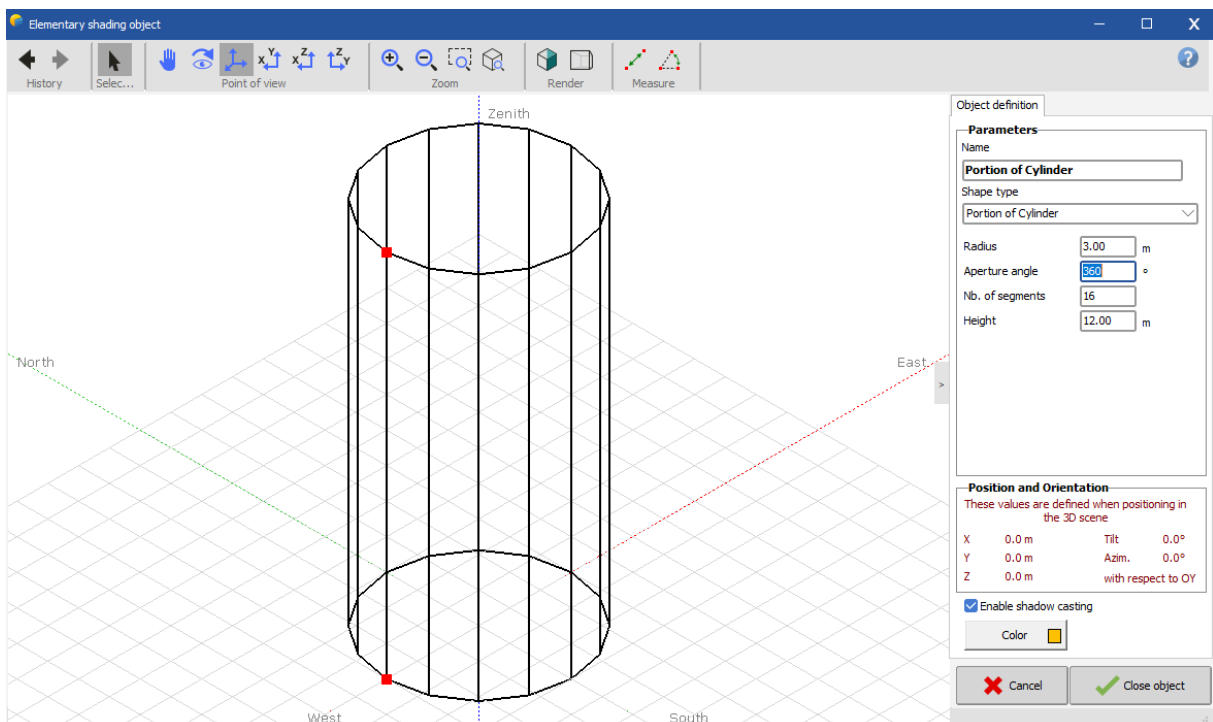
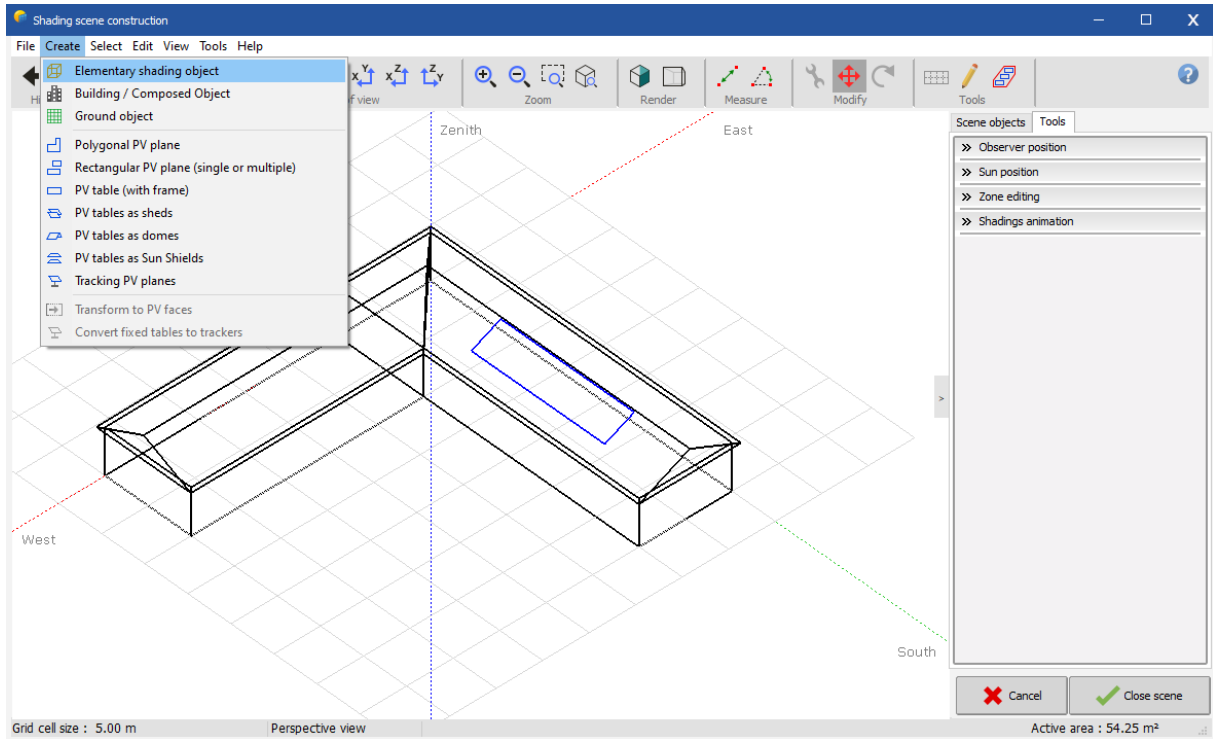
- You can then check the position using the 3D button 





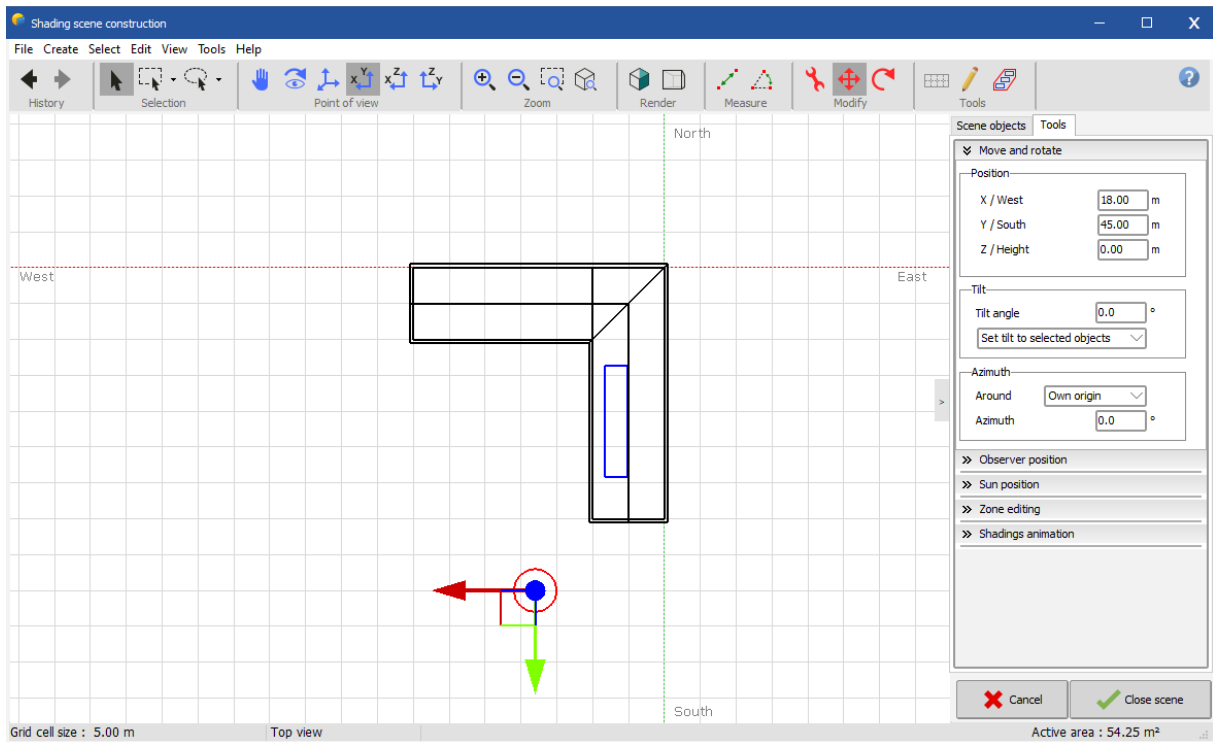
Adding more shading objects

In our example we will now add a silo and a tree to the scene. These are “Elementary shading objects” that will be positioned directly inside the main 3D scene.

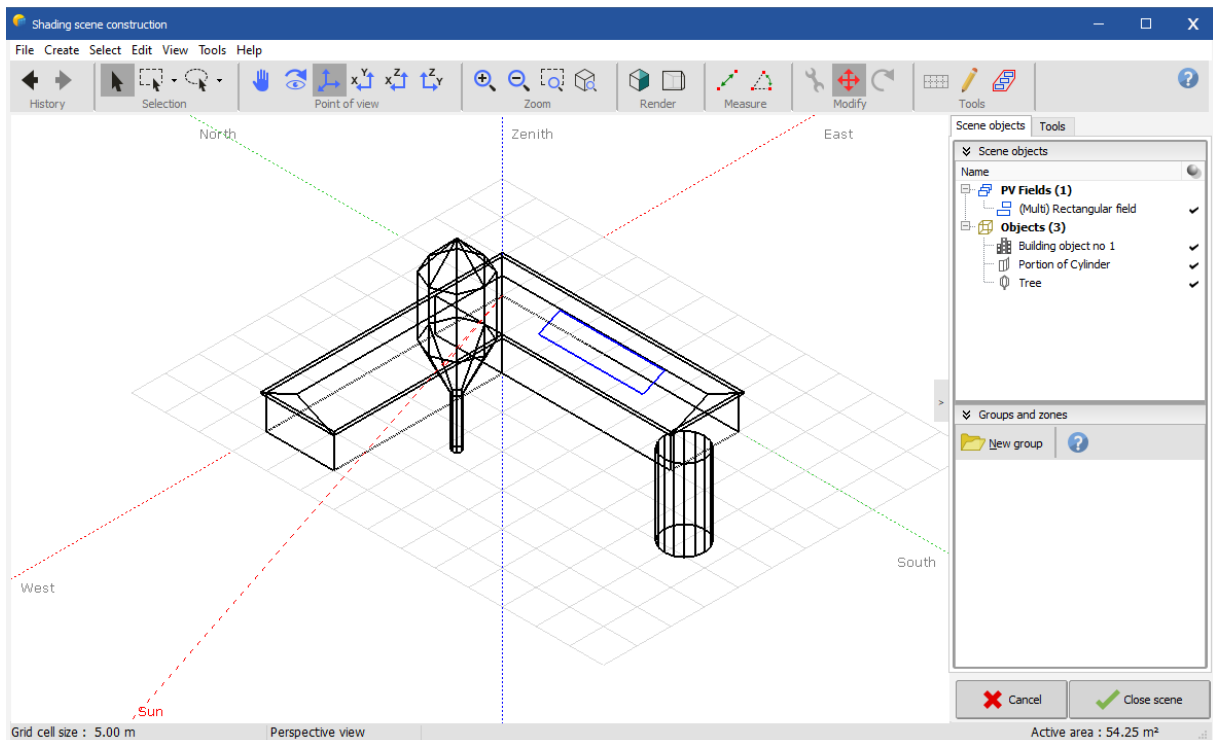
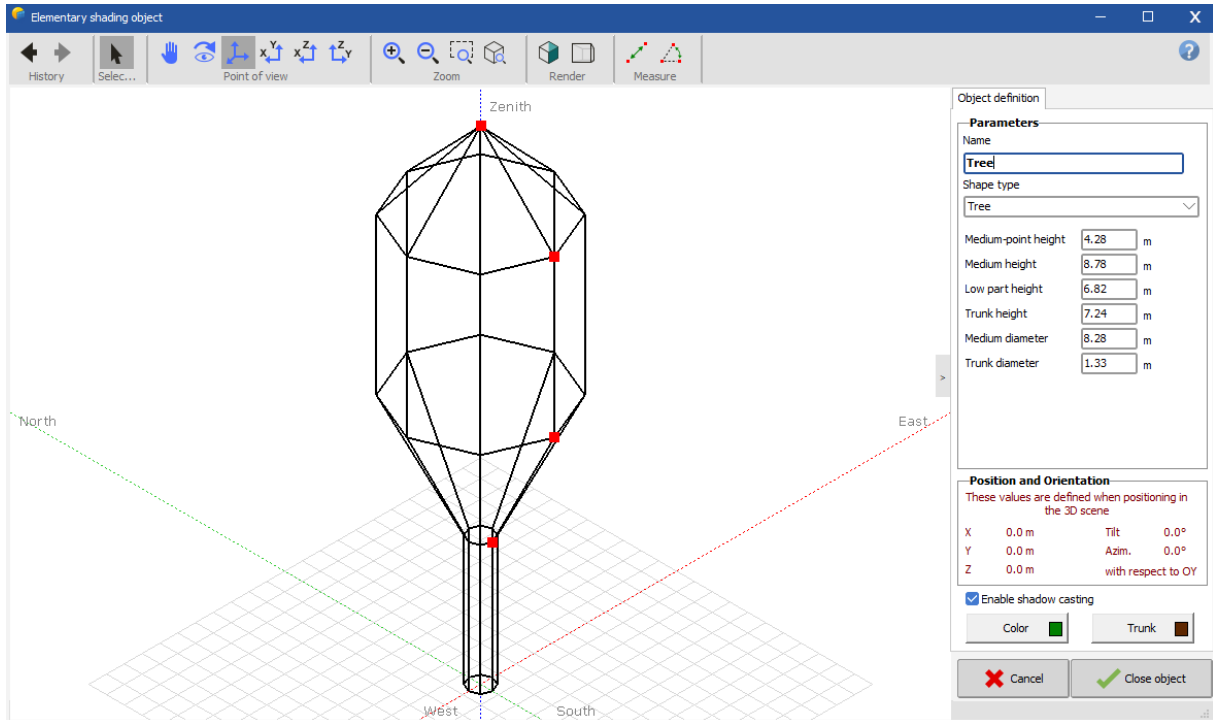
- In the main scene select "Object" / "New..." / "Elementary shading object" / "Portion of cylinder". According to the drawing, define Radius = 3m, Aperture angle = 360°, Nb of segments = 16, Height = 12m. Click "OK".




- In the main scene, be sure that the "Positioning" tool  is activated, click "Top view"  and position the silo with the mouse (if you don't know the order of magnitude or signs), and then with values (X = 18m, Y = 45 m).



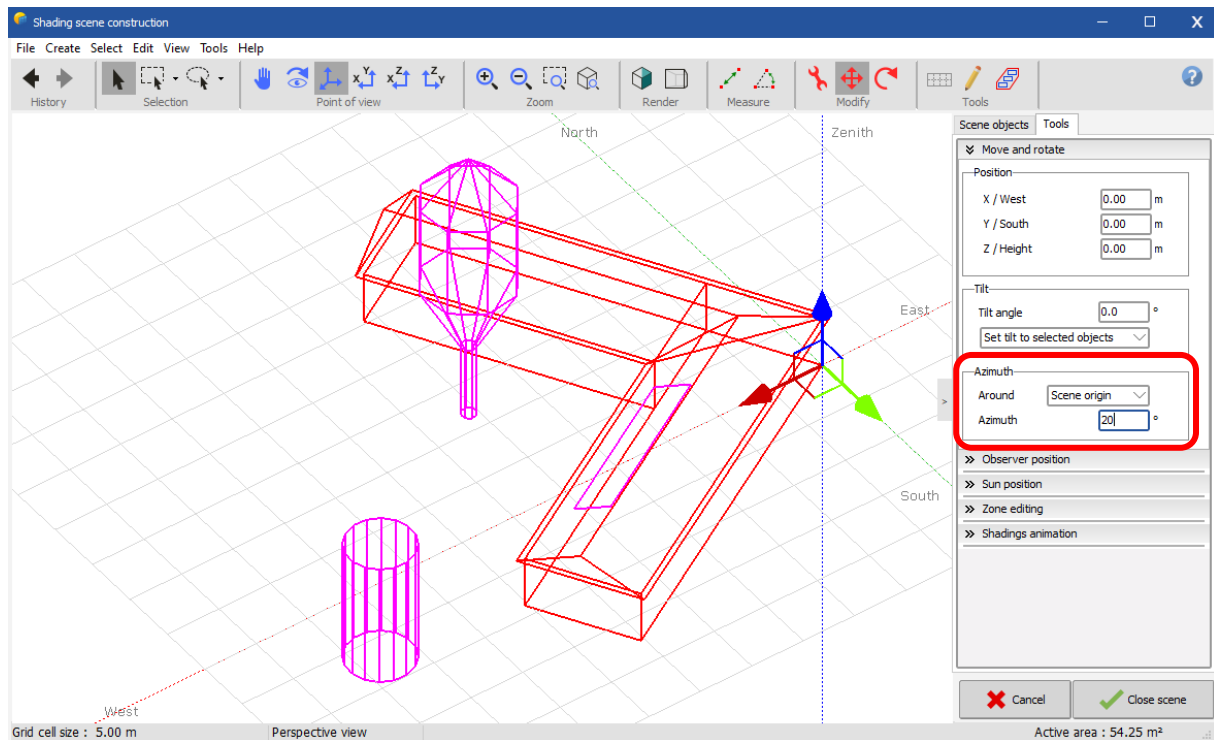
- You can now add a tree in the courtyard by selecting "Object" / "New..." / "Elementary shading object" / "Tree". To define shape and size of the tree, select "Front view" from the toolbar, and then click on the red points with the mouse and drag them to adjust shape and size of the tree. When you are done, position the tree to your like in the courtyard (always remember for your future projects, that a tree does not have a definitive size, the shading may vary as the tree grows or is pruned!).



Positioning with respect to the cardinal direction

Usually you construct a scene first in the reference coordinate system that is used in the drawings, and that has been chosen by the architect. After that, the button "Rotate whole scene"  will allow you to perform the final rotation of the global scene to fit the real orientation of the installation with respect to the cardinal direction.

- Select the reference object for the orientation (normally the PV plane).
- In the "Rotate Whole Scene" dialog, define the new azimuth (here +20°, west). This will rotate the whole scene by 20° towards west.



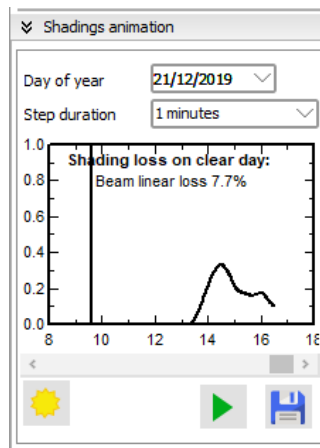
If later on you need to re-position or add a new object in the scene, it might be easiest to rotate back to the original coordinate system. To do this, select an object which is aligned with the coordinate system in which you would like to work and put a value of 0° or 90° into the "Rotate whole scene" dialog. Perform the modifications and then apply the reverse rotation.

Shading test and animation

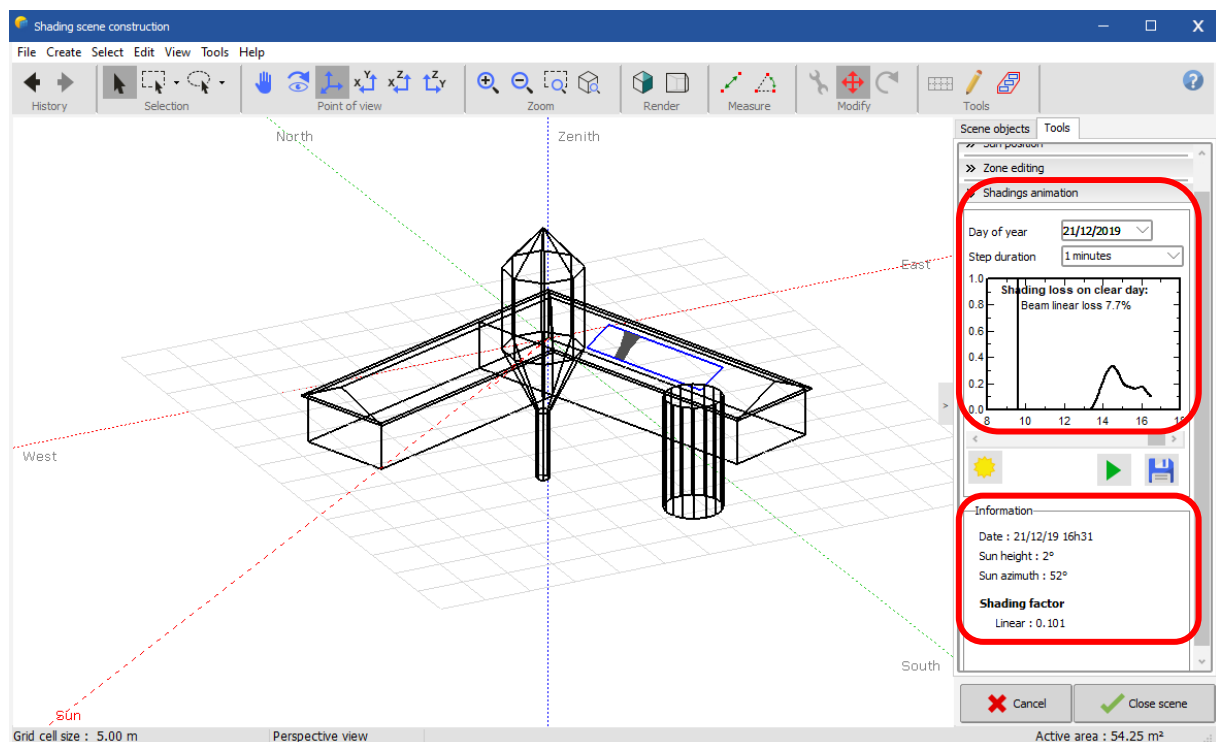
Now that the 3D scene holds all the potential obstacles and the sensitive panel area, we are ready for a first shading analysis.

- Click Tools on the left pane and choose Shadings animation sub panel.

✖ Shadings animation | The "Shadow animation" tool will expand and here you click on "Play/Record animation". The shadows will be shown for the whole selected day. After execution you have a scrollbar for reviewing one or the other situation.




For each time step, the date/hour, sun position and shading factor are displayed on the bottom of the 3D window. You can try this for different dates in the year, the two extreme situations being June 21st and December 21st.

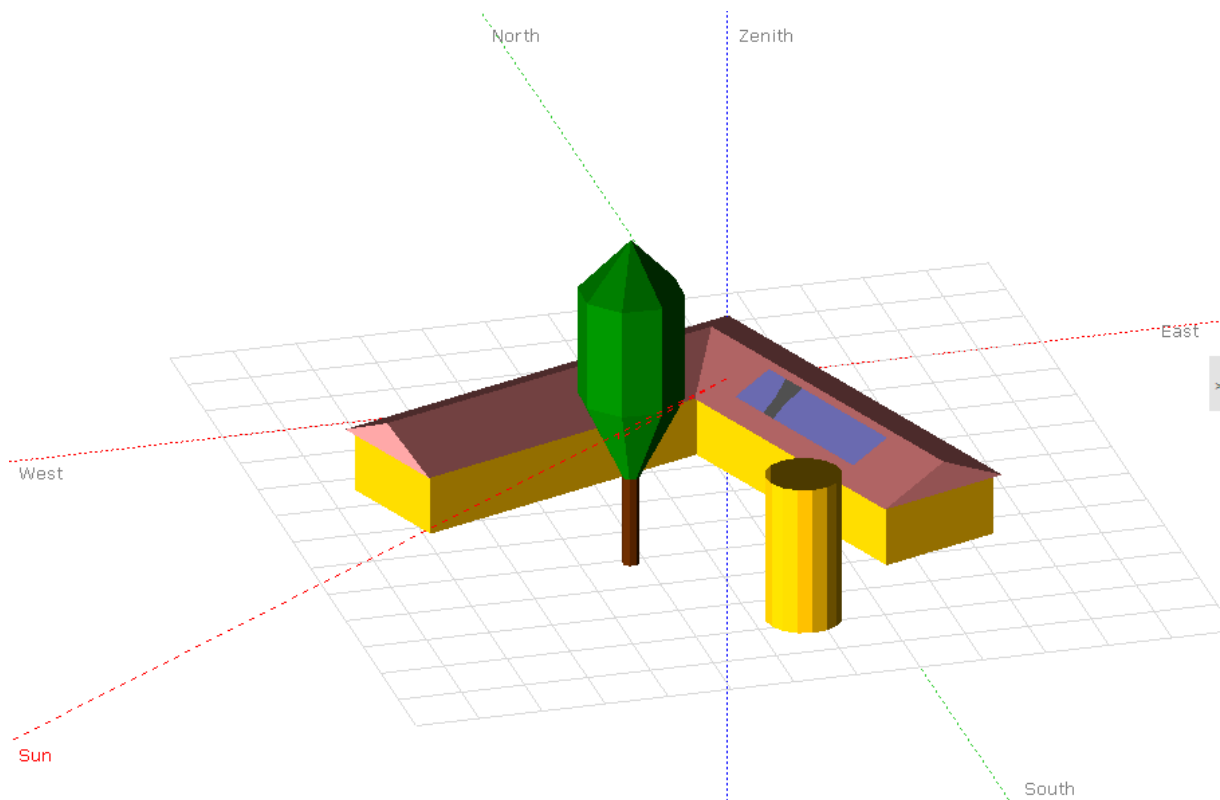


More Options

Colors


You can personalize the view of your scene by defining colors.

- Click the button "Realistic / technical view" on the "render" toolbar .
- The color of each element can be defined in its definition dialog.
- For example for the building: Double-click the building, this will open the building construction.
- Double-click the roof, this will open the definition dialog for the roof.
- In this dialog you can define the color of the roof, and the color of the gables independently of each other.

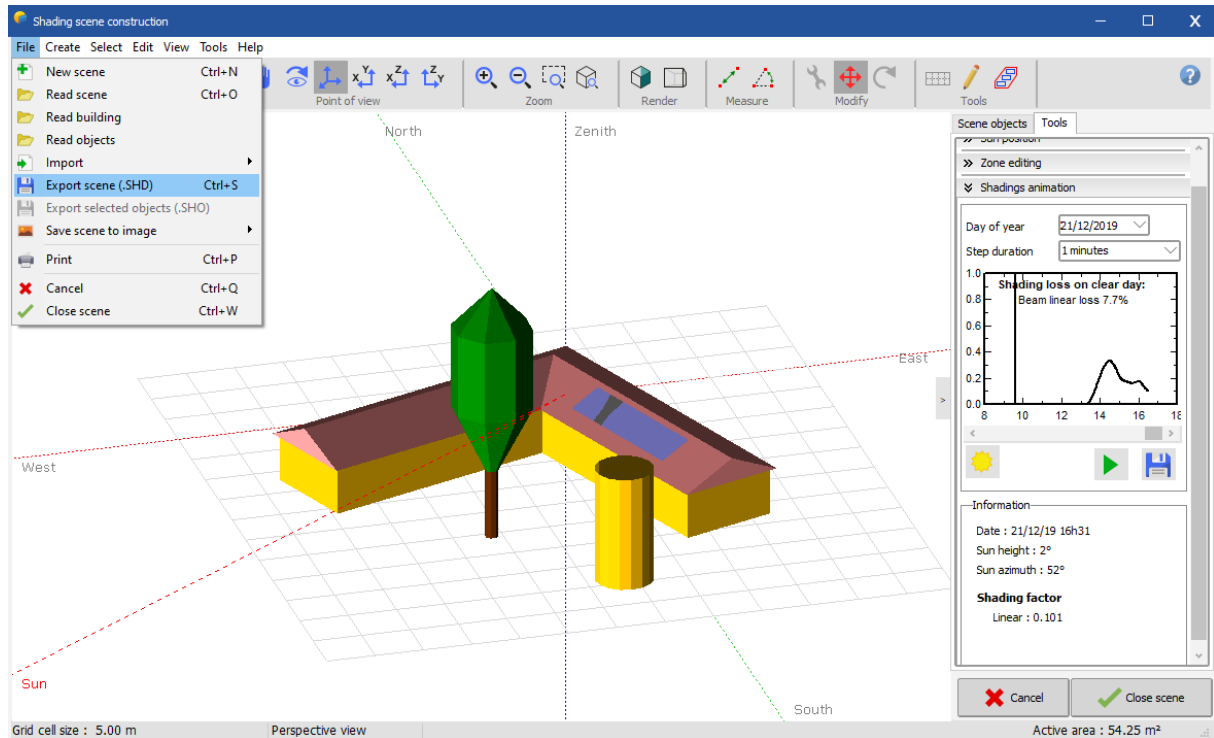


- If you define your own colors, store them as "personalized color" in order that you can reuse them for other similar objects.

Saving the scene

If you do some bad manipulation, you can undo it with the "Undo" button  from the top toolbar.

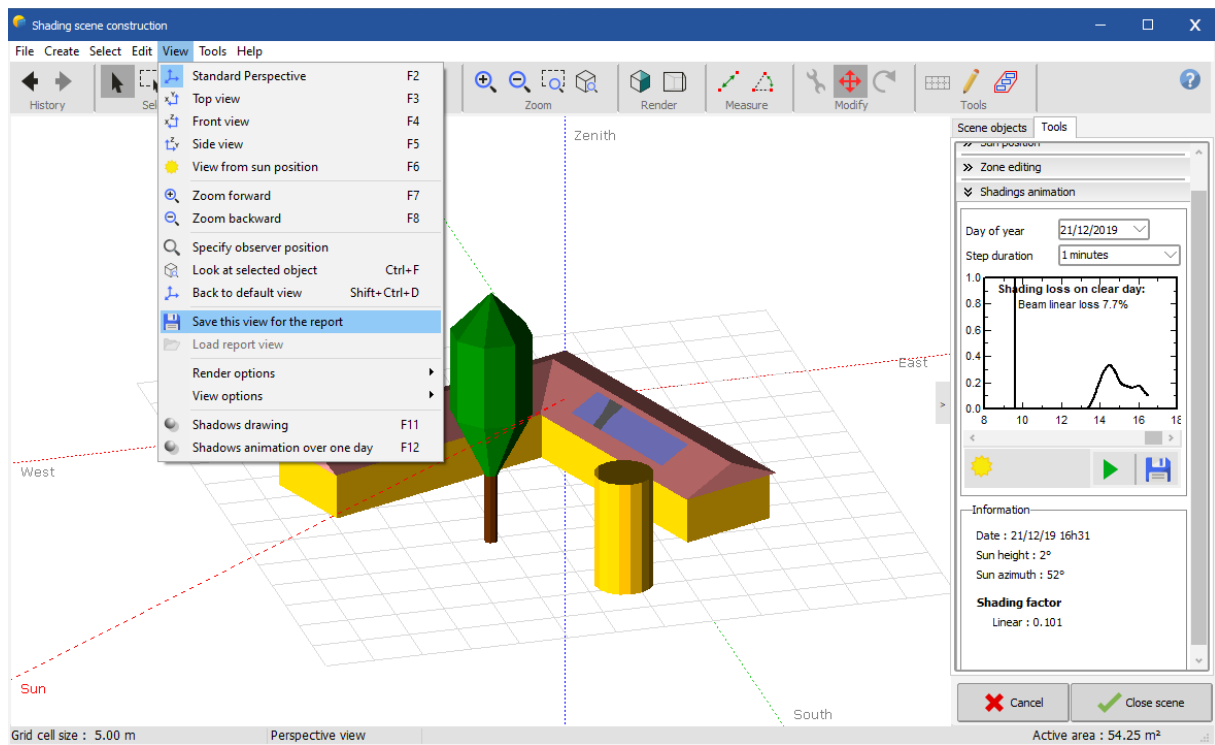
You are advised to periodically save your shading scene using "File" / "Export scene" as a *.shd file. This will allow you to roll back in case you made an unwanted modification and avoid losing your work in case of a crash (Alas there still remain some bugs in PVsyst).



Please note: your final scene (used in the simulation) will be stored along with your "MyProject.VCI" file. It does not need an *.SHD file.

Display in report

This scene will appear on the final report. If you want to have a specific view of the scene in the report, you can request it by "View" / "Save this view for the report".

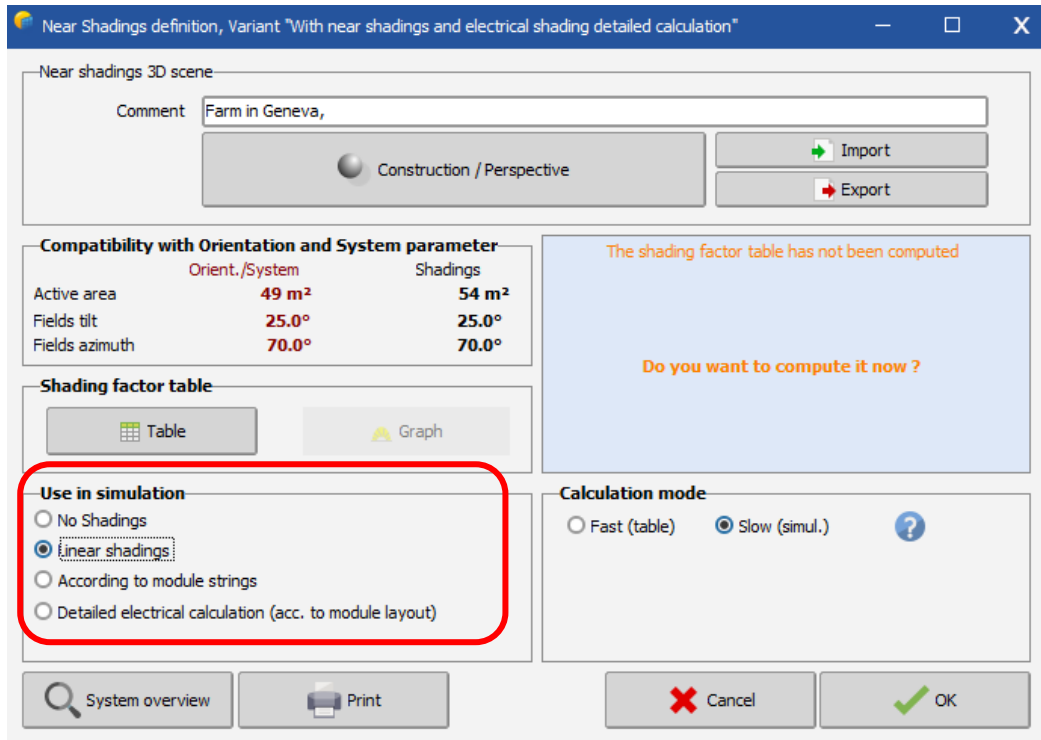


2- Use the 3D scene in the simulation

Linear Shadings

Your shading scene is now ready for the simulation.

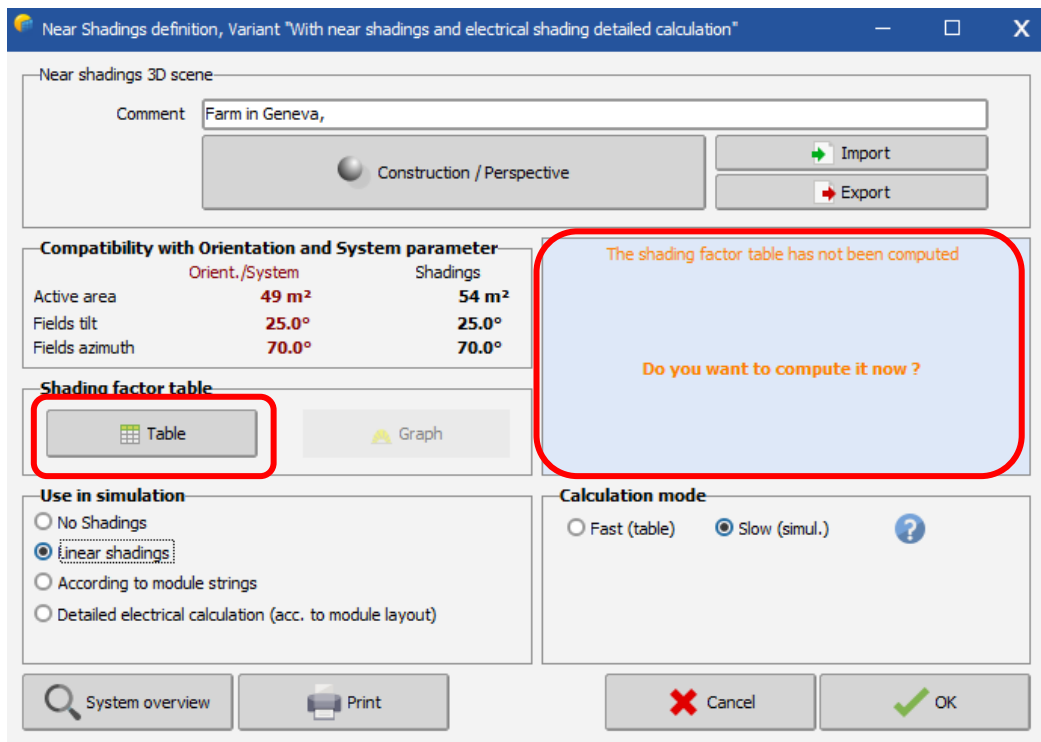
- Choose "File" / "Close". You return in the near shadings dialog.
- Choose "Linear shadings" in the box "Use in simulation".



Now the program checks the compatibility of your 3D scene with the other definitions of your system.

- The plane orientation should match the one defined in the "Orientation" part. If it does not, there is a button to correct the "Orientation" parameters according to the 3D construction.
- The sensitive area should be large enough to position the PV modules defined in the system definitions. This is a rough test, which checks only the total area and does not take into account the individual sizes and geometrical positions of the modules. A warning will be issued if the total area of the panels exceeds the total sensitive area of the 3D scene. If the total area of the panels is much smaller than the sensitive area defined in the 3D scene, there will also be a warning. The threshold for this warning is much higher (factor of 1.5) to allow spacing between the PV panels. The thresholds for both warnings are defined in the "Hidden Parameters" and can be modified if necessary.

- When everything is correct, the program will ask you to compute the Table of the shading factors. Click on the "Table" button.



Shading factor table (linear), for the beam component, Orient. #1

Close Print Export Help

Recompute

Plane orientation
Fixed Tilted Plane **Tilt = 25°, Azimuth = 70°**

Shading factor table (linear), for the beam component, Orient. #1

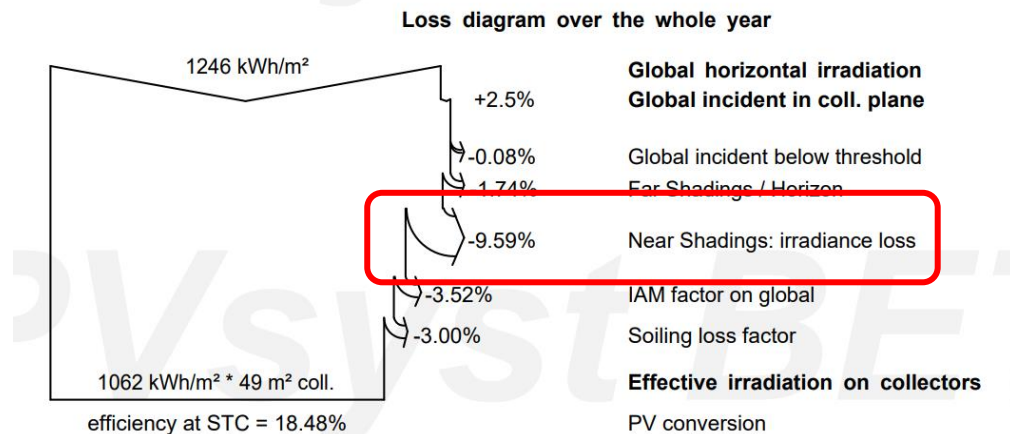
Azimuth	-180°	-160°	-140°	-120°	-100°	-80°	-60°	-40°	-20°	0°	20°	40°	60°	80°	100°	120°	140°	160°	180°	
90°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
80°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
70°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
50°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.069	0.069	0.000	0.000	0.000	0.000	0.000	0.000
40°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.227	0.517	0.428	0.010	0.000	0.000	0.000	0.000	0.000
30°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.240	0.534	0.433	0.010	0.000	0.000	0.000	0.000	0.000
20°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.089	0.231	0.485	0.409	0.000	0.000	0.000	0.000	0.000	0.000
10°	0.001	0.000	Behind	Behind	Behind	Behind	0.000	0.000	0.000	0.012	0.597	0.168	0.261	0.259	0.000	0.000	0.001	0.004	0.001	0.001
2°	0.002	Behind	Behind	Behind	Behind	Behind	0.000	0.000	0.012	0.597	0.086	0.100	0.100	0.282	0.642	0.734	0.759	0.002	0.002	0.002

Shading factor for diffuse: 0.072 and for albedo: 0.245

The table is a calculation of the shading factor (shaded fraction of the sensitive area, 0 = no shadings, 1 = fully shaded), for all positions on the sky hemisphere "seen" by the PV plane. It allows the calculation of the shading factor for the diffuse and albedo (which are integrals of this shading factor over a spherical segment). For each hourly value, the simulation process will interpolate this table - according to the sun position - to evaluate the current shading factor of the beam component.

This also allows the construction of the iso-shadings graph, which gives a synthetic view of the times of the day and seasons where the shadings are particularly problematic. The 1% line for example, shows all the sun positions (or time in the year) for which the shading loss is 1%, i.e. the limit of shadings.

Clicking "OK" will incorporate the shading effects in the next simulation. In the final loss diagram on the report, there will be a specific loss for the "Near shadings". This loss reflects the fact that a fraction of the sensitive area will be shaded at certain times of the day and year.




Electrical effect: partition in module strings

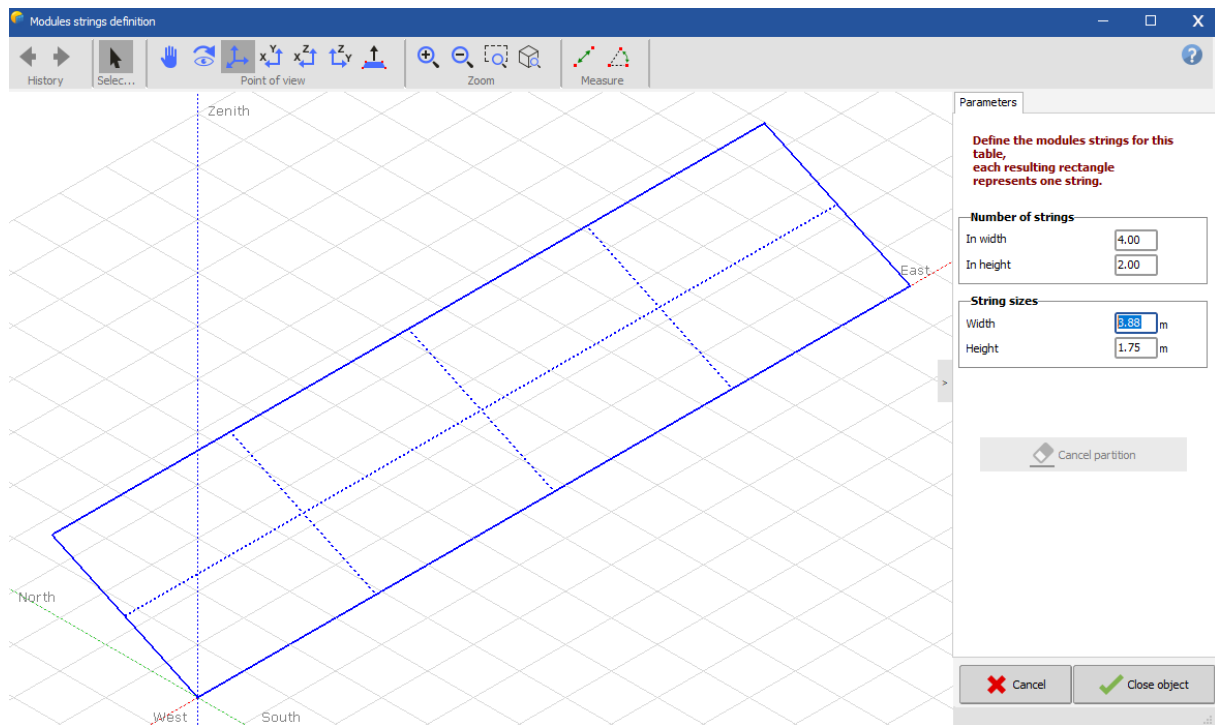
When a PV cell is shaded, the current in the whole string is affected (in principle the current of the string is the current in the weakest cell). There is no possible accurate calculation for this complex phenomenon in PVsyst. We will just assume that when a string is hit by a shade, the whole string is considered "inactive" concerning the beam component. This is an upper limit on the shading effect: the truth should lie between the low limit - which we call the "Linear shading" - representing the irradiance deficit, and this upper limit (see partition in module strings), representing the electrical effect.

More realistic simulation "According to module strings":

- Go back to the Near Shadings definition, button "Construction/Perspective"

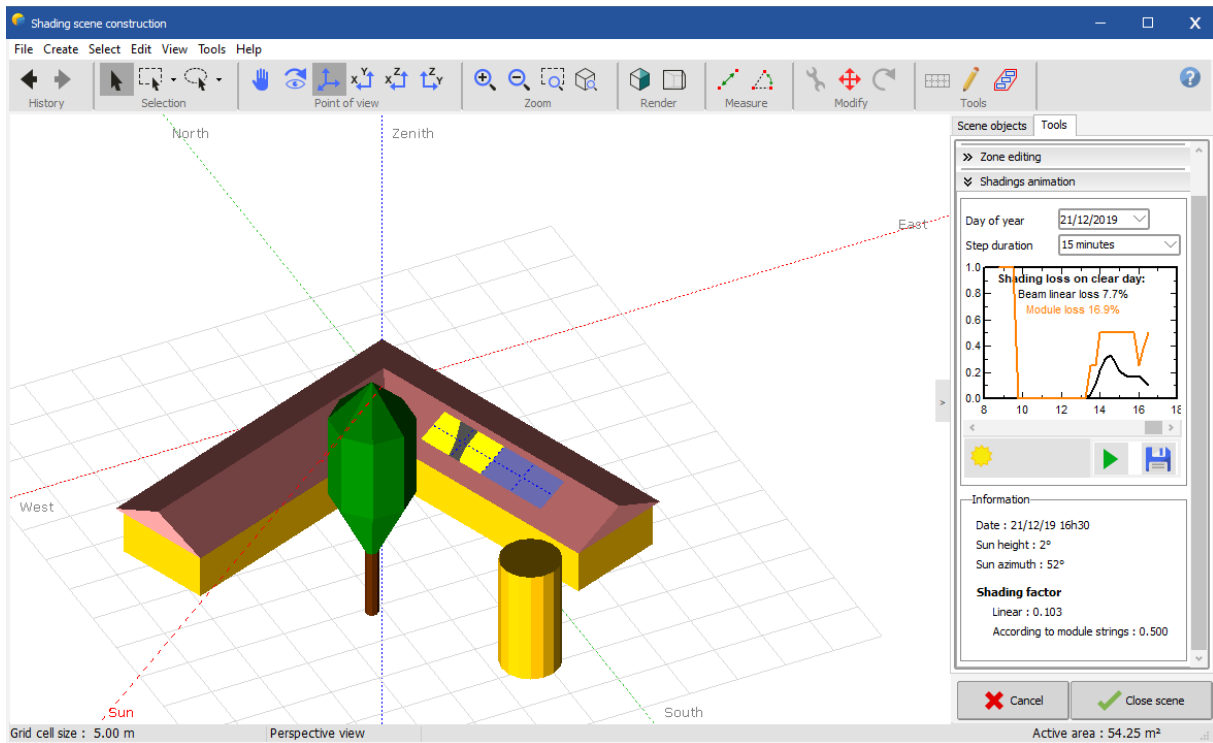
- Click the button "Partition in module chains"  on the left.

- Here you can split the field into several equivalent rectangles, each representing the area of a complete string (not a module!). If there are several subfields, you should do this for every subfield rectangle.



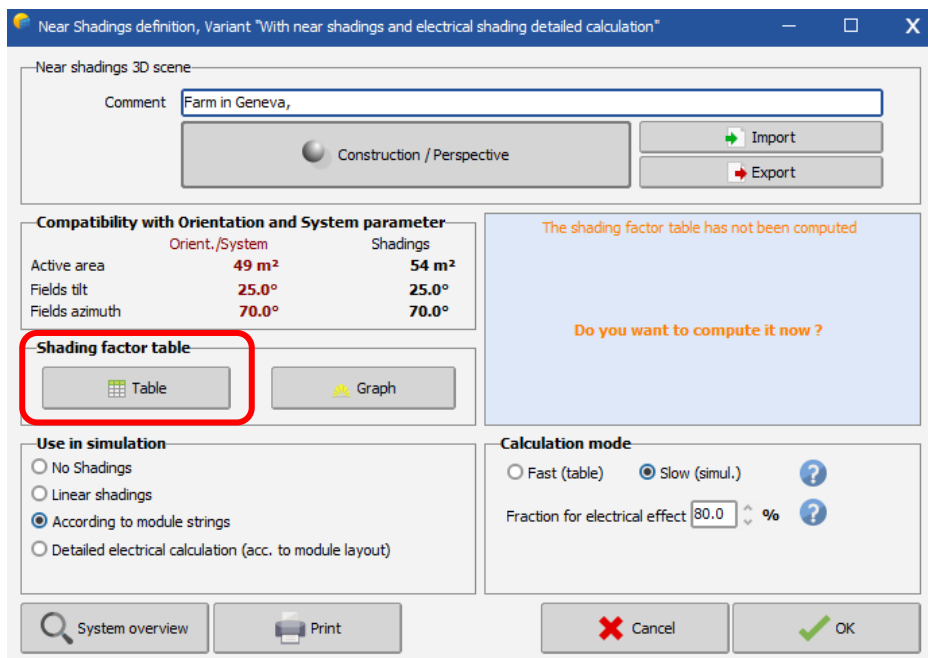
The fact that one has to use rectangles for the strings limits the possibilities to shape complex arrangements of panels within a string, perhaps you will not be able to represent the exact arrangement of the modules. Since the impact on the simulation is not very high, a rough estimation should be sufficient to give good results. If you want to get a feeling of the impact that the non-perfect arrangement of panels into strings has on the simulation, you should perform the simulation with different configurations and examine the variation of the results.

When performing the shading animation, the partially shaded rectangles will now appear in yellow. The improved shading factor is the sum of the grey and yellow areas, with respect to the field area.

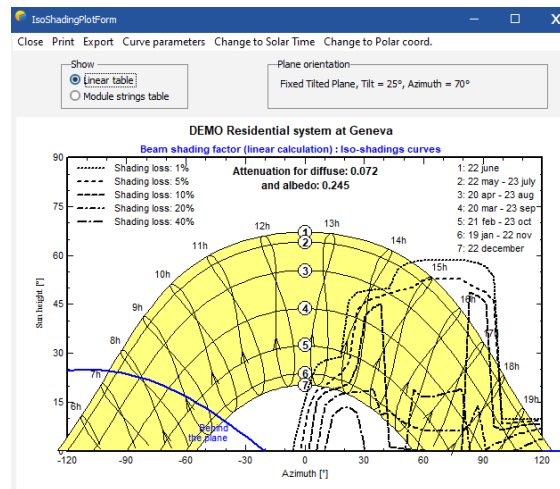


Use in the simulation

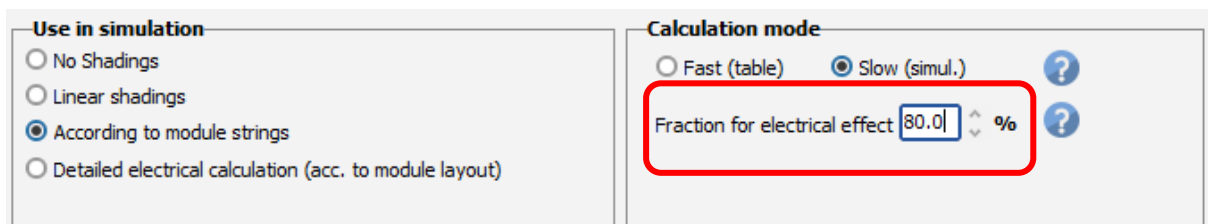
Like before, go the "Near shadings" dialog and choose "According to module strings" in the options field "Use in simulation".



You will be asked once more to compute the shading factor tables, after which you can open the iso-shading graph to compare the results of the improved shadings with the "Linear shadings" case.



"Fraction for Electrical effect": this is the way how the yellow parts will be treated in the simulation. A 100 % value will withdraw the total electrical production of these areas in the simulation. This is the upper limit of the shading effect. Perform a simulation with this value.



For the simulation that you will present to you end-customer, you can fix a different value to get closer to reality. For the present time there is no means to get a good estimation of this factor (a reasonable guess would be around 60-80%, accounting for a partial recovery due to the by-pass diodes).

Combining the near shadings with the horizon (far) shading

In a first step of the simulation, the program will evaluate the beam component according to the horizon line, resulting in full or zero beam depending if the sun is above the horizon or not. After this, the near shadings factor is applied to the beam component.

Therefore, when the sun is below the horizon line, there will be no near shading loss for the beam component, as the beam is null. In other words, potential near shadings for sun positions already affected by the horizon will not produce any additional losses in the beam component.

Note that also the diffuse component is affected by the near shadings and the horizon. The diffuse light gets only slightly changed by the horizon line and there will still be near shading losses on the remaining diffuse contribution.

Part 3: Meteorological Data Management

1- Introduction

This tutorial will guide you through the different options for the management and organization of meteorological data in PVsyst and explain the importing of data from external sources.

The meteorological data (short: 'meteo' data) are the starting point of the evaluation of a project. Special care should be taken when importing and generating these data, since they represent the main source of uncertainty for the simulation. We recommend using only data from reliable sources and to always perform some basic crosschecks on them, as will be explained in this tutorial. This will make sure that no serious mistake was made which could compromise the quality of the results.

Self-measured data should only be used, if the measurements were performed with the proper equipment that has been installed, carefully calibrated and the results analyzed by qualified experts.

Data organization

Input Data

The first input that PVsyst needs is the geographical location of the project to be simulated. This will determine the sun path over the year and allow to interpolate meteorological data for places where no direct measurements were taken.

The meteorological data that is used as input for the simulation consists of the following quantities:

- Horizontal global irradiation (required)
- Average external ambient temperature (required)
- Horizontal diffuse irradiation (optional)
- Wind velocity (optional)

The first two, horizontal global irradiation and average external ambient temperature, must be supplied as external input to the simulation. There is no good way to estimate them just from the geographical location. The other two quantities can either also be supplied as external measured data or, in case there are no good measurements available, they are estimated by PVsyst with the help of established models.

Synthetic generation of hourly data

The simulation of PVsyst is done in hourly steps over a whole year. The built-in data from Meteonorm come in monthly values. It is therefore necessary to generate artificially the hourly values, starting from the monthly ones. PVsyst uses special algorithms to generate the hourly values for the meteorological data. Most of the external data sources provide data directly in hourly values for full years (e.g. TMY from PVGIS or NSRDB).

*.SIT and *.MET files

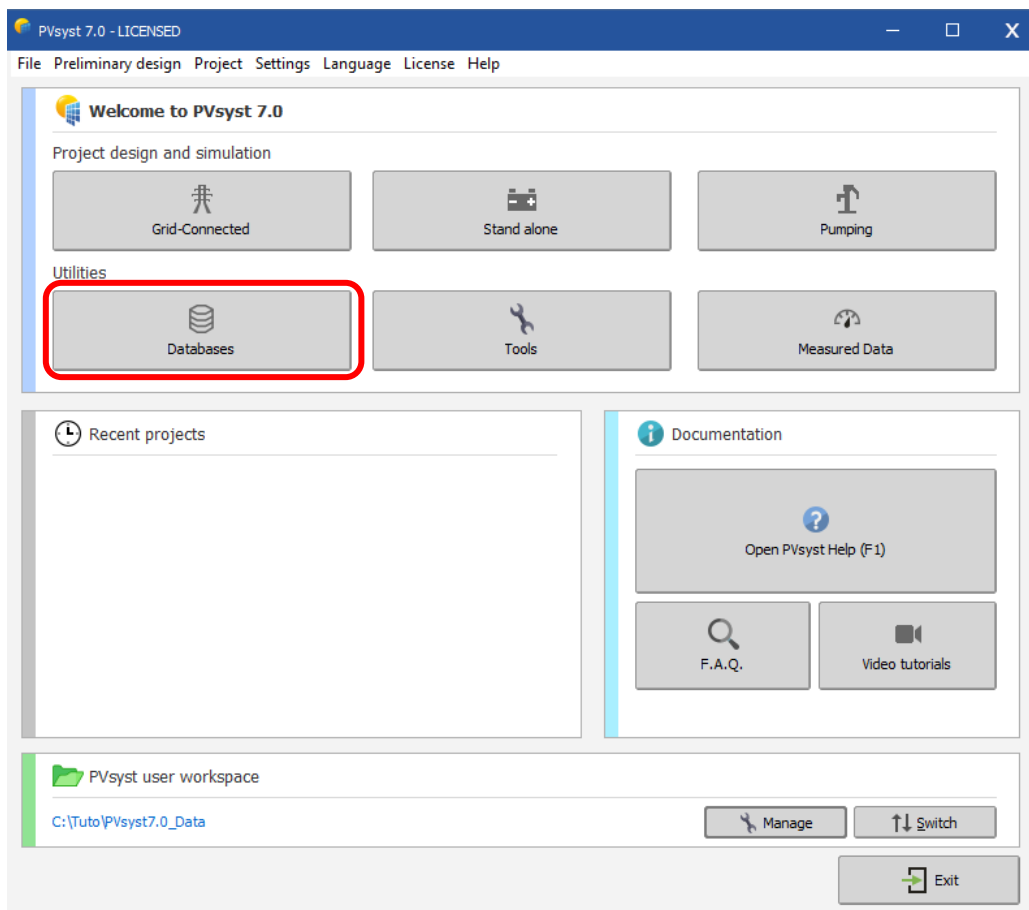
PVsyst stores the geographical location together with the monthly meteo data in one file for each site. These files have the extension '.SIT'. You can have more than one file for each site if you have monthly data from different sources or from different years that you would like to compare. The hourly data is stored in files with the extension '.MET' and here too you can have more than one file per site to compare different years or different data sources. If you obtain a '.MET' file without a '.SIT' for the same coordinates, you can directly export it from 'Meteo tables and graphs' by pressing 'Export site'.

Data Sources

The built-in meteorological data source of PVsyst is the monthly database of METEONORM. Meteonorm delivers monthly meteorological data for almost every spot on the globe and PVsyst will use this source by default if no other is explicitly specified. As a last resort if Meteonorm return errors, it is also possible to choose satellite data from the legacy NASA-SSE. Furthermore, PVsyst gives an easy access to several public sources directly available from the Web like PVGIS, NSRDB among others. Self-measured data and data from other providers like national meteorological offices may also be imported from text files(or .csv) using a tool that can be adapted to different data formats.

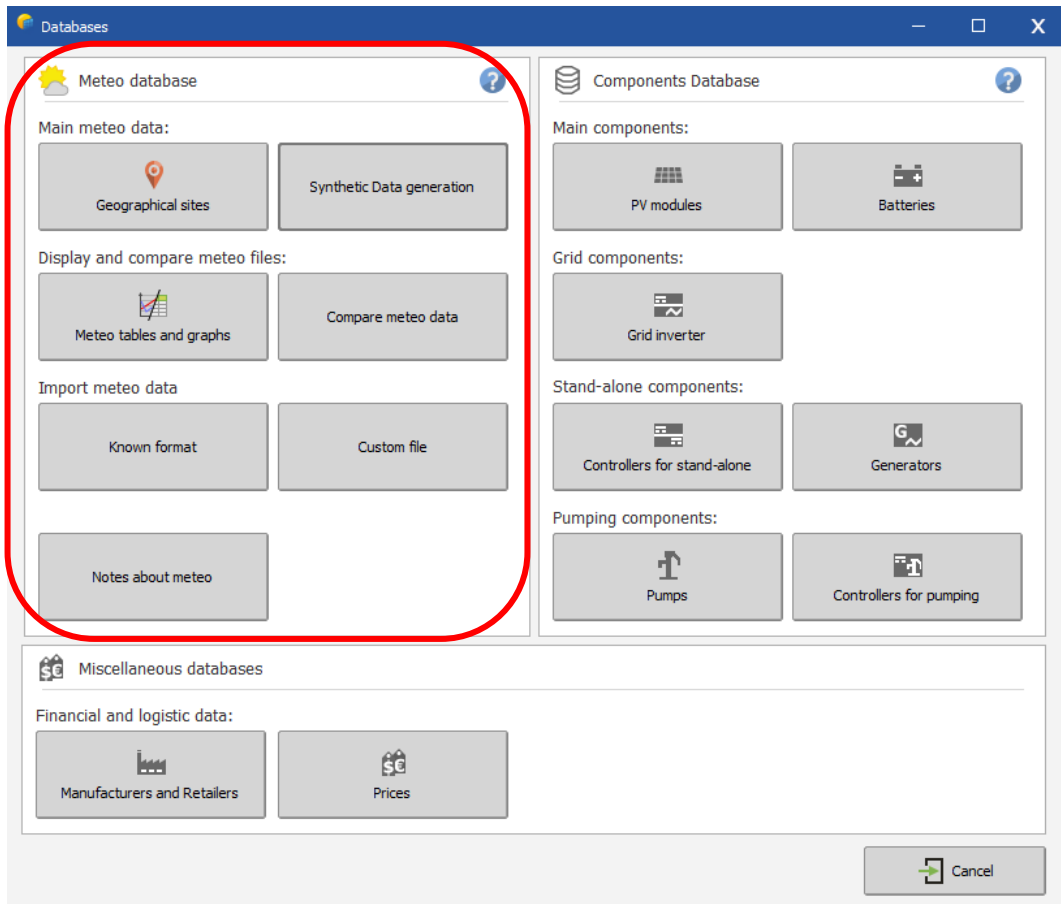
Opening the meteorological data management options

All manipulations and visualizations of the meteo data are accessed through the option "Databases" in the Main Window:



After clicking on this Button, the Database Window will pop up on the screen. The left side contains the options related to meteorological data. It contains the options:

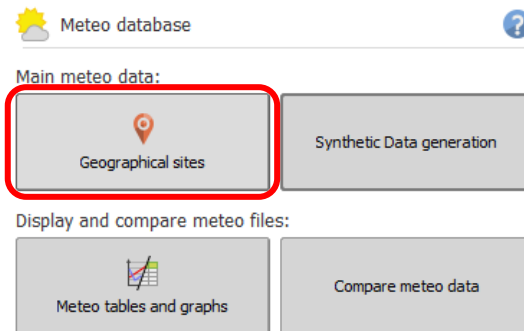
Geographical sites:	Monthly data management
Synthetic data generation:	Generate hourly values from the monthly data
Meteo tables and graphs:	Visualization and crosschecks of the hourly data
Compare meteo data:	Compare different meteo files
Known format:	Import meteo data from predefined sources
Custom file:	Import meteo data with custom format



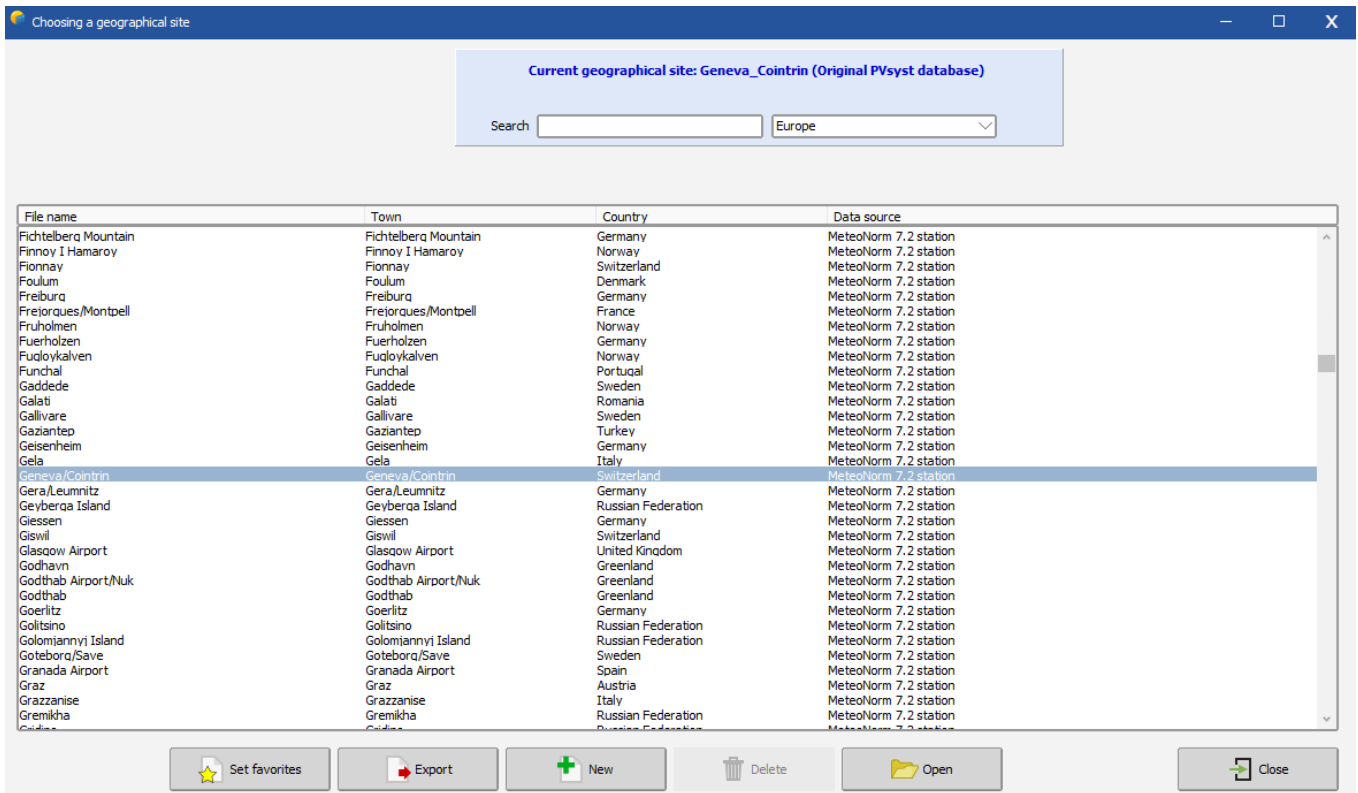
2- Geographical sites

The main database is given as objects including the geographical coordinates and associated monthly meteo data. These objects are stored as files with the name *.SIT, situated in the workspace in the subfolder \Sites\.

Click on "Geographical sites":



You will get a dialog for the choice of the geographical site, where you can choose the country or region of interest and a given station. The first column is the name of the site, the second one the country in which the site is located and the third one describes the source of the monthly meteorological data.

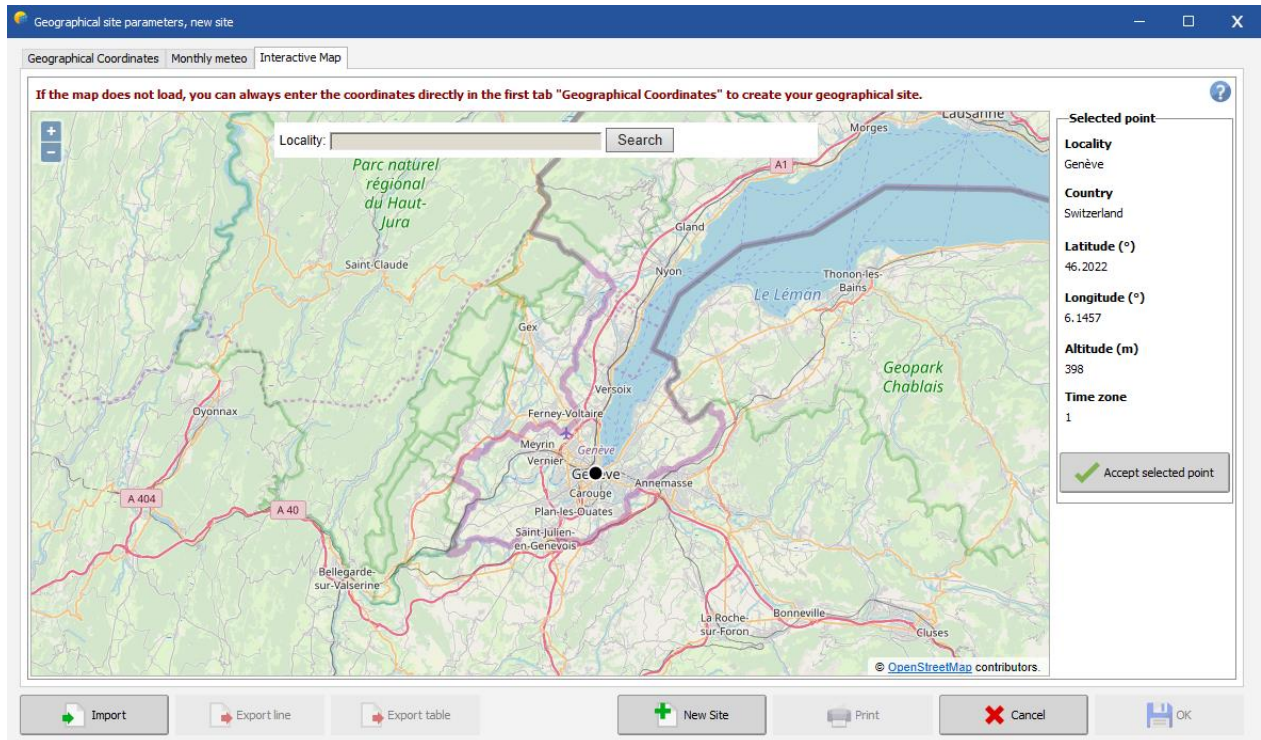


To create a new site for a project, click on 'New'. You will get a window with the geographical site parameters that contains three tabs:

Geographical Coordinates

Monthly meteo

Interactive Map

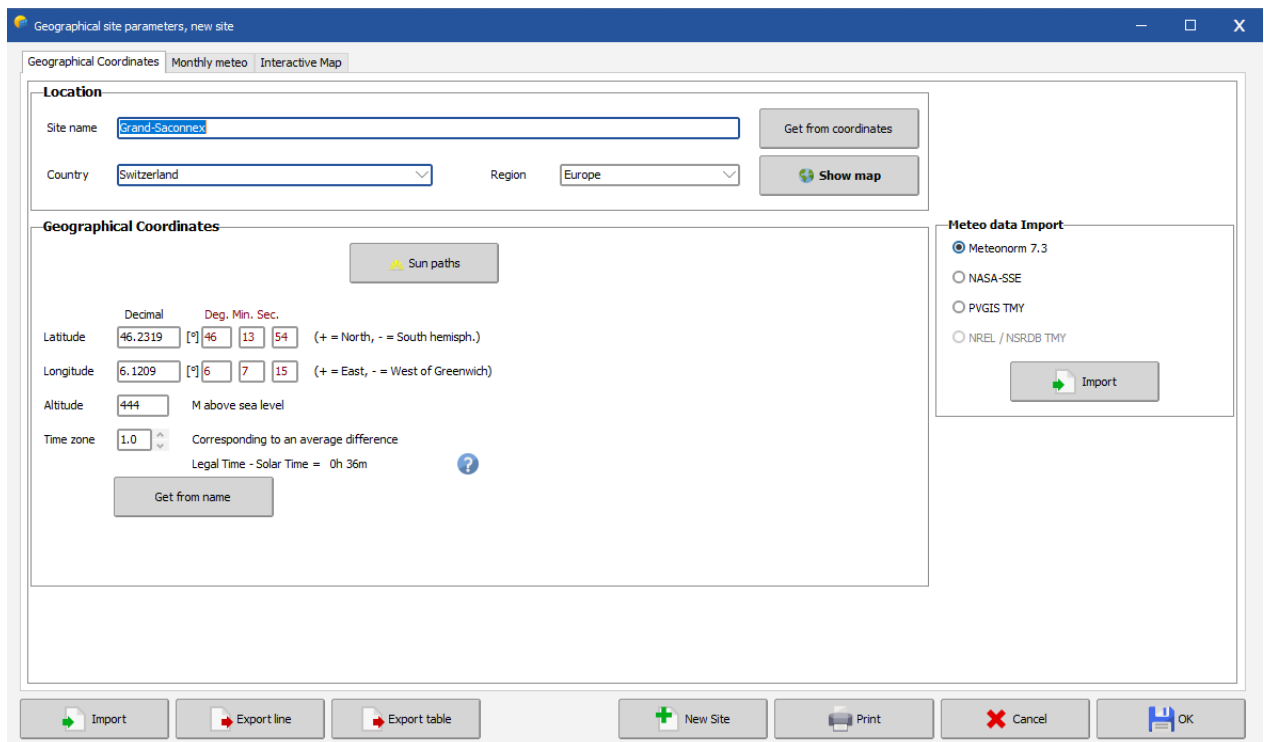


The tab "Interactive Map" allows you to select interactively the location of your site using Google maps. You can click on the map to choose the site location. You can zoom into and out of the map, and you can use the search field to find the name of a place. When the red mark is at the desired place, click on "Import" to transfer the location to the "Geographical Coordinates" tab.

In case of internet connection problems, you can always define the coordinates and all site information in the "Geographical Coordinates" tab without using the map.

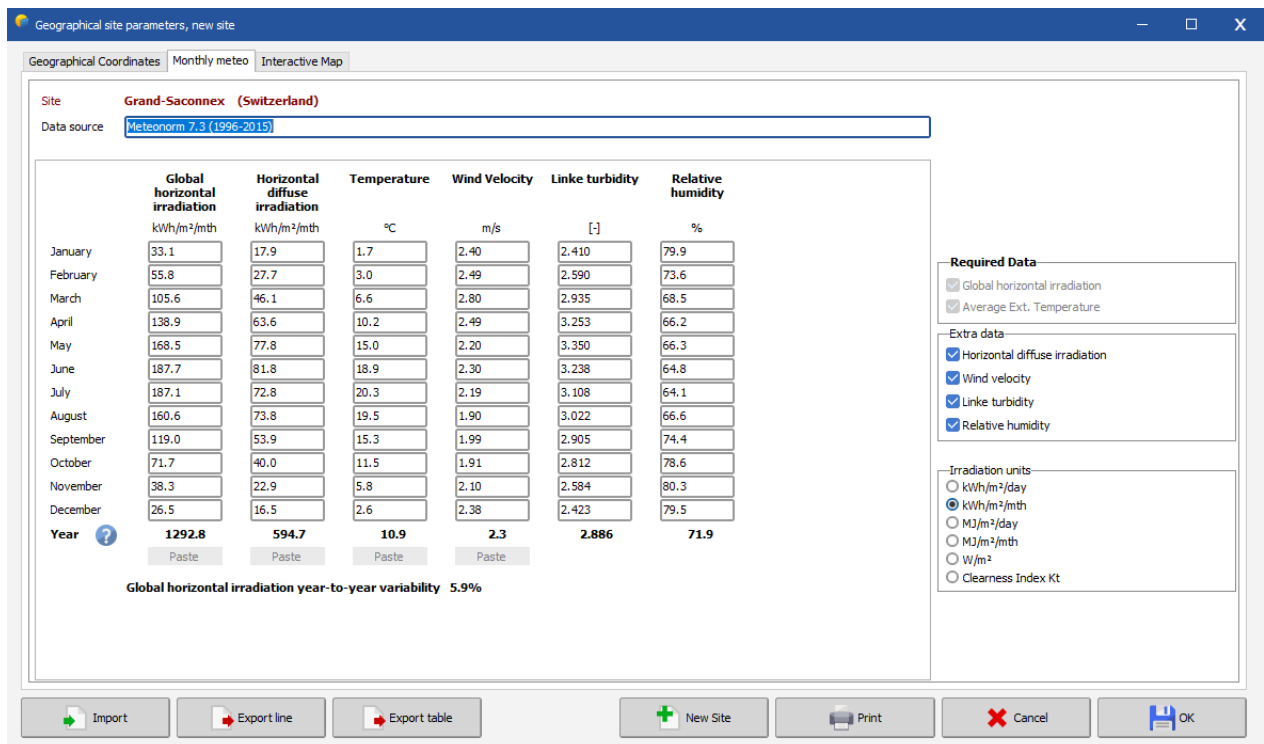
In the tab "Geographical coordinates" you define:

- | | |
|---------------------------|---|
| Site name: | Choose a name for the site of your project |
| Country and Region: | Normally you do not need to change this |
| Geographical Coordinates: | The Latitude, Longitude, Altitude (which uniquely define the (x,y,z) coordinates of a given point of the earth), and the time zone. Ex: for central Europe, the wintertime corresponds to UTC+1, while the summertime is UTC+2. You can obtain accurate Latitude/Longitude coordinates from your GPS or Google Earth. |



In this dialog you can also:

- see the sun paths corresponding to your site,
- import/export the site data with "copy/paste" (for example into or from a spreadsheet like EXCEL),
- print a complete form with the data of this site.
- If you define a new site (by its geographical coordinates), PVsyst will import by default the data from METEONORM, which is a reliable source for monthly meteorological data.



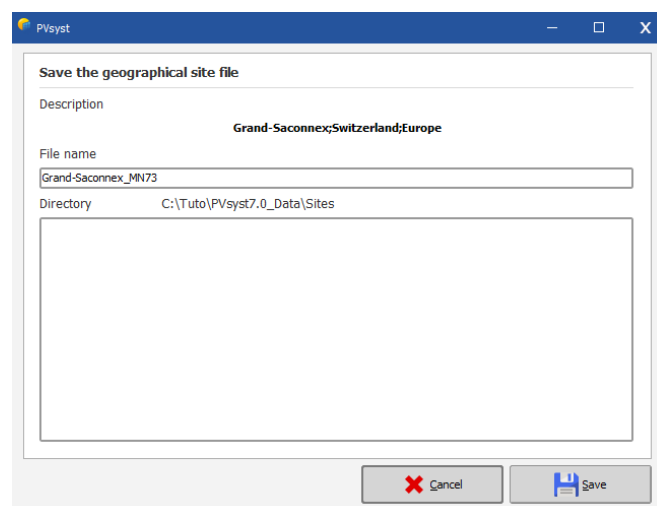
Once monthly data has been imported, the tab "Monthly meteo" will display the monthly values. Values for Global irradiance and Temperature are mandatory input for the simulation. Global diffuse and wind velocity are optional. They will be evaluated by models when necessary.

Data source: Describe the source of the monthly meteo data, PVsyst will fill this field when you import the data from a predefined source.

Irradiation units: You can choose the units in which the global and diffuse irradiation values are displayed. This is useful to import or compare to data sources that use units different from the PVsyst default.

Data fields: You can edit these values by hand. If data are given as lines or columns in a spreadsheet, you can "paste" entire columns at a time.

After defining or modifying a site, the program will ask whether you want to keep your modifications, and if so it will modify or create a new site in the database (i.e. a new file in the \Sites\ directory).



Managing Favorites

The sites will normally have a white background in the selection list. Green entries are sites that have been defined as favorites by the user. New sites that are created by the user are put into favorites by default. They can be removed from the list of favorites by clicking on 'Set Favorites', selecting the site from the list and clicking on 'Close Favorites'. In the same way you can add more sites to the list of favorites.

PVsyst's built-in database

The built-in site database of PVsyst is based on the METEONORM database, which defines about 2'500 "Stations" for which measured irradiances on the ground are available.

In Meteonorm, data of all other sites are interpolated between the three nearest stations and satellite data. For most of the European countries, all the measured stations available in Meteonorm are inside the PVsyst built-in database. But for many other regions of the world, the measured "Stations" are very scarce, and Meteonorm uses Satellite data to complete this information.

Besides the built-in database, PVsyst also offers tools for easily importing meteo data from many other sources. This will be described in the chapter "Importing data from predefined sources".

The year 1990

In PVsyst, we have adopted the convention to label all data which don't correspond to really measured data at a given time as 1990. This is the case, namely, of all synthetic hourly data or TMY data files.

3- Synthetic data generation

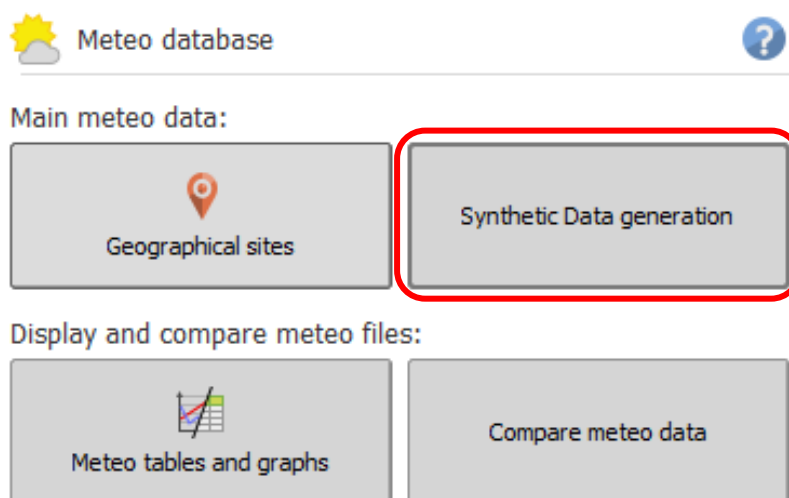
The simulation process in PVsyst operates on hourly values. If no measured hourly data is available, PVsyst constructs a set of hourly meteo data from the monthly values. The hourly data will be stored in *.MET files, which reside in the \Meteo\ directory.

For the irradiance, the synthetic generation of hourly values from monthly averages is performed by using stochastic models that have been developed by the Collares-Pereira team in the 1980's. This model first generates a sequence of daily values, and then a sequence of 24 hourly values per day, using Markov transition matrices.

For the temperatures there is no model predicting the temperature evolution as function of the daily irradiation, as the temperatures are mostly governed by atmospheric circulations. Therefore, the sequence of daily temperatures is mostly random, with constraints on the transition from one day to the other. Within a day, the temperature profile is well correlated to the irradiance. This results in a sinusoidal-like shape over 24 h, with an amplitude proportional to the daily irradiation and a phase shift of around 3 hours with respect to the highest solar angle (the warmest hours are at around 3:00 solar time).

Please note that the generation of the hourly values is a fully random process, two successive generations performed with the same monthly data will result in different hourly values. When performing simulations of grid-connected systems, this may produce variations of 0.5 to 1% in the yearly result.

To generate a synthetic hourly file, head to the “Synthetic data generation” dialog.



First choose a site holding monthly meteo data. Now you can specify:

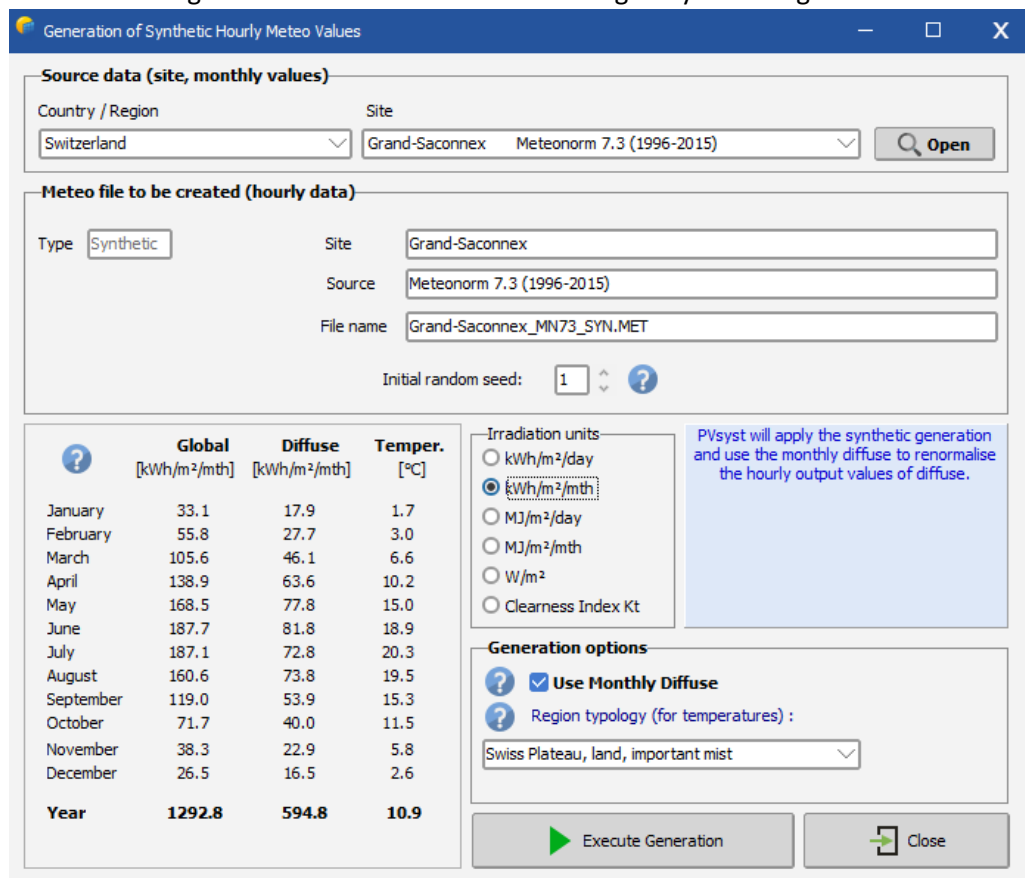
Site name: This is the site name that will be used in the .MET file. You can have it different from the one used in the .SIT file if you want to generate more than one .MET file for the same site. This site name will be visible if you select a meteo file for your project.

Source: The source of the data. This is automatically filled in and normally you do not need to change this. This information will also be visible when you select a meteo file for your project.

File name: Select a unique name for a new file or overwrite an existing one.

Press the “Execute Generation” button.

The successful generation of the data is acknowledged by a message



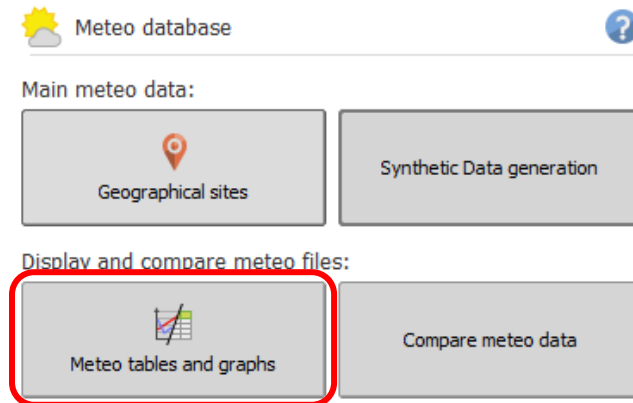
There are some options that you will in principle never modify:

"Use monthly diffuse": The diffuse part is evaluated using the Liu-Jordan hourly correlation. At the end of each month, the diffuse values are renormalized in order to match the specified monthly diffuse.

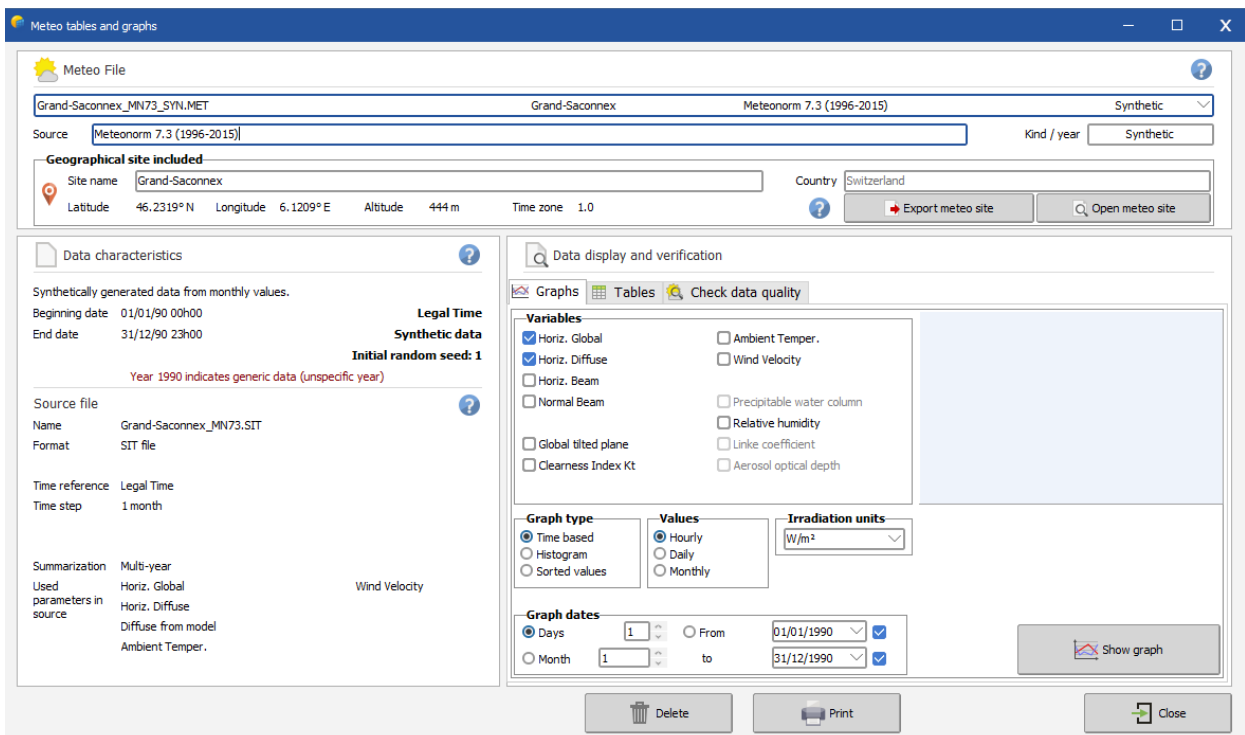
Region topology: The temperature model that is used by PVsyst was established using Swiss data, with a detailed analysis of climate type dependence. It is possible to choose one of the topology types that are defined for this model, but the differences between all these options are very small (slight coupling differences between irradiance and amplitude, or inertial shifts). If you are unsure which option to use, select the PVsyst default “Swiss Plateau, land, important mist”.

4- Meteo tables and graphs

In PVsyst, the hourly values are stored in *.MET files, they are stored in the \Meteo\ subfolder in your workspace. For visualizing their contents, you must use the button “Meteo Tables and Graphs” in the "Tools" group.



The “Meteo Tables and Graphs” dialog will appear on the screen. After choosing a meteo file, information on the site is shown at the top and the type of data is displayed on the left side of the dialog. On the right side it is possible to select if you would like to have a graphical output ("Graphs") or a table ("Tables"). Both options allow you to look at hourly, daily or monthly values. The third tab “Check data quality” allows you to perform some deeper analysis on the data quality. This step is very important, especially if you imported data with custom format.



Graphical output

When the tab "Graphs" is selected you can first select the Graph type:

- Time evolution: Plots the data values against time.
- Histogram: Plots a distribution of the values.
- Sorted values: Displays all values in decreasing order.

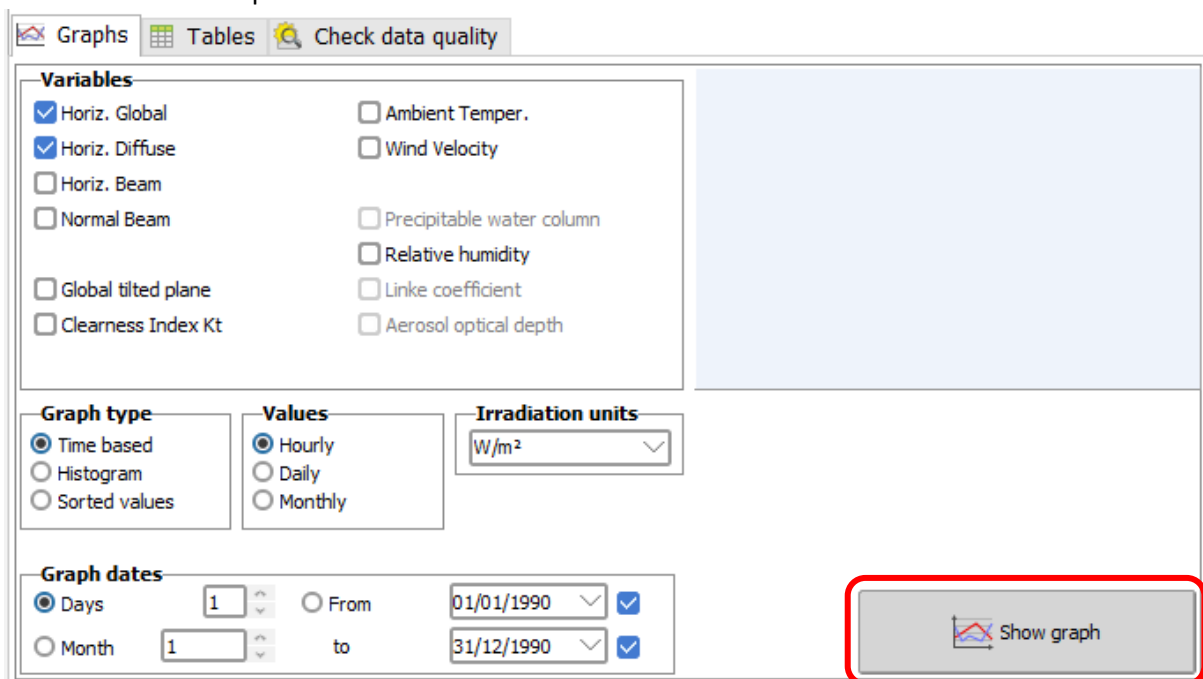
The main variables preselected are:

- Horizontal global irradiance
- Horizontal diffuse irradiance

Note that since some of the other options exclude each other you will not be able to select all the variables at the same time.

Graphs of hourly values

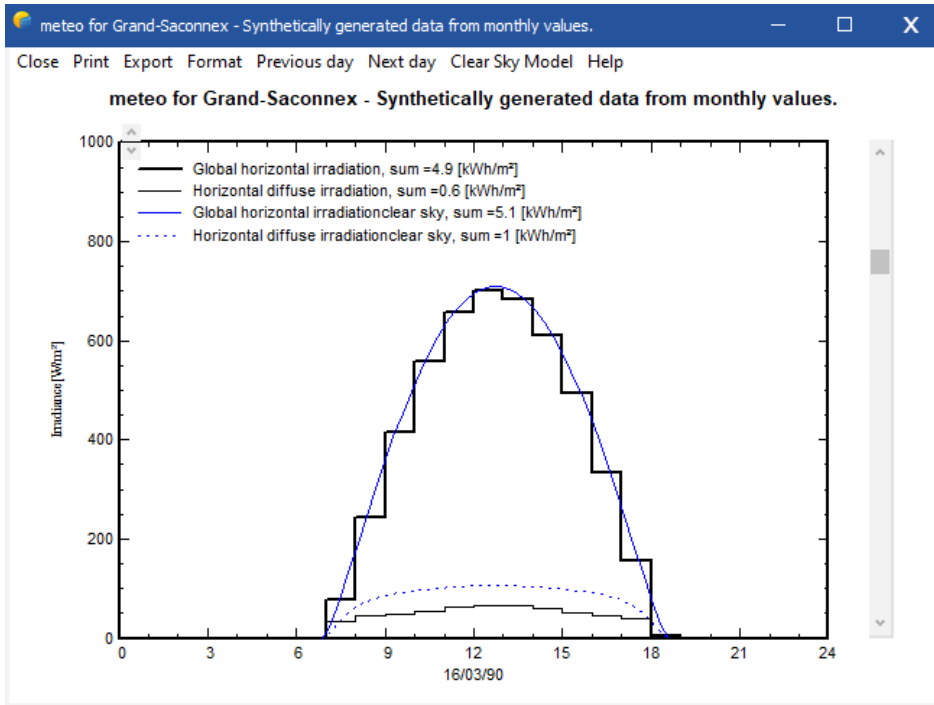
In the "Graph" tab, choose "Time evolution", "Hourly", "Global" and "Diffuse" (default selection), and click the button "Graph".



The screenshot shows the 'Graphs' tab interface with the following settings:

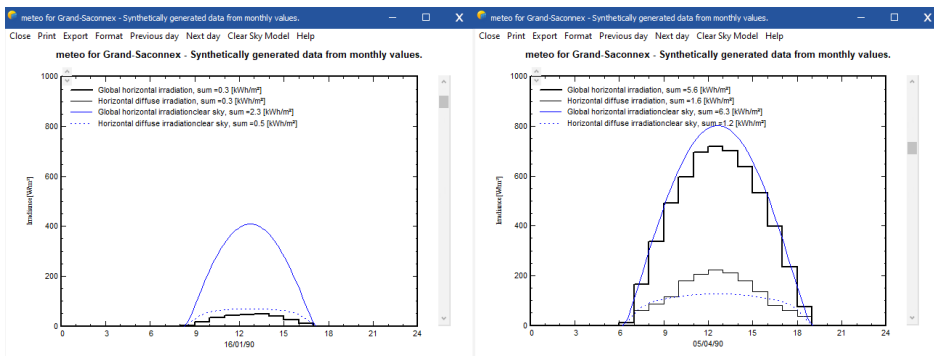
- Variables:**
 - Horiz. Global
 - Horiz. Diffuse
 - Horiz. Beam
 - Normal Beam
 - Global tilted plane
 - Clearness Index Kt
 - Ambient Temper.
 - Wind Velocity
 - Precipitable water column
 - Relative humidity
 - Linke coefficient
 - Aerosol optical depth
- Graph type:**
 - Time based
 - Histogram
 - Sorted values
- Values:**
 - Hourly
 - Daily
 - Monthly
- Irradiation units:** W/m²
- Graph dates:**
 - Days: 1
 - From: 01/01/1990
 - to: 31/12/1990
- Show graph button:** A button with a graph icon and the text 'Show graph' is highlighted with a red border.

This will open a graph with the hourly meteo values, and you can walk through your entire data using the Scrollbar on the right. The plot includes a blue line, which represents the Clear sky model, superimposed on your data. It is very important that the data is not shifted on the time axis with respect to the blue line. This will always be the case for the synthetic data, or the data imported from known sources using the "Import meteo data" PVsyst tool.



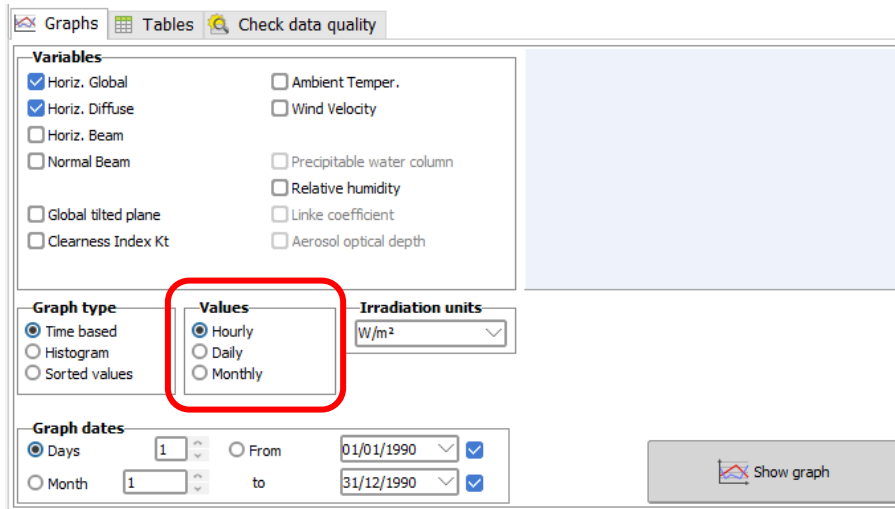
But this may be different for personal data that is imported with the "custom files" tool. If the data are not matching the Clear day model and are shifted toward morning or evening, this indicates that the time stamps of the data don't match the PVsyst standard, and all the models using solar geometry will not work properly.

When walking through the year, you will see that clear conditions, where the horizontal global irradiation matches well the clear sky model, correspond to a low diffuse component. When the sun becomes hazy and the horizontal global irradiation is well below the blue line of the clear sky model, the diffuse part increases. The difference between the global and the diffuse corresponds to the beam component.



Graphs of daily values

To get a plot with daily values, select “Daily” in the “Values” selection.



The screenshot shows the PVsyst software interface with the 'Values' selection menu highlighted by a red box. The 'Values' menu is located in the middle section of the interface, below the 'Variables' section and above the 'Graph dates' section. The 'Values' menu has three options: 'Hourly' (selected), 'Daily', and 'Monthly'. The 'Irradiation units' dropdown menu is set to 'W/m²'. The 'Graph type' section has 'Time based' selected. The 'Graph dates' section has 'Days' selected, with a range from '01/01/1990' to '31/12/1990'. A 'Show graph' button is visible in the bottom right corner.

You will get a scatter plot of the irradiation values against the day of the year. Each point represents the irradiance for a single day in [kWh/m²/day]. The blue envelope curve describes the Clear sky model. This plot gives a quick crosscheck of the quality of the data. The Clear sky model is an upper limit for the measured irradiance, and none of the points should exceed this curve significantly (more than 3-5%). If larger discrepancies are seen, this indicates that the data are not good.

Tables

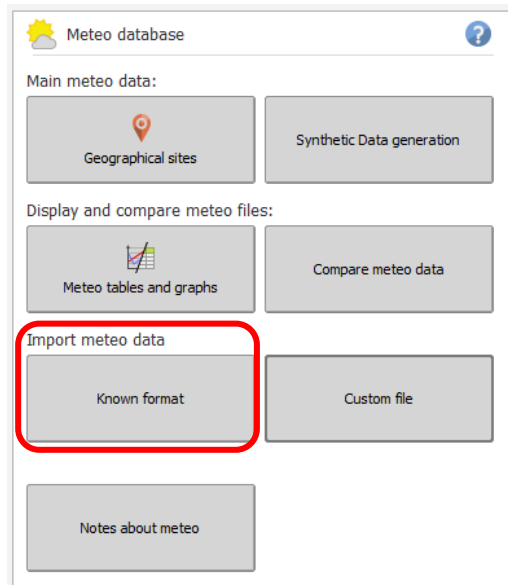
You can also show your data as tables. You can choose up to 8 values to be put into the table at the same time, including the irradiance on a tilted plane (transposition model) or the normal beam component (for concentration).

As for each data table in PVsyst, you have the possibility to:

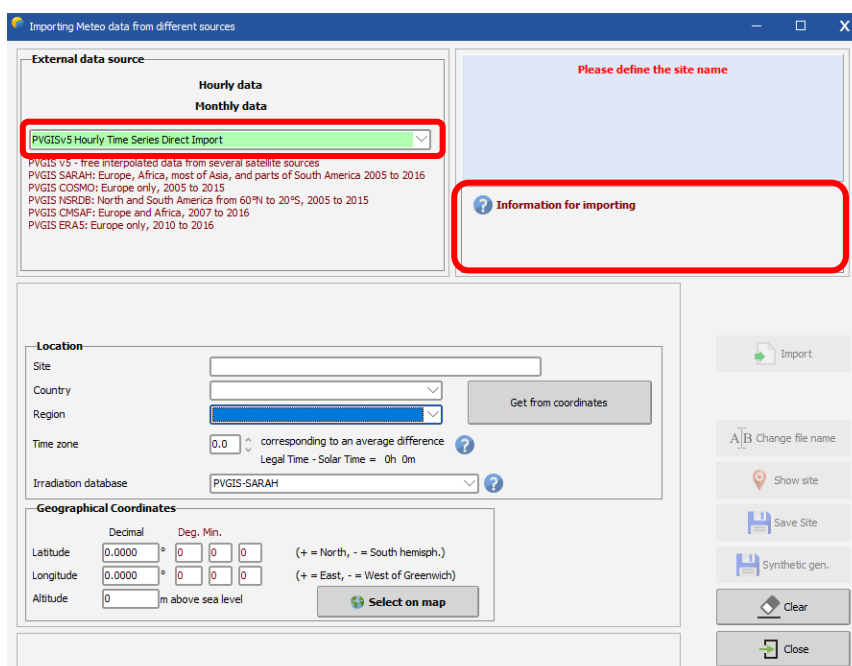
- Print the table: You will get the Print dialog, where you can add comments to the header of the table and specify the time range for which you want to print the values.
- Export / Copy as text: This will "copy" the full table to the clipboard, from where so you can "Paste" it directly into an external spreadsheet like MS Excel. Remember that in MS EXCEL, the imported data will usually be gathered in one single column. To expand the data to cells you have to use the standard EXCEL options for importing data: menu “Data” / “Convert...”, and here you should choose “Delimited” / “Semicolon” separator.
NB: The data will be copied with a decimal point. If you are using decimal commas (international preferences in Windows), you will perhaps have to change all points to commas.
- Export / Copy as image: Will copy a bitmap image of the table to the clipboard, from where you can paste it into a report.
- Export / Copy to file: Will create a CSV file which you can open in any spreadsheet program.
NB: Due to contractual constraints of the METEONORM provider, the hourly tables of METEONORM data cannot be exported.

5- Importing Meteo data from predefined sources

In PVsyst it is also possible to import meteorological data from external sources. There is a set of predefined data sources for which importing has been semi-automatized. To access this option, click the "Known format" button in the Meteo database window.



The "Import Meteo Data" dialog will pop up, which gives access to the easy-to-use tools for importing meteo data from predefined sources. If you press F1 you will obtain a detailed description of the available data sources. After choosing a source, clicking on "Information for importing" button will open the online help window with a detailed procedure for importing the data. Please follow it carefully and pay attention to the messages written in red at the top of the screen during your progress.



The data from the different sources are not always completely comparable. The online Help of PVsyst includes a comparison of such data for 12 sites from the north to the south of Europe.

The following section contains an example on how to import meteorological data from the PVGIS project.

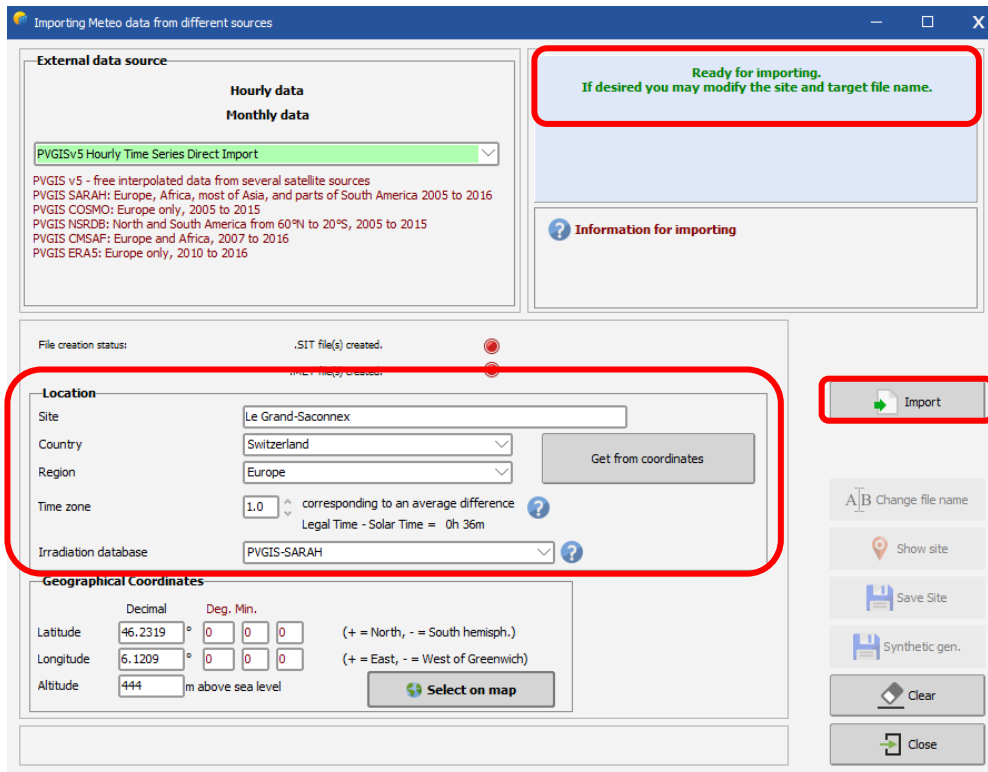
Importing PVGIS Data

PVGIS (PhotoVoltaic Geographical Information System) is a research, demonstration and policy-support instrument for solar energy resource, part of the SOLAREC action at the JRC Renewable Energies unit of the European Communities (Ispra). You will find a complete description of this project at <https://ec.europa.eu/jrc/en/pvgis>. The PVGIS database covers Europe, Africa, most of Asia, part of South America, central and North America with data from NSRDB.

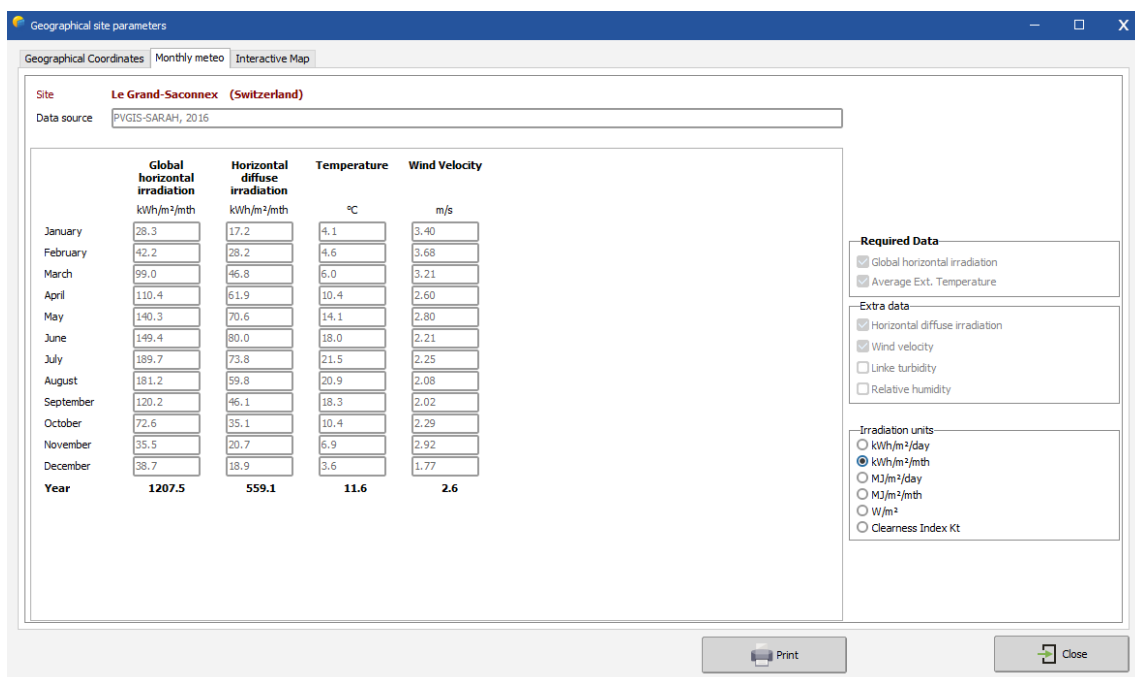
Importing PVGIS data is automatic after choosing the coordinates manually or from the map.

The screenshot shows the 'Importing Meteo data from different sources' window. The 'External data source' section is set to 'Hourly data' and 'PVGISv5 Hourly Time Series Direct Import' is selected. Below this, a list of data sources is provided: PVGIS v5 - free interpolated data from several satellite sources; PVGIS SARAH: Europe, Africa, most of Asia, and parts of South America 2005 to 2016; PVGIS COSMO: Europe only, 2005 to 2015; PVGIS NSRDB: North and South America from 60°N to 20°S, 2005 to 2015; PVGIS CMSAF: Europe and Africa, 2007 to 2016; PVGIS ERA5: Europe only, 2010 to 2016. The 'Location' section includes fields for Site, Country, Region, Time zone, and Irradiation database. A 'Get from coordinates' button is highlighted with a red box. The 'Geographical Coordinates' section has input fields for Latitude, Longitude, and Altitude. A 'Select on map' button is also highlighted with a red box. On the right side of the window, there is a vertical toolbar with buttons for 'Import', 'Change file name', 'Show site', 'Save Site', 'Synthetic gen.', 'Clear', and 'Close'.

After the coordinates have been set and the rest of the data are filled, you can press the button "Import" to obtain a full timeseries for 10+ years of hourly data. Each year imported creates a separate .MET file.



When the .MET files have been saved, you can press “Save Site” to save a site with monthly data based on the average of the timeseries. After saving the site you can generate a synthetic hourly meteo file based on the average of the timeseries by pressing the “Synthetic gen.” button. The dialog “Generation of Synthetic Hourly Meteo Values” will pop up. Click on “Execute Generation” and PVsyst will create the .MET file with the hourly values based on the monthly averages of the timeseries.

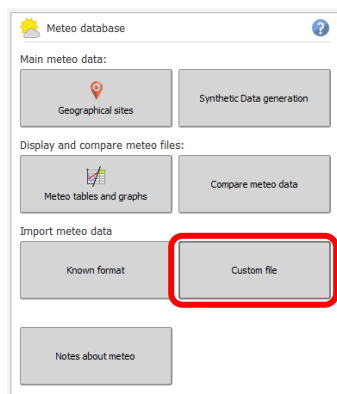


6- Importing Meteo data from custom file

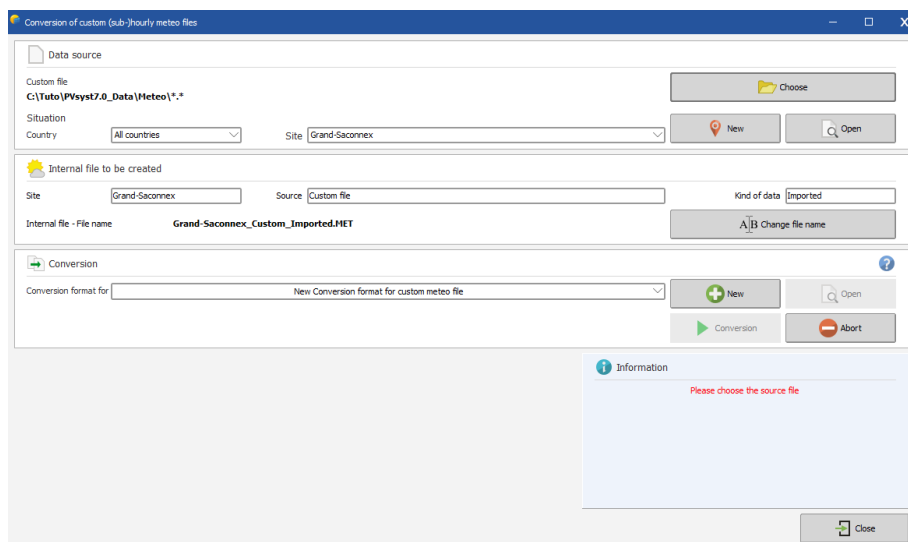
If none of the predefined data sources contains satisfactory data for your project, or if you have access to a better data source, you can import this data to PVsyst from custom files.

Please note, that measuring and analyzing meteorological data is a complex and difficult task. It is very easy to get biased or wrong results due to wrong calibration of instruments or inadequate analysis tools. If you want to use self-measured data, please make sure that it has been measured with adapted equipment and analyzed by an expert with the necessary skills. Always perform basic crosschecks on the data as explained in this tutorial. The meteorological data is at the origin of the main uncertainties of the simulation. Poorly measured or processed data can lead to significant deviations of the results.

To import custom meteorological data, click on “Custom file” in the Database window:



The “Conversion of custom (sub-) hourly meteo files” dialog will pop up.



Carefully follow each step of the conversion dialog.

- Choose your source file, which can reside anywhere on your disk.
- Choose an existing site or create a new site to link the resulting .MET file to the correct coordinates.

- Give a significant name to the internal file to be created. This will identify the file in the meteo or measured data list boxes. Please carefully choose this title since you will not be able to change it after conversion.
- Choose an existing or create a new format file that will tell how PVsyst must read the file.
- In some cases (depending on the format file), the program will still ask for the beginning date or the year.

This list is not exhaustive, for detailed instructions please refer to the online help of PVsyst. When you are ready, press the "Start Conversion" button.

During execution, a control executing window displays the contents of the source-file's line currently being processed, as well as the converted meteo values, which will be transcribed on the internal destination-file. After conversion, you are advised to check your file with the "Tables and Graphs" tool (either for meteo or for measured data files), and carefully check the time shift of your data.

Detailed example of importing a custom file

For this example, we will use the file "METEO_PVsyst_Standard_Geneva_GPI.csv" which can be found in the PVsyst workspace under "Templates" (if missing, "Manage" your workspace and press "Reload templates"). The file contains meteorological data for the year 2006 in hourly steps for Geneva in Switzerland. There are several quantities stored in this file, among which there is the ambient temperature and the Global irradiance measured on a plane with a tilt of 30°. These two are the values we will use in the present example.

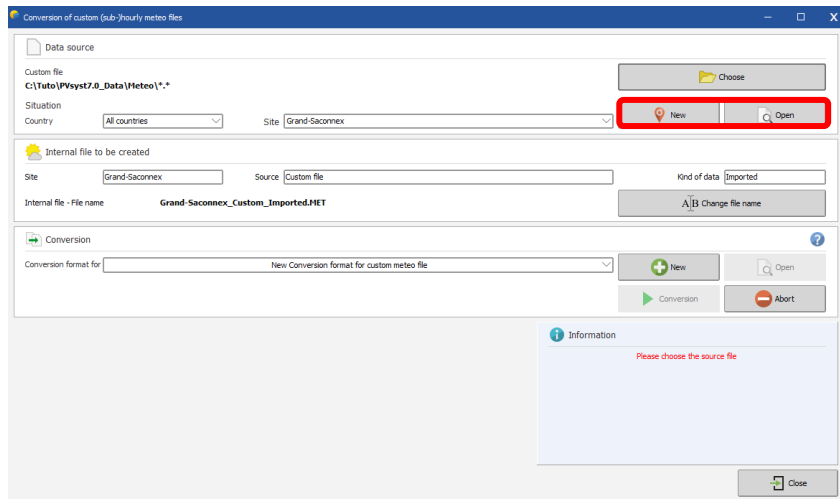
After opening "Databases" in the main PVsyst window and selecting "Custom file", you will get the "Conversion of custom (sub-) hourly meteo files" dialog, which is divided into four fields:

Data Source
 Hourly file to be created
 Conversion
 Info – Warning

We will go through the first three of them in detail. The "Info – Warning" field will give you information and hints to guide you through the different steps that are required for the successful importing of the data.

Data Source

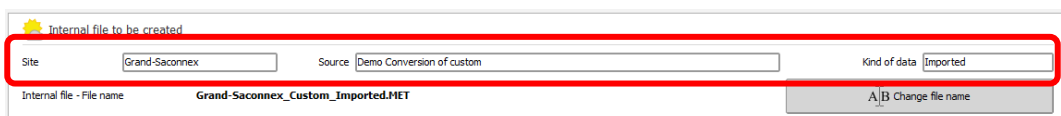
When you import meteorological data, you will take an existing text file with the data and create a new file in the PVsyst format with hourly meteorological values. This file will be of type *.MET and it will be associated to the site that you select in "Data Source". You can have several files with hourly values associated to the same site. Make sure that you have already created the site to which you want to attach the *.MET file that will be created. In the dialog click on "Choose". A file selection dialog will pop up where you can search for the data file. The default filter will display files of type *.DAT, *.TXT and *.CSV.



Once you have selected the file you specify a site for this data. To select the site you first select a country or region to narrow down the choices in the “Site” drop down list.



Next you give a small description of the data that will be attached to the output file. This information will be displayed in PVsyst in dialogs or reports as description of the Meteo file (*.MET file). You have three fields for which PVsyst proposes default values and that you can complete or change to any text you want. It is recommended to give short descriptions, so that they will fit into the dialog fields.



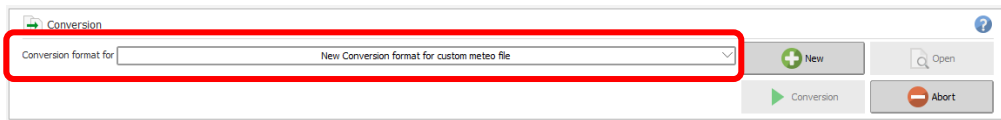
The three fields are:

- Site: The default will be the site name chosen in “Data Source”, but you can change or complete the name in this field.
- Source: Here you should put a short label describing from where the data has been retrieved, e.g. the source filename, or “Measured on site”, or “Provided by Meteo Inc.”, etc.
- Year/kind: Default is “imported”. Give a short label with the year for which this data is valid, and if it is hourly, daily or even sub-hourly data. Try not to exceed the visible width of the field, so you can read this label easily in other PVsyst dialogs.

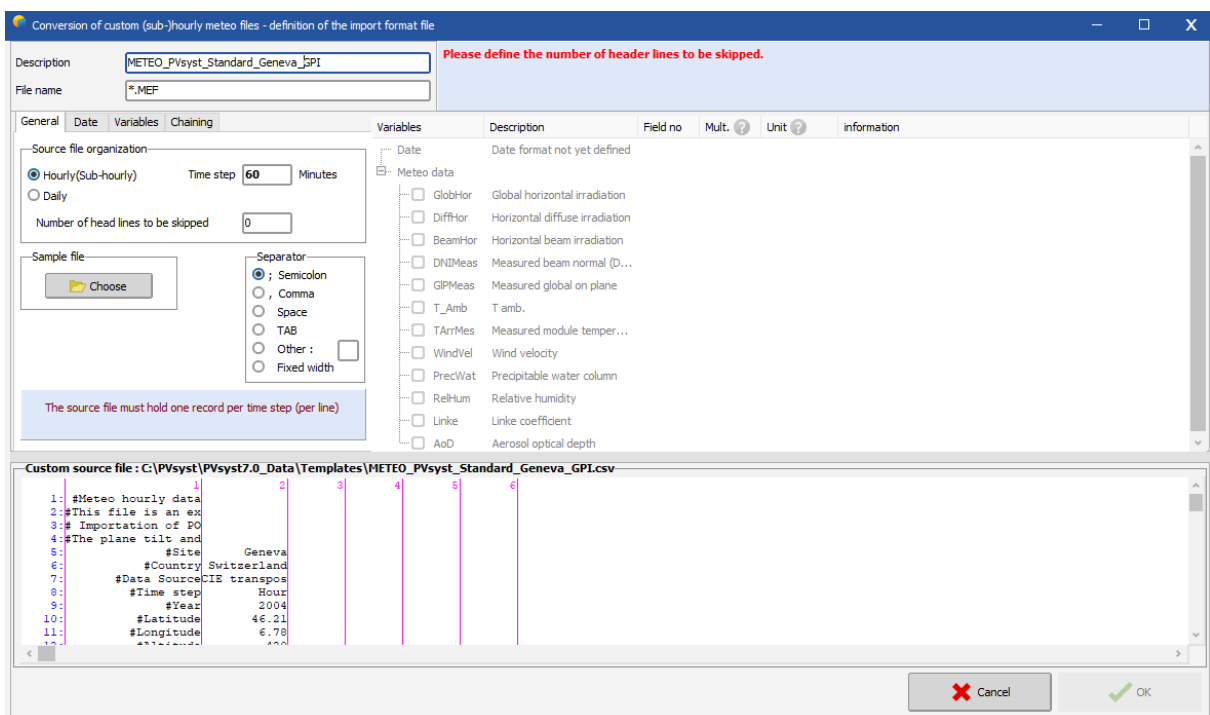
You can specify the output filename. PVsyst proposes a filename generated from the site name in the “Data Source” field. If your source file contains several data sets for the same site, like for different years or measurements in the horizontal and tilted plane, you are advised to change the output filename to something that will identify which portion of the data is being imported.

Define the data format

You need to tell PVsyst what kind of data will be imported from the text file, and where to find the data fields in the file. This information will be stored in an internal PVsyst file of type *.MEF, stored in \Meteo\. You can create as many of these format protocol files as you like.

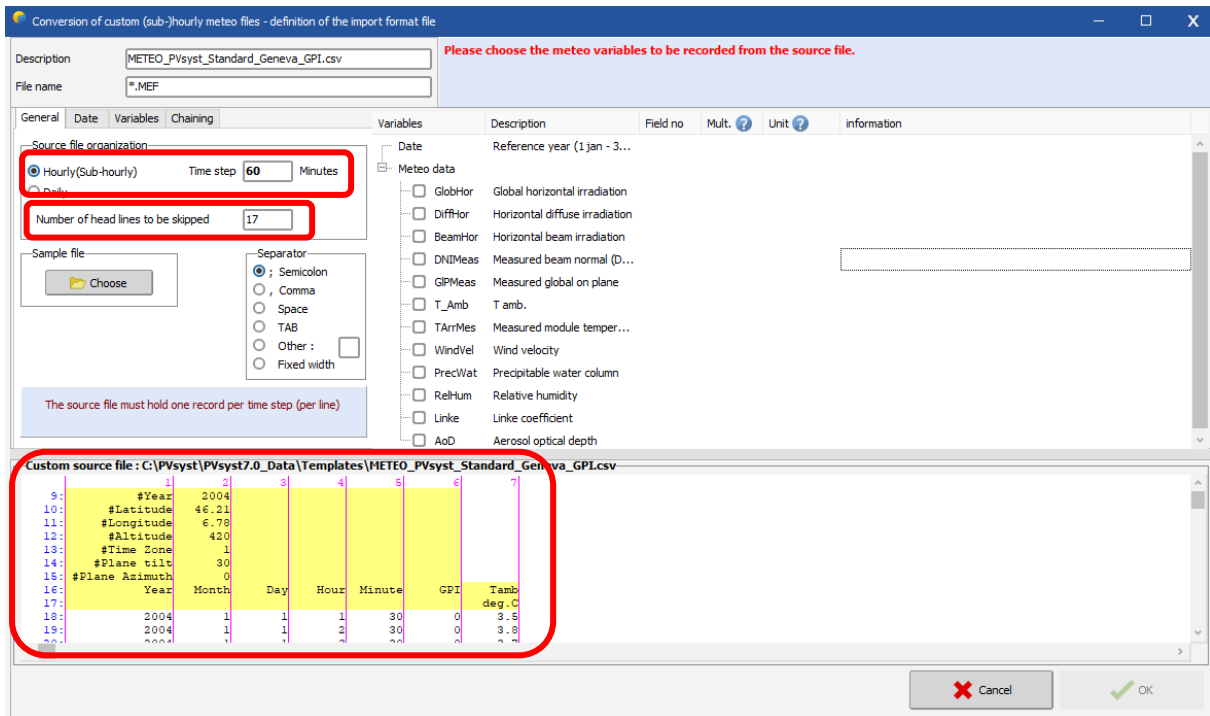


The dialog “Conversion of custom (sub) hourly meteo files – definition of the import format file” will pop up. It contains a field “Format description” where you must give a name that will identify this format protocol. The dialog contains four different tabs, “General”, “Date Format”, “Meteo Variables” and “Chaining files”. We will look in detail at the first three tabs. The last tab, “Chaining files”, is needed if your data is distributed among several files and will not be described in this example. The lower part of the dialog gives a visual feedback on how the format file that is being defined will apply to the content of the data source file. Here you can quickly check if the different values have been selected properly or if there are problems with the format definition.



Tab “General”

For the example file, which contains hourly data, you can leave the default selection “(Sub)-hourly data” with a time step of 60 min. The demo file also uses the default separator, which is a semicolon. In the lower part of the window you can check that the columns containing the data start on line 20 of the file. In the field “Number of head lines to be skipped” you enter therefore 19. In the bottom display the background of the skipped lines will now turn yellow and you can check that the first line with white background is also the first line containing data.

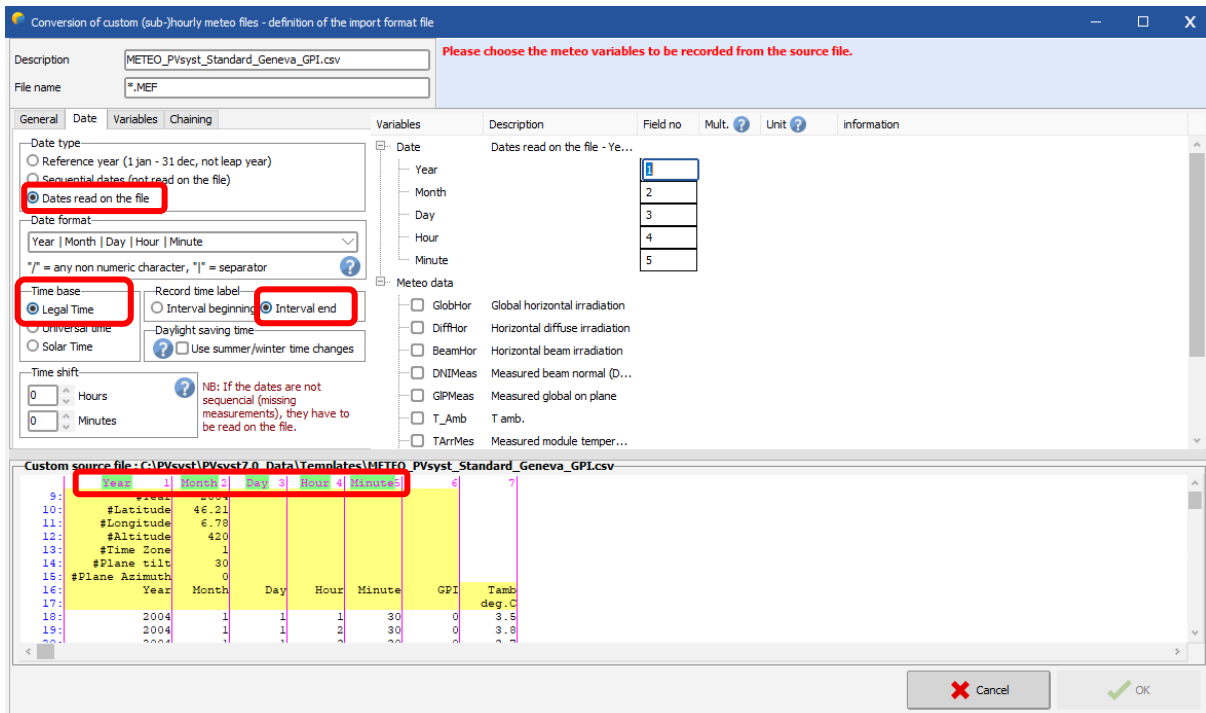
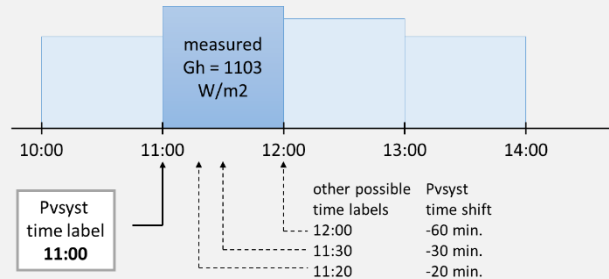


Tab “Date Format”

In this tab you specify how to read the time of your file. If possible, it is always better to select “Dates read on the file” to read the time, the other options “Reference year” and “Sequential dates” are very sensitive: any missing line of data introduces a time shift for all remaining lines of data. For our example you need to select “Dates read on the file” and choose the adequate format from the drop-down list “Date format”. In this case it is “DD/MM/(YY) / hh / mm”, which means that the date is ordered as Day/Month/Year hour / minute and that date and time are not in separate columns. The slashes are wildcards and represent any non-numeric character except for the column separators. Then on the right, in the column “Field no” you specify the column where the timestamp can be found, which is “1” in our example. In the bottom part of the dialog you will see a green header for the specified column. Finally, you need to specify how the time label is related to the measurements. In our example the time labels correspond to the end of the measurement.

Time Labels

In PVsyst any hourly value with a time stamp should be representative for the hour that follows the moment given by the time stamp. Thus, if for example the irradiance is measured and averaged over an hour, and then labelled with a timestamp corresponding to the end or middle of this interval, this will lead to a time shift.

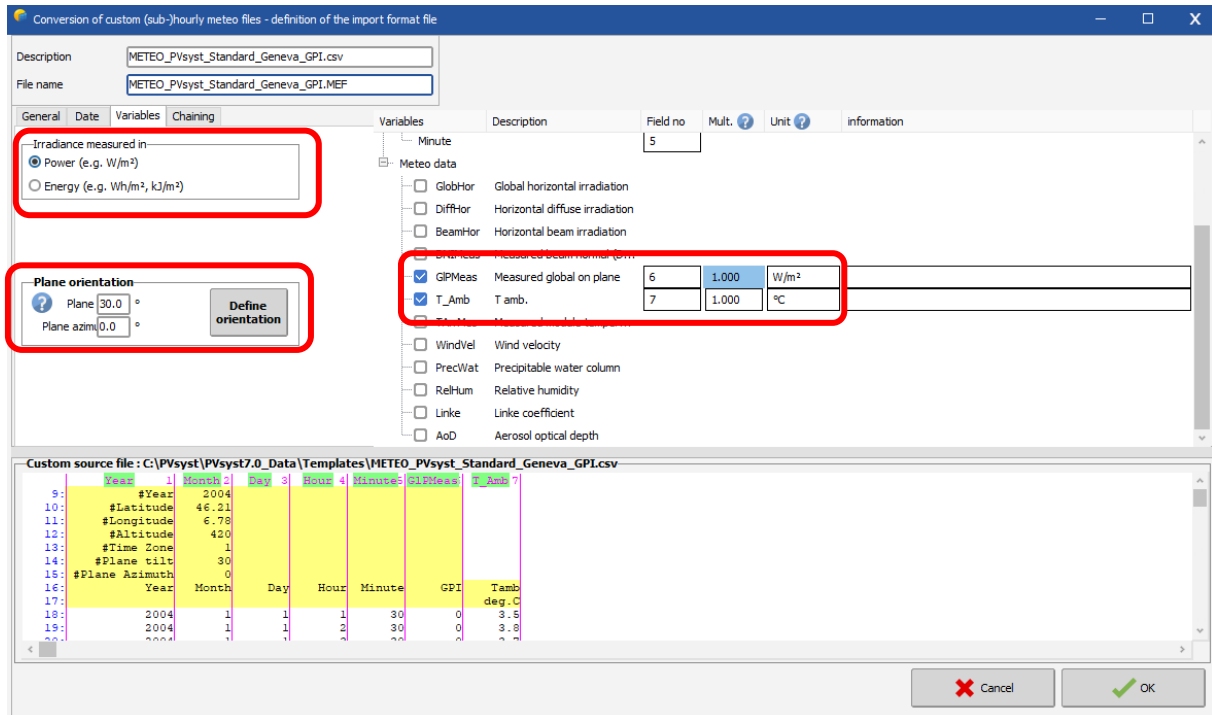


“Variables” selection

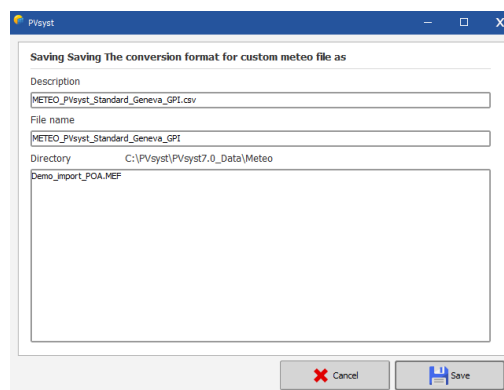
For the example you need to select “Global on tilted plane” and “Ambient temperature” in the right list. For each selected variable, the column for “Field no” in which the variable can be found in the file must be filled. In our example these are the columns 3 for the Irradiance and 4 for the temperature. The default units for these variables are W/m2 and °C respectively. If the data comes in different units you have the possibility to specify a factor which will be multiplied to the values. In our example file the units correspond to the default values and we can leave 1.000 as factor. Once you have specified a field number for a variable you will see that the corresponding column in the bottom part of the dialog gets a green header with the variable name. This allows to quickly control if the supplied values are correct.

Tab “Variables”

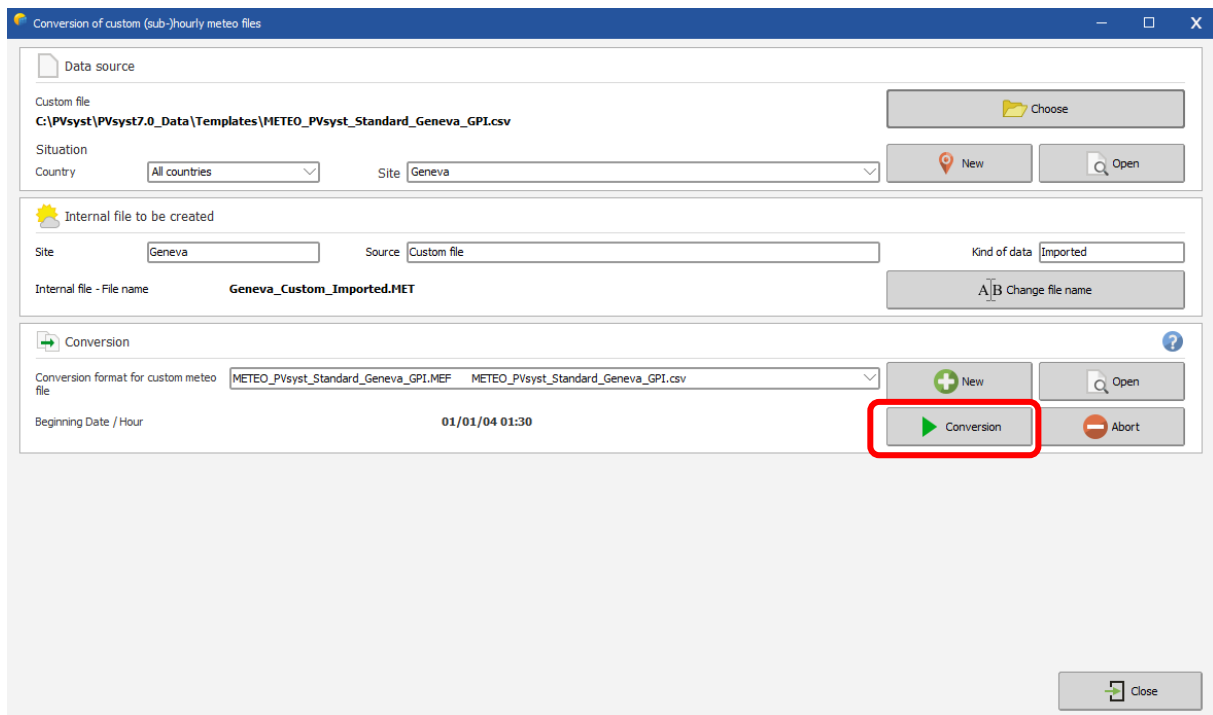
Since the measurements are for an inclined plane, you must specify tilt and azimuth of the plane in the “Variables” tab. In the field “Plane orientation” enter 30° for the tilt and leave the azimuth at zero (south). Note that this field will only be present if a variable for an inclined plane has been selected in the right part of the dialog.



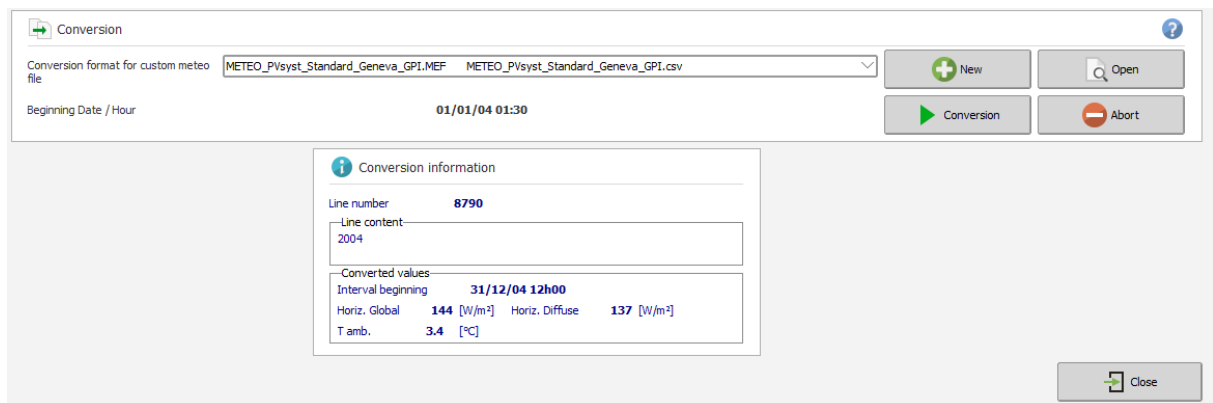
When all the specifications of the format file have been entered, define a proper description and file name then click on “OK” and you will be asked to save the newly defined format file. You can change a last time the filename before clicking on “Save”. If a file with the same name already exists, you will be asked to confirm to overwrite it.



After successfully saving the format file you will get back to the dialog «Conversion of custom meteo (sub)-hourly files». You can now click on « Start Conversion » to import the data from the custom file.

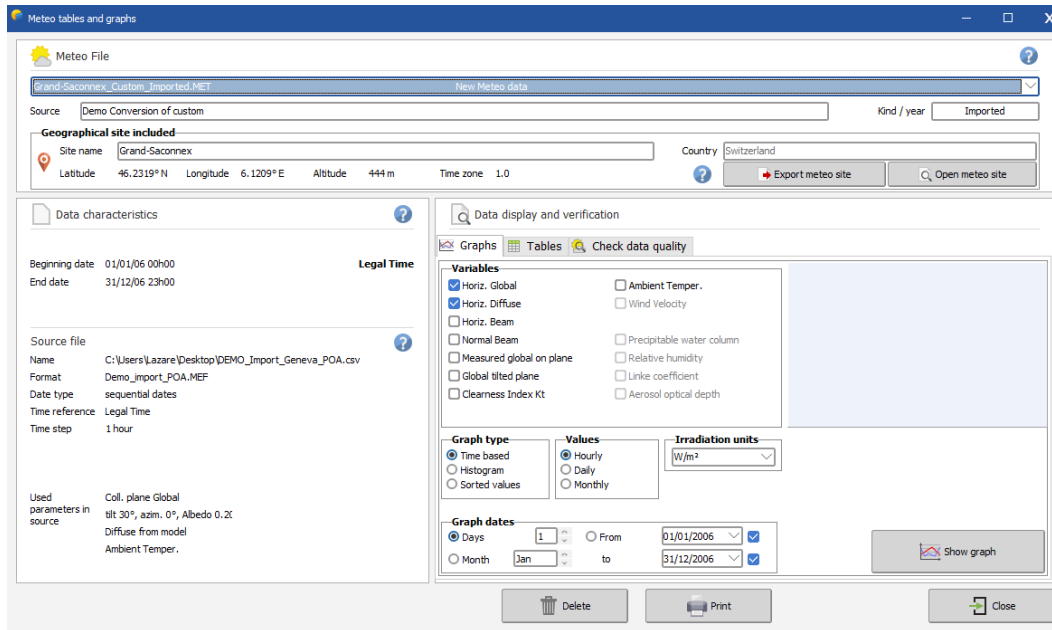


In the example file the timestamp in the last line of data is already the first hour of the following year (2007). You will be prompted with a corresponding warning message that you acknowledge by clicking on “Yes”. When the conversion is finished you will get a prompt where you click on “OK”.



The conversion is now finished, you should carefully check if the result does not contain any obvious error or inconsistency. A prompt asking if you want to open the dialog for visualizing the meteorological data will pop up. Click on “Yes” to open the dialog.

Check the imported data

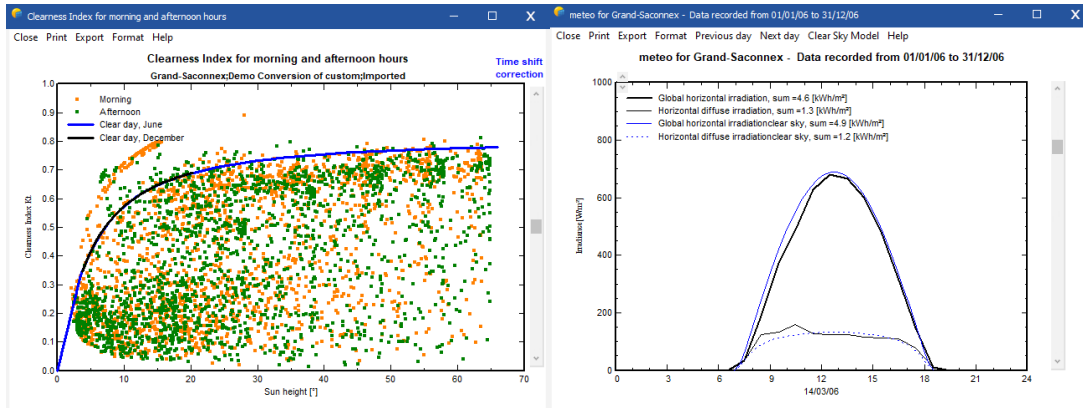


You should always perform some basic checks on the meteorological data that you want to use for a simulation of a PV installation. PVsyst offers a variety of tools to do this in the dialog “Meteo tables and graphs” that will pop up when you select “Yes” in the final prompt after importing a custom file as described in the previous paragraph.

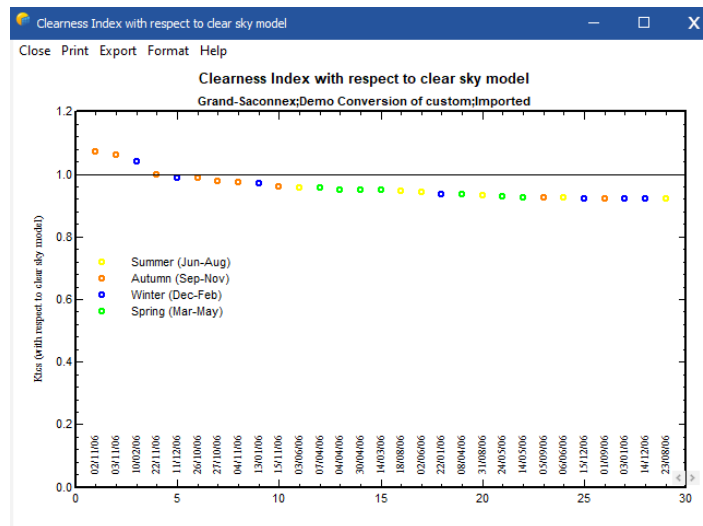
In the upper part of the dialog you will find the two fields “Source” and “Kind/Year” that you filled when creating the file. Below them there is detailed information on the site to which this meteo file has been associated. On the left side you will see the time range covered by the data and some of the details of the original file from which the data was imported and that you defined in the format file. The right side of the dialog contains the options to visualize the meteorological data and is subdivided into three tabs. Select the tab “Check data quality”. The tab contains a small control plot displaying the time shift that PVsyst estimates for the imported data. In the current example it should be close to zero.

There are two more ways to visualize a possible time shift contained in the data. The first one is to look at the clearness index for morning and afternoon hours. The orange dots show the clearness index as a function of the sun height in the morning, while the green dots show the same information for times after 12:00. Both colors should follow roughly the same distribution.

The second possibility is to compare the daily evolution of the measured irradiation (global and diffuse) to the clear sky model. If you press on the button “Monthly best clear days”, you will get a plot like the one shown below on the right side. PVsyst selects for each month of the year the day that fits best to the clear sky model. You can scroll through these 12 plots with the scrollbar on the right. You should see no significant horizontal shift between the measured data in black and the clear sky model in blue.

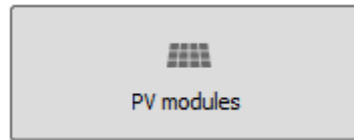


The third control plot “Best clear days Ktcs” displays the sorted Ktcs of all days of the year. The Ktcs is the clearness index referenced to the clear day model (not to the extraterrestrial). This graph gives an idea of the calibration of the irradiance sensor: the best days of the data should be close (within 5%) of the clear sky model, i.e. $Ktcs=1$.



Part 4: Components Management

1- PV Modules definition in Pvsyst



We will analyse the PV module's definitions in PVsyst (PAN files) by defining a **new module** from the datasheet.

NB: in practice, it is much easier to start from an **existing** similar component present in the database, modify its parameters according to the datasheets, and save it under a new file name, therefore creating a new component in your database.

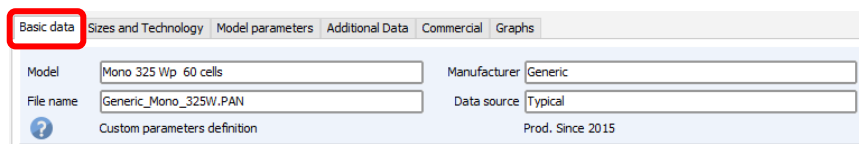
Defining a PV modules from Datasheets

All datasheets hold about the same information. The first page gives general features (usually rather "promotional"). The second page gives the technical specifications.

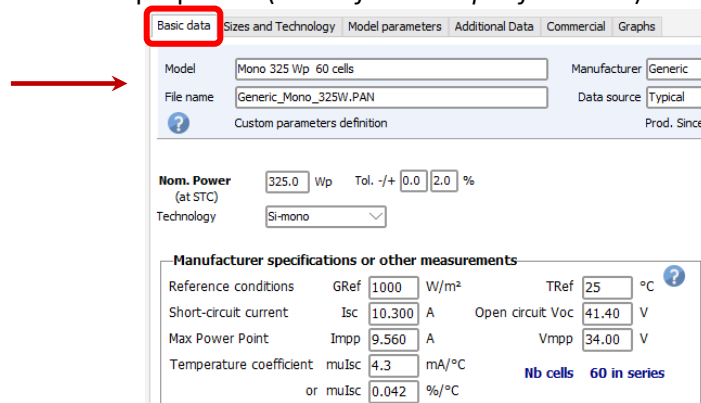
When opening a New PV module, we have to **define the "basic data"**:

- The Model,
- The manufacturer (if already existing in the DB, exactly the same name),
- The data source (and possibly date of recording)
- The file name, which is the Primary key in the database, and should be unique.

The convention in PVsyst is to define the filename as *Manufacturer_Model.PAN*



Then you define the main properties ("*Manufacturer Specifications*") of the module:



From the 2nd page of the Datasheet:

- Nom power: the nameplate definition of the module (here 250 Wp)
- Tolerance: usually specified as % of PNom; here through «*Pmpp range from ... to*».
- The technology: here Poly-crystalline (as mentioned elsewhere on the datasheet).
- The STC values I_{mpp} , V_{mpp} , I_{sc} , V_{oc} .

NB: The product $V_{mpp} * I_{mpp}$ should match the PNom (nameplate) within 0.2%.

Otherwise: *change the I_{mp} value to PNom / V_{mp} .*

Electrical data (at standard conditions (STC) irradiance 1000 watt/m², spectrum AM 1.5 at a cell temperature of 25° C)

Type	Nominal output P_{mpp}	Nominal voltage U_{mpp}	Nominal current I_{mpp}	Short circuit current I_{sc}	Open circuit voltage U_{oc}	Module conversion efficiency
AC-240P/156-60S	240 Wp	30.54 V	7.87 A	8.48 A	37.26 V	14.75 %
AC-245P/156-60S	245 Wp	30.91 V	7.93 A	8.57 A	37.46 V	15.06 %
AC-250P/156-60S	250 Wp	31.45 V	7.98 A	8.65 A	37.90 V	15.37 %
AC-255P/156-60S	255 Wp	31.56 V	8.10 A	8.70 A	38.20 V	15.67 %

- Efficiency at STC: not a parameter in PVsyst.
- NOCT: never specified in PVsyst!
- Reverse current feed: property of the by-pass diodes, not used in PVsyst.

Many datasheets mention operating parameters (I_{mpp} , V_{mpp} , I_{sc} , V_{oc}) under NOCT conditions.

This information is not well standardized; we don't use it in PVsyst.

Next page of the PV module dialog to be filled: "Sizes and technology"

The screenshot shows the 'Sizes and Technology' tab in the PVsyst software. The description is 'Generic, Mono 325 Wp 60 cells'. The 'Module' section includes fields for Length (1640 mm), Width (992 mm), Thickness (50.0 mm), Weight (19.80 kg), and Module area (1.627 m²). The 'Cells' section includes fields for In series (60), In parallel (1), Cell area (237.0 cm²), Total nb. cells (60), and Cells area (1.422 m²). The 'Maximum Array Voltage' section includes fields for Maximum voltage IEC (1000 V) and Maximum voltage UL (US) (600 V). The 'By-pass protection diodes' section includes a field for Nb. of submodules (3 /module) and radio buttons for Submodule partition: In length, Twin half cells, In width, and Shingled cells. The 'Module technology and specificities' section includes checkboxes for Tile module, CPV: Concentrating module, and Bifacial module. A text box contains the following information: Frame: Aluminium, Structure: 3,2 mm tempered, Connections: MC-4, Generic module for DEMO.

Usually you will find all these informations on the datasheet:

Design	
Frontside	0.13 inch (3,2 mm) hardened, low-reflection white glass
Cells	60 polycrystalline high efficiency cells 6 inch (156 x 156 mm)
Backside	Composite film
Frame	1.57 inch (40 mm) silver anodized aluminium frame
Mechanical data	
L x W x H	64.57 x 39.06 x 1.57 inch (1640 x 992 x 40 mm)
Weight	42,99 lbs (19,5 kg) with frame
Power connection	
Socket	Protection Class IP65 (3 bypass diodes)
Wire	43.3 inch, AWG 11
Plug-in system	Plug/socket IP67, MC4 mateable

Limit values	
System voltage	1000 VDC (UL) 1000 VDC (IEC)
NOCT (nominal operating cell temperature)*	45°C +/-2K
Max. load-carrying capacity	113 PSF
Reverse current feed IR	15.0 A

(No external voltages greater than Vo may be applied to the module)

* NOCT, irradiance 800W/m²; AM 1.5; wind speed 1m/s; Temperature 20°C

- **Module size:** mandatory, the area will determine the efficiency of the module.
- **Cells number:** the number in series is mandatory, as the model is defined for one cell.
- **Cells size:** if defined, the cell's area may be used for defining the efficiency at cell level.

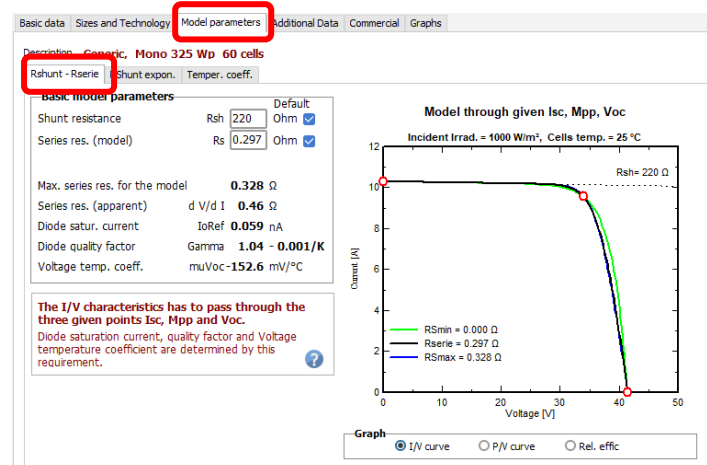
Usual values: Poly 6" = 15.6 cm x 15.6 cm = 243.3 cm², Mono: idem - 6 cm² = 237.3 cm²

- Maximum IEC or UL voltage: used for the array sizing (may be 1'500V for new modules).
- Number of by-pass diodes: used for the "Module layout" electrical losses calculation.
- You can add some informative features in the "Remarks» (5 lines of free text).

Third page: "Model parameters», page «Rshunt - Rserie"

On this page you should let the Rserie and Rshunt at their default value (checkboxes).

Sometimes you will have to check them several times.



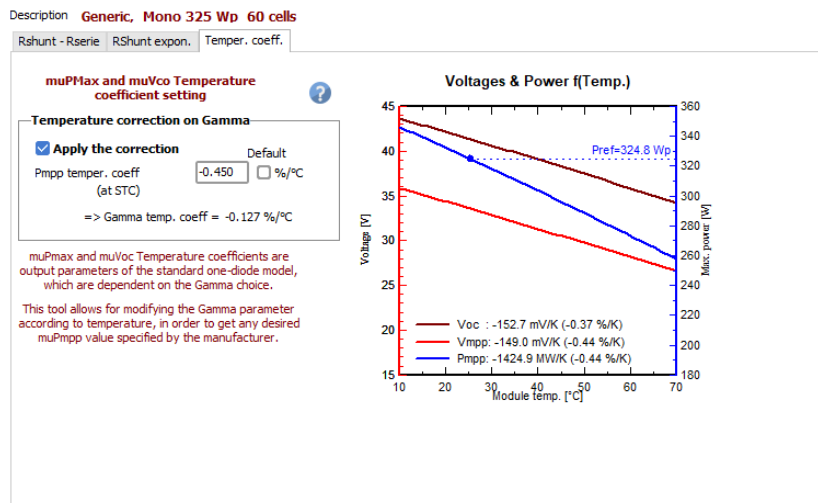
This page summarizes other parameters, as calculated when establishing the one-diode model.

NB: here the "muVoc" temperature coefficient is a result of the model. It cannot be matched to the datasheet's specified value. This coefficient is only used during the sizing (safety low-temperature condition), it is not involved in the simulation.

Third page: "Model parameters», page «Rshunt exponential"

In absence of really measured values, let the parameters at their default value.

Third page: "Model parameters», page «Temperature coefficient"



You define here the Pmpp temperature coefficient, as specified on the datasheet:

Temperature coefficients	
Voltage Uoc	-0.33 %/K
Current Isc	0.06 %/K
Output Pmpp	-0.44 %/K

This is a fundamental parameter for the simulation. PVsyst slightly modifies the normal One-diode model for getting the exact specified value.

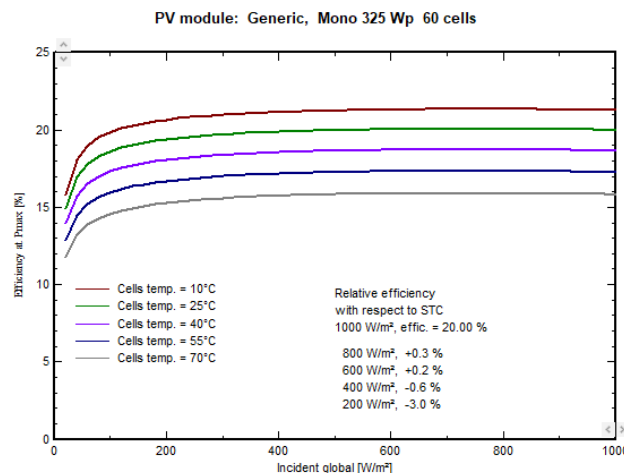
NB: The Current Isc temperature coefficient has been specified on the first page.

The Voltage Uoc temp. coefficient may not match the value calculated by the model (Page "Model parameters > Rshunt-RSerie).

This is not important, only used during the sizing for the voltage limits. If you want to use the value specified by the manufacturer, you can define on the page "Additional data» and choose to use it in the project's parameters.

"Graphs" page:

Now the model is fully determined: you can see the results either as graphs, or on the "Basic data" page > "Internal Model result tool", for any Irradiance and temperature conditions.



"Additional Data" page:

- "Secondary parameters": sometimes useful parameter,
- "IAM": if you want to define a specific IAM profile for this module (special AR coating, etc),
- "Low-light data": Explicitly specify low-light performances if measured.
- "Measured I/V curve": allows to determine the model parameters from a measured I/V curve.

Don't mind unless special requirements.

"Commercial" page:

- Coordinates of the manufacturer (web site).
- Availability (years of introduction and possible retrieval from the market).
- Prices of the component (you may specify them by yourself).

"Show optimization" button:

- Allows to modify the parameters and immediately see the effect on the behaviour of the module.

"Copy to table" button:

- Exports the PAN file definitions as one line to an EXCEL document

(see the template in c:\Program files (x86)\PVsyst6.x.x\PVsyst660_Data\UserData\Components.XLS).

2- Inverter definition in Pvsyst

Inverter definition in PVsyst



We will define the Inverter's definitions in PVsyst (.OND file) by defining a **new inverter** from the datasheet.

NB: in practice, it is much easier to start from an **existing** similar component present in the database, modify its parameters according to the datasheets, and save it under a new file name, therefore creating a new component in your database.

Defining an inverter from Datasheets

Most of the datasheets are rather similar. The first page gives general features, and the second page gives the technical specifications.

When opening a new inverter, we have to **define the "basic data"** (exactly like for a PV module):

- The Model,
- The manufacturer (if already existing in the DB, exactly the same name),
- The data source (and possibly date of recording)
- The file name, which is the Primary key in the database, and should be unique.

The convention in PVsyst is to define the filename as *Manufacturer_Model.OND*

A screenshot of the 'Main parameters' tab in the PVsyst software. The 'Main parameters' tab is highlighted with a red box. The form contains the following fields: Model: 7.5 kWac inverter; File name: Generic_7_5kW.OND; Manufacturer: Generic; Data source: Generic device; Prod. Since: 2020. There is also a 'Custom parameters definition' section with a question mark icon.

Then we have to find/identify the main parameters on the datasheet

A screenshot of a technical specifications page from a datasheet, divided into two main sections: 'Input side (DC PV field)' and 'Output side (AC grid)'.
Input side (DC PV field):
Minimum MPP Voltage: 150 V
Min. Voltage for PNom: N/A V
Maximum current per MPPT: N/A A
Nominal MPP Voltage: 450 V
Maximum MPP Voltage: 750 V
Absolute max. PV Voltage: 900 V
Power Threshold: 60.00 W (Default)
Contractual specifications, without real physical meaning: ? Required
Nominal PV Power: 8.00 kW
Maximum PV Power: 10.00 kW
Maximum PV Current: 38.00 A
Output side (AC grid):
Frequency: 50 Hz (checked), 60 Hz (checked)
Grid Voltage: 230 V
Nominal AC Power: 7.50 kVA
Maximum AC Power: 8.00 kVA
Nominal AC current: 18.00 A
Maximum AC current: 20.00 A
Efficiency:
Maximum efficiency: 98.50%
EURO efficiency: 98.00%
Efficiency defined for 3 voltages:

Input side: mainly concerns voltage conditions:

Technical data	Sunny Tripower 12000TL-US	Sunny Tripower 15000TL-US	Sunny Tripower 20000TL-US	Sunny Tripower 24000TL-US
Input (DC)				
Max. usable DC power (@ $\cos \phi = 1$)	12250 W	15300 W	20400 W	24500 W
Max. DC voltage*	1000 V	1000 V	1000 V	1000 V
Rated MPPT voltage range	300 V...800 V	300 V...800 V	380 V...800 V	450 V...800 V
MPPT operating voltage range	150 V...1000 V	150 V...1000 V	150 V...1000 V	150 V...1000 V
Min. DC voltage / start voltage	150 V / 188 V	150 V / 188 V	150 V / 188 V	150 V / 188 V
Number of MPP tracker inputs	2	2	2	2
Max. input current / per MPP tracker input	66 A / 33 A	66 A / 33 A	66 A / 33 A	66 A / 33 A

- **"Minimum /Maximum MPP voltage"**: the voltage range for the MPP operation.

In the PVsyst model, when attaining one of these limits, the inverter will "clip" the operating voltage to the limit voltage. We suppose that this corresponds to the «*Rated MPP voltage range*».

We don't know exactly what the behaviour of the real inverter is outside of this range (what is specified as "MPP operating voltage range", 150 ... 1000V). This is not involved in PVsyst.

- **"Minimum voltage for PNom"** : this is specified for some inverters: under this voltage the inverter will not be able to yield its full nominal power. This corresponds indeed to an input current limitation.
- **"Nominal MPP Voltage"**: sometimes specified, not used in PVsyst.
- **"Absolute Maximum PV voltage"**: this is the voltage which should not be exceeded, under the worst conditions: lower possible temperature and 1000 W/m².
- **"Power threshold"**: when using an automatic efficiency profile, this value is necessary and cannot be lower than 0.5% of Pnom.
- **"Nominal and Maximum PV power"** are not used in PVsyst, except when they are a contractual condition which affects the guarantee of the device (case "Required" checked). In this case they prevent simulating the system.
- **"Maximum PV current"** is sometimes specified (ISC of the array)), but not used in PVsyst.

Output side: grid-connexion conditions

Output (AC)	Sunny Tripower 12000TL-US	Sunny Tripower 15000TL-US	Sunny Tripower 20000TL-US	Sunny Tripower 24000TL-US
AC nominal power	12000 W	15000 W	20000 W	24000 W
Max. AC apparent power	12000 VA	15000 VA	20000 VA	24000 VA
Output phases / line connections	3 / 3-NPE			
Nominal AC voltage	480 / 277 V WYE			
AC voltage range	244 V...305 V			
Rated AC grid frequency	60 Hz			
AC grid frequency / range	50 Hz, 60 Hz / -6 Hz...+5 Hz			
Max. output current	14.4 A	18 A	24 A	29 A
Power factor at rated power / adjustable displacement	1 / 0.8 leading...0.8 lagging			
Harmonics	< 3 %			
Efficiency				
Max. efficiency	98.2 %	98.2 %	98.5 %	98.5 %
CEC efficiency	97.5%	97.5%	97.5%	98.0%

- **"Frequency"**: Here "Rated AC grid frequency" is 60Hz (for US market); we don't understand well what is meant by "AC grid frequency range".
- **"Grid voltage"** is specific for US. The usual voltage is 400 V (in Europe). This voltage may be used in the simulation if AC losses are defined.
- **"Nominal AC Power"**: if phase shift is allowed, this limitation is usually applied to the apparent power, and therefore expressed as [kVA].
- **"Maximum AC Power"**: some manufacturers allow to overcome the Pnom value if the temperature is not too high. This behaviour will be specified on the 4th page "Output parameters".
- **"Nominal and Maximum AC current"** are not used in PVsyst.

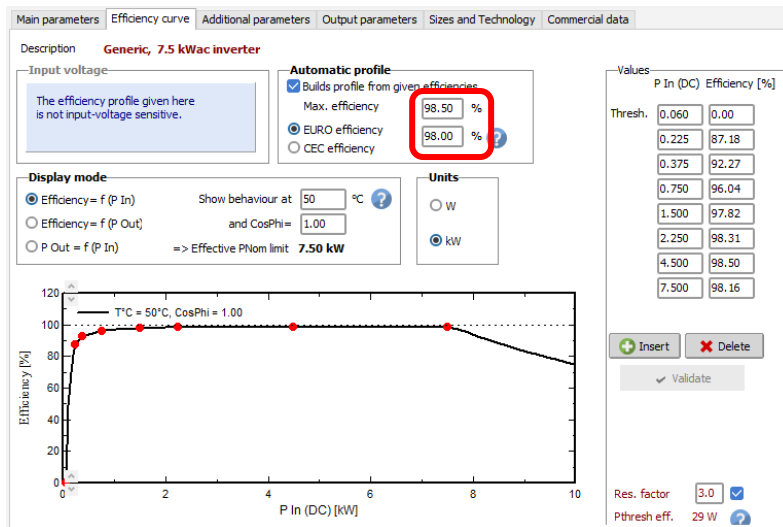
Efficiency variables:

- "Maximum and Euro or CEC efficiency» values are a **result** of the second page (not editable here).
- "Efficiency defined for 3 voltages" should be checked here when using this feature.

"Efficiency curve" page

As we don't have the description of a full curve, we define the efficiency profile according to the datasheet:

- Max efficiency = 98.2 %
- CEC efficiency = 97.5 %



NB: For the PVsyst database, the manufacturers usually specify their efficiency profiles as curves, often for 3 voltages. However, these values are not present on the datasheets.

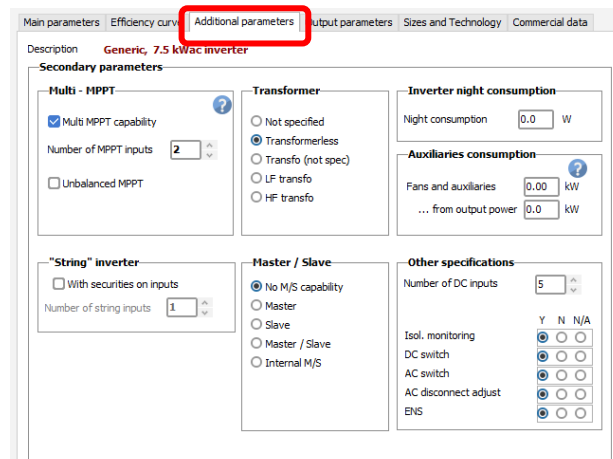
"Additional parameters" page

This gives miscellaneous information, that you have to gather on the Datasheets.

Among this information, only the "Multi-MPPT capability" and "number of MPPT inputs" are really used for the system definition and simulation.

The "Auxiliary consumptions" are marginally used as default when defining the detailed losses.

You will get a warning if you use a *transformerless* inverter with amorphous modules.



"Output parameters" page

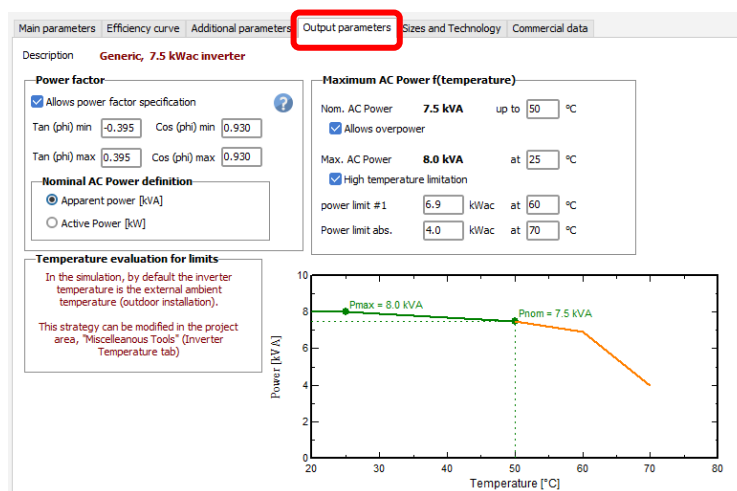
Power factor: Specifies the capabilities of this inverter for producing reactive *energy*.

Producing reactive energy (Phase shift) may be a requirement of the grid manager.

It is normally an operating parameter (command) set by the operator of the plant.

- "*Tan(phi) min/max*» or «*Cos(phi) Leading/Lagging*": the limits which may be set for this inverter. But the real value to be used for the simulation will be specified in the "*Miscellaneous parameters*" of the calculation version.
- "*Nominal AC power (PNom) defined as ...*": specifies whether the nominal output power Pnom applies to the Active power [kW] or the Apparent power [kVA].

In practice, this is most often applied to the Apparent power, as this corresponds to an output current limitation.



Max. AC power f(Temperature)

Many inverters specify a "*PNom*" value, and a "*PMax value*", which represents a power attainable when the temperature is not too high.

- "*Allows overpower*" specifies if this is implemented for this inverter.
The involved PMax is specified on the "*Main parameters*" page.
If not defined or equal to the PNom value, this option is disabled.
- "*High temperature limitations*": defines other limitations as f(Temperature) on PNom.

NB: The temperature involved in these specifications during the simulation is specified in the "*Miscellaneous Tools*". It may be the ambient temperature (outdoor installation), the ambient plus a constant, or a fixed (room) temperature.

"Sizes" page

- "*Technology specificities*" allows to specify some features in max. 5 lines of free text.
- "*Operating conditions – Behavior at limits*": Never modified, don't mind.

"Commercial" page

Identical to the corresponding page for PV module