UNIVERSIDAD DE VALLADOLID

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COMPARISON OF PV-SYSTEMS FOR A HOUSEHOLD

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ABSTRACT

From ancient times to the present day, the most human concern is energy which maintains and develops human life. With the coming running out of non – renewable fossil fuels and the rapid growth of human energy demand, renewable energy resources also known as sustainable energy resources have been considered as one of the most important global challenges. Moreover, renewable energy resources have been used widely to increase the share of electricity generated which is an invaluable way to increase energy security and supply while reducing environmental risks associated with the growing demand for electricity.[1] In this project, the renewable energy I focus is solar energy. Photovoltaic (PV) is the solar technology that I want to use in this project to compare two PV systems which are own-consumption PV system and standalone PV system, to design suitable PV system for household. After comparison between two PV systems, I choose standalone PV system for household because of having advantage of economy and environment.

Keywords

Photovoltaic (PV) system; own-consumption PV system; standalone PV system; household; energy use; power.

I. INTRODUCTION:

Electric power plants are one of the essential consumers of imported fossil fuels; nevertheless, renewable energy resources also known as sustainable energy resources have been used widely to increase the share of electricity generated which is an invaluable way to increase energy security and supply while reducing environmental risks associated with the growing demand for electricity.[2] Solar energy is one of the most dependable, develop, and normal types of renewable energy for electricity production. Solar technologies have been increasingly developing by recent economic and technical advances, thanks for that the installed price of solar energy has dropped by as much as half price since 2010.[3] The most critical advancement in the development of solar technology has been Photovoltaic (PV), a solar energy system that uses semi-conductors to directly convert solar radiation into electricity. Owning a PV system allows you to create your own power to supply your entire house and lifestyle without being tied to the issues that can occur with utility grids.[4] In this project, I will focus two PV system which quite common for household just use only solar energy to supply the house, which are a standalone PV-system and an own-consumption PV-system.

II. OBJECTIVE:

The aim of this project is to make a comparison between two different PV-systems for the same household: a standalone PV-system and an own-consumption PV-system in how to set PV system, economy, environment, and regional; to find the advantage and disadvantage of both PV systems then known which one suitable for this specific location – household in Spain. First, I have to set up two PV systems after that using the result from PVsyst then comparison.

III. MATERIAL:

1. PV System:

According to first version of the book Solar Energy: Fundamentals, Technology and Systems which is taught at the Delft University of Technology, a PV-system contain many different components besides the PV modules. For successfully planning a PV system it is crucial to understand the function of the different components and to know their major specifications. Further, it is important to know the effect on the location of the expected performance of a PV system.

PV systems can be simple consisting a PV module and load and only need sunlight to operate. Depending on the system configuration, we can distinguish three main types of PV systems: stand-alone, grid-connected, and hybrid. The basic PV system principles and elements remain the same. Systems are adapted to meet particular requirements by varying the type and quantity of the basic elements. A modular system design allows easy expansion, when power demands change.

1.1. Types of PV system:

1.1.1. Stand-alone systems:

Stand-alone systems rely on solar power only. These systems can consist of the PV modules and a load only or they can include batteries for energy storage. When using batteries charge regulators are included, which switch off the PV modules when batteries are fully charged, and may switch off the load to prevent the batteries from being discharged below a certain limit. The batteries must have enough capacity to store the energy produced during the day to be used at night and during periods of poor weather. Figure 1 shows schematically examples of stand-alone systems; (a) a simple direct current (DC) PV system without a battery and (b) a large PV system with both DC and alternating current (AC) loads.

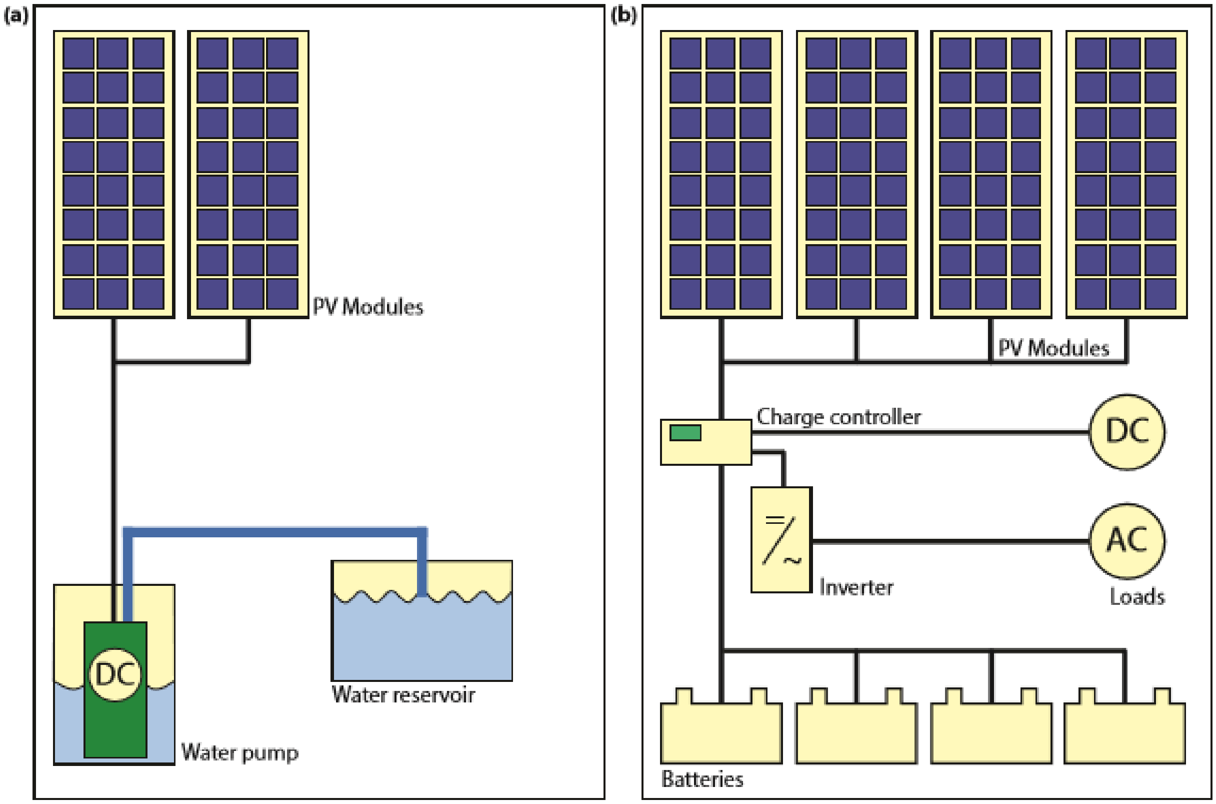


Figure 1: Schematic representation of (a) a simple DC PV system to power a water pump with no energy storage and (b) a complex PV system including batteries, power conditioners, and both DC and AC loads.

1.1.2. Grid-connected systems:

Grid-connected PV systems have become increasingly popular for building integrated applications. As illustrated in Figure 2, they are connected to the grid via inverters, which convert the DC power into AC electricity. In small systems as they are installed in residential homes, the inverter is connected to the distribution board, from where the PV-generated power is transferred into the electricity grid or to AC appliances in the house. These systems do not require batteries, since they are connected to the grid, which acts as a buffer into that an oversupply of PV electricity is transported while the grid also supplies the house with electricity in times of insufficient PV power generation.

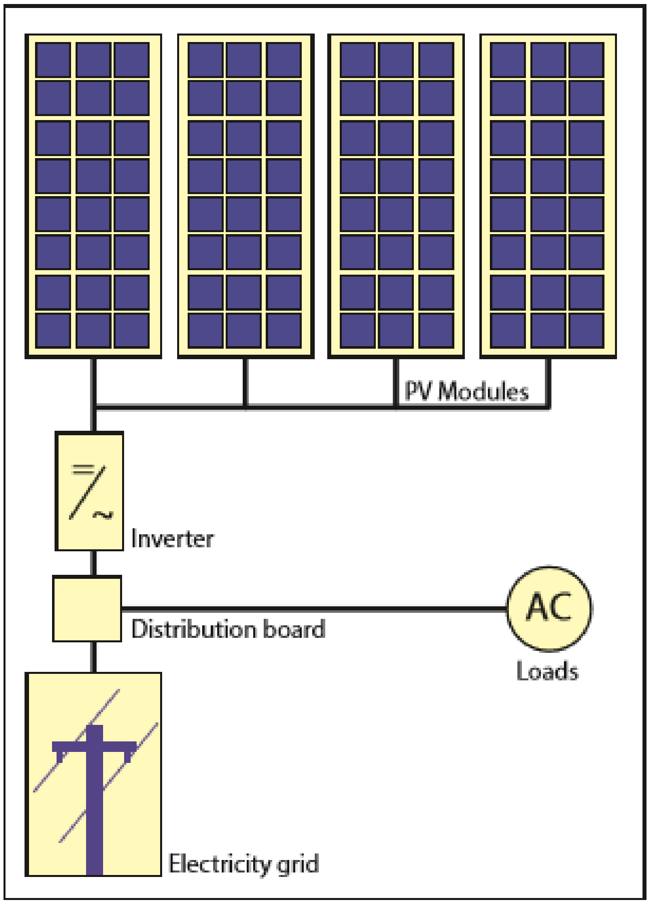


Figure 2: Schematic representation of a grid-connected PV system.

1.1.3. Hybrid systems:

Hybrid systems consist of combination of PV modules and a complementary method of electricity generation such as a diesel, gas or wind generator. A schematic of an hybrid system shown in Figure 3. In order to optimize the different methods of electricity generation, hybrid systems typically require more sophisticated controls than stand-alone or grid-connected PV systems. For example, in the case of a PV/diesel system, the diesel engine must be started when the battery reaches a given discharge level and stopped again when battery reaches an adequate state of charge. The back-up generator can be used to recharge batteries only or to supply the load as well.

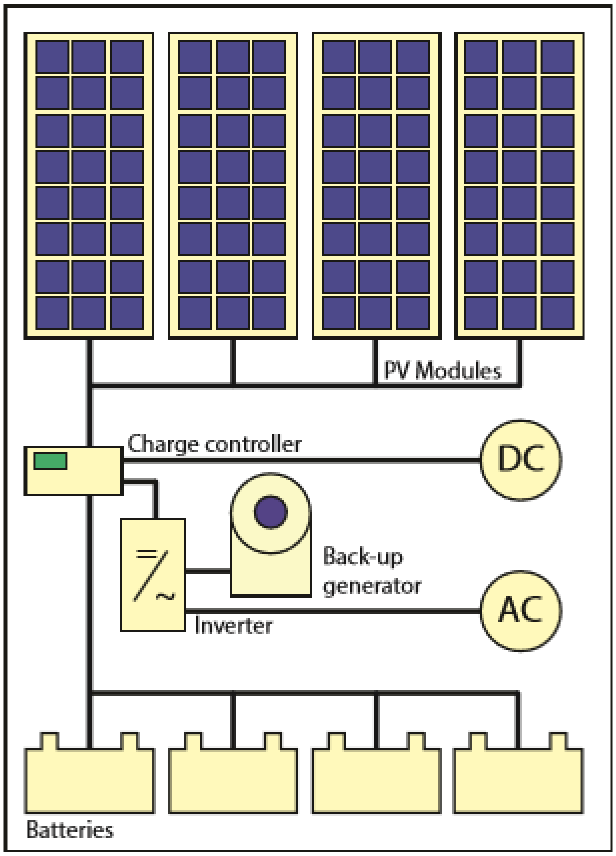


Figure 3: Schematic representation of a hybrid PV system that has a diesel generator as alternative electricity source.

1.2. Components of PV systems:

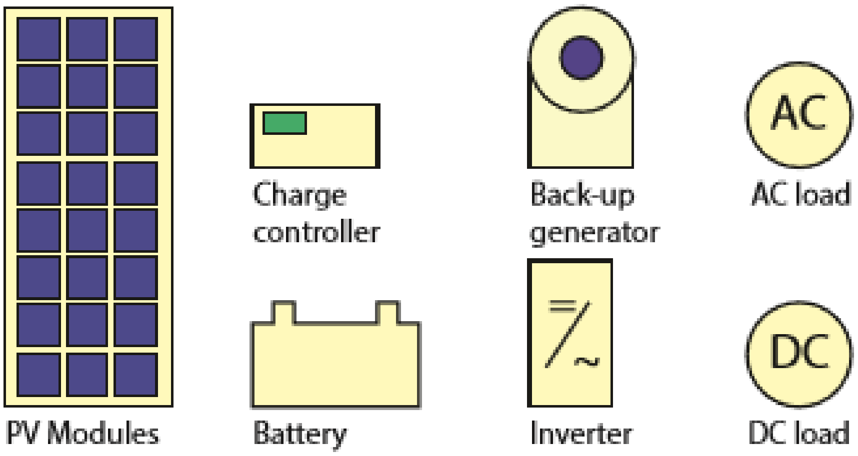


Figure 4: A schematic of the different components of a PV system.

A PV module, which have known like a heart of a PV system, contain a number of solar cells have to be connected together to form a solar panel in order to use solar electricity for practical devices, which require a particular voltage and/or current for their operation. Due to the limited size of the solar cell it only delivers a limited amount of power under fixed current-voltage conditions that are not practical for most applications. And for large-scale generation of solar electricity solar panels are connected together into a solar array.

Beside a PV module, many other components are required for a working system, which are called the Balance of System (BOS). These components are required depends on whether the system is connected to the electricity grid or whether it is designed as a stand-alone system. The most important components belonging to the BOS are:

- A mounting structure: is used to fix the modules and to direct them towards the sun.
- Energy storage: is a vital part of stand-alone systems because it assures that the system can deliver electricity during the night and in periods of bad weather. Usually, batteries are used as energy storage units.
- DC-DC converter: are used to convert the module output, which will have a variable voltage depending on the time of the day and the weather conditions, to a fixed voltage output that e. g. can be used to charge a battery or that is used as input for an inverter in a grid-connected system.
- Inverter or DC-AC converter: are used in grid connected systems to convert the DC electricity originating from the PV modules into AC electricity that can be fed into the electricity grid.
- Cables: are used to connect the different components of the PV system with each other and to the electrical load. It is important to choose cables of sufficient thickness in order to minimize resistive losses.

Even though not a part of the PV system itself, the electric load, all the electric appliances that are connected to it have to be taken into account during the planning phase. Further, it has to be considered whether the loads are AC or DC loads.[5]

2. PV software:

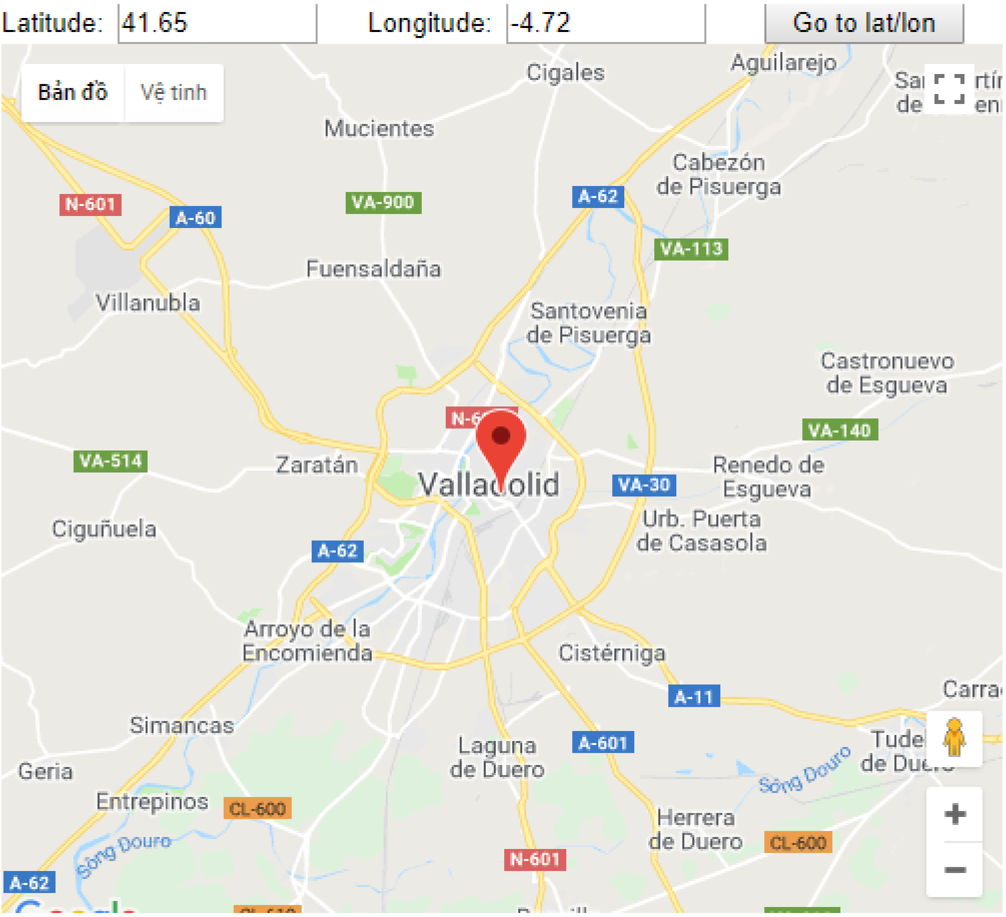
According to Photovoltaic systems (PVsyst) software:“PVsyst is designed to be used by architects, engineer, and researchers. It is also a very useful educative tool. It includes a detailed contextual Help menu that explains the procedures and models that are used and offers a user-friendly approach with a guide to develop a project. PVsyst is able to import meteo data from many different sources, as well as personal data.”[6]

This project will use the software PVsyst 6.6.2 to design two different PV-systems for the same household: a standalone PV-system and an own-consumption PV-system.

3. Household:

3.1. Location:

The household in this project is located on Calle de González Dueñas, 47010 Valladolid, Spain. The figure 5 is shown the household's location on the map, its latitude is 41.65, its longitude is -4.72 and its altitude is 702. The details data is taken from PVGIS CM SAF, satellite 1998-2011.



Latitude: 41.65

Longitude: -4.72

Figure 5: The map of household's location

Its location has Monthly meteorological data which are associated with every geographic site and are used to build the hourly data. Monthly meteorological files contain the site name, the country, the world region; the geographical coordinates: latitude, longitude, altitude and time zone; the monthly Global Horizontal Irradiation; the monthly averages of the ambient temperature; and the monthly Diffuse Horizontal Irradiation. In the table 1 below, the monthly Global Horizontal Irradiation; the monthly averages of the ambient temperature; and the monthly Diffuse Horizontal Irradiation have been shown.

Month	Horizontal Global irradiation	Diffuse irradiation (kWh/m^2)	Ambient Temperature

	(kWh/m²)		**(°C)**
January	53.6	29.5	4.2
February	80.4	34.6	4.5
March	134.5	57.9	7.9
April	156	65.5	11.3
May	199	73.6	14.8
June	221.7	68.7	19.3
July	241.2	55.5	22.8
August	210.8	50.6	22.6
September	155.7	45.2	18.8
October	107.3	41.8	13.7
November	63.6	30.5	8.1
December	50.5	25.8	4.5
Year	1674.3	579.2	12.7

Table 1: Monthly meteorological data of household's location

3.2. Consumptions:

Household has appliances which have an AC distribution. The power of each appliance has been shown on table 2.

Appliances	**Numbers**	**Power(W)**
Compact fluorescent	10	15
Incandescent	5	40
LED 1	3	12
LED 2	3	5
Laptop	3	55
Charger laptop	3	65
Telephone Movista	1	9
Smartphone charge	3	5
Rice cooker	1	182.5
Microwave	1	133
Fridge	1	132
Induction cooker	1	2300
Oven	1	2000
Washing machine	1	500
Iron	1	106.7
Hair dryer	1	600
TV 20"	1	40
Wi-Fi modern	1	24
Vacuum cleaner	1	800
Fan	3	55
Air condition	1	2637

Table 2: The power of appliances have been use on household

IV. PV SYSTEMS FOR THE SAME HOUSEHOLD: AN OWN-CONSUMPTION PV SYSTEM AND A STANDALONE PV SYSTEM:

1. Method for two PV-systems:

The method for two PV- systems follows the steps in PVsyst which include orientation, user's needs, and PV system, near shading and economic value. To easy to comparison between 2 PV systems, I use the same use's need and same branch PV panel for set PV system.

2. An own-consumption PV-system:

2.1. User's need:

Two different PV-systems which are a standalone PV-system and an own-consumption PV-system have designed for same household so they have same user's need. The data used for user's need based on the real data from daily life with my two colleges friends which I rent in Valladolid.

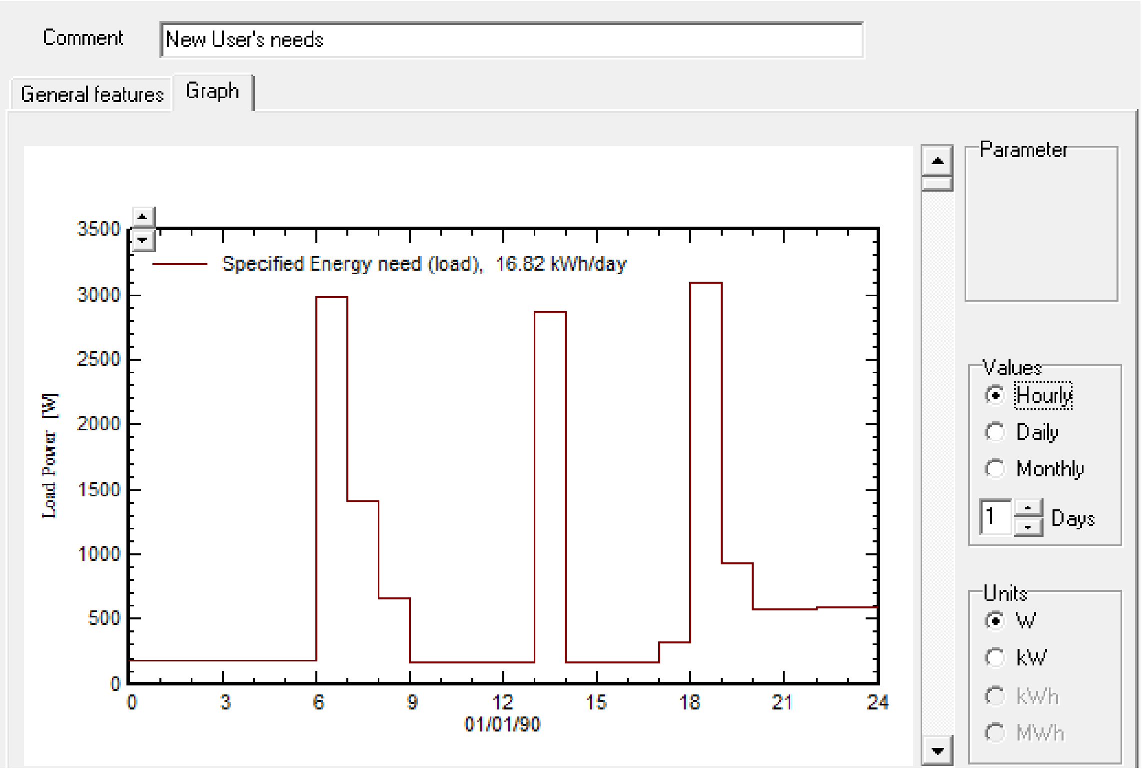
The user's need has a different profile all along the year which distributes into two seasons: summer from milder of June to September and winter from January to milder of June, from October to December. The difference of user's need based on the behavior of the user in different seasons assumes that they don't have any holiday and study all along the year. In winter, the day is shorter and the night is longer which demands more lighting hours using lighter than summer; the weather is extremely cold to cool so they don't use fan and air condition. In summer, the day is longer and the night is shorter which don't need too much lighting hours using lighter comparison with winter but the weather is hot so the number hours of use fan and air condition is raising up. The reason that I only divide the year into two seasons winter and summer not into four seasons spring, summer, august and winter depends on the lighting hours and the number hours of using fan and air condition.

The represent for each season is a week which divides into weekly days from Monday to Thursday and weekend days which are from Friday to Sunday. For the weekly days, we go to school all day so the number of hours using electric devices less than weekend days. However, we have more free times on weekend days so we clean our flat using vacuum cleaner and enjoy weekend by using oven to cook meals.

The daily profile in hourly values is performing in CSV. The table 3 and the graph 1 have been shown the example of daily profile in hourly values of one weekly day in winter which the total energy for that day is 16.82kWh.

Date	Load (W)
1/1/2018 0:00	180
1/1/2018 1:00	180
1/1/2018 2:00	180
1/1/2018 3:00	180
1/1/2018 4:00	180
1/1/2018 5:00	180
1/1/2018 6:00	2981
1/1/2018 7:00	1412
1/1/2018 8:00	665
1/1/2018 9:00	165
1/1/2018 10:00	165
1/1/2018 11:00	165
1/1/2018 12:00	165
1/1/2018 13:00	2863
1/1/2018 14:00	165
1/1/2018 15:00	165
1/1/2018 16:00	165
1/1/2018 17:00	315
1/1/2018 18:00	3089
1/1/2018 19:00	926
1/1/2018 20:00	576
1/1/2018 21:00	576
1/1/2018 22:00	591
1/1/2018 23:00	591

Table 3: Data of user's need for one weekly day of winter



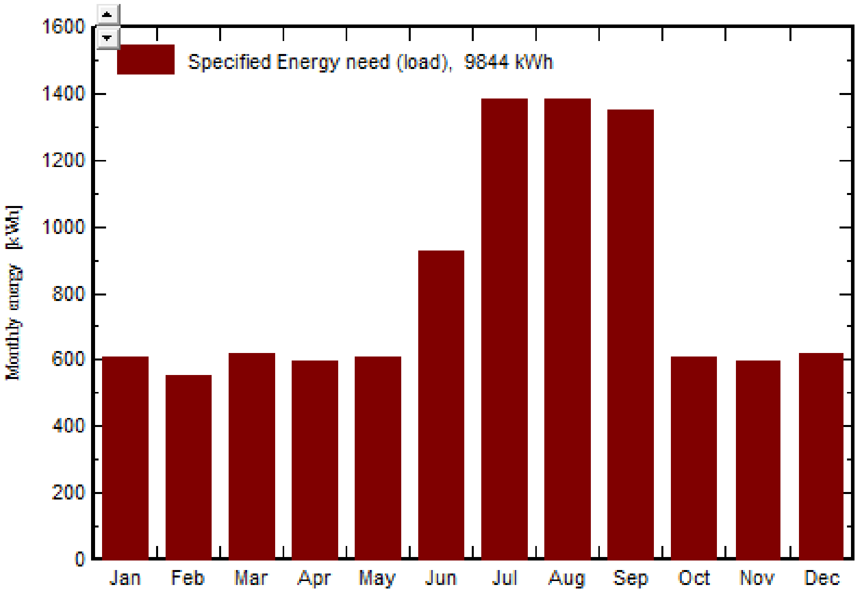
Comment: New User's needs

Values: ● Hourly ○ Daily ○ Monthly — 1 Days

Units: ● W ○ kW ○ kWh ○ MWh

Graph 1: The specified energy need from the load for one weekly day of winter

The graph 2 shows the graph of specified energy need of the load for each month; and table 4 show specified energy need from the load for each month and the total energy need of whole year is 9844kWh.



Graph 2: The specified energy need from the load for each month

Month	**Energy need from the load (kWh)**
January	604
February	554
March	618
April	595
May	604
June	926
July	1386
August	1386
September	1353
October	604
November	595
December	618
Year	9844

Table 4: The specified energy need from the load for each month

2.2. Orientation:

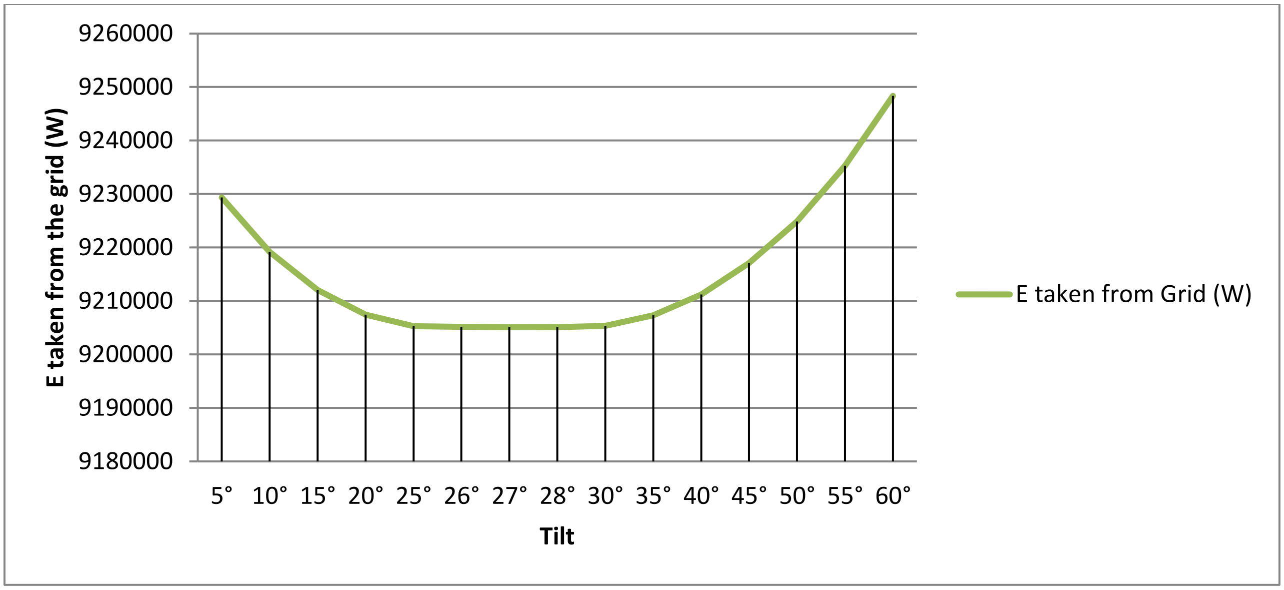
For the orientation part, the field type and field parameters have been need to choose. For the field type, I choose Fixed Tilted Plane. About the field parameter, the number has been analyzed.

The location is Valladolid in Spain belonged to Northern Hemisphere, which led to in order to absorb the maximum irradiation from the sun; the panel must have to face the South. So we have Azimuth: 0° to the South.

To choose the suitable tilt in this case which mean the energy I take from the grid is the less. To find the perfect tilt, I have listed the values of the tilts from 5° to 60° apart each other 5° with the power of the PV system can produce is 0.5kWac. I have found that increasing tilt is also decreasing energy taken from the grid to the tilt 25° which I have the number is the smallest, continuing raise the tilt, the energy is also increasing. However I try to find the exact figure of the tilt so I raise the tilt 1° and go on and finally the suitable tilt I got is 27° which have the less energy taken from the grid. The values of the tilt and corresponding energy (E) taken from the grid have shown in the table 5 and the graph 3 below.

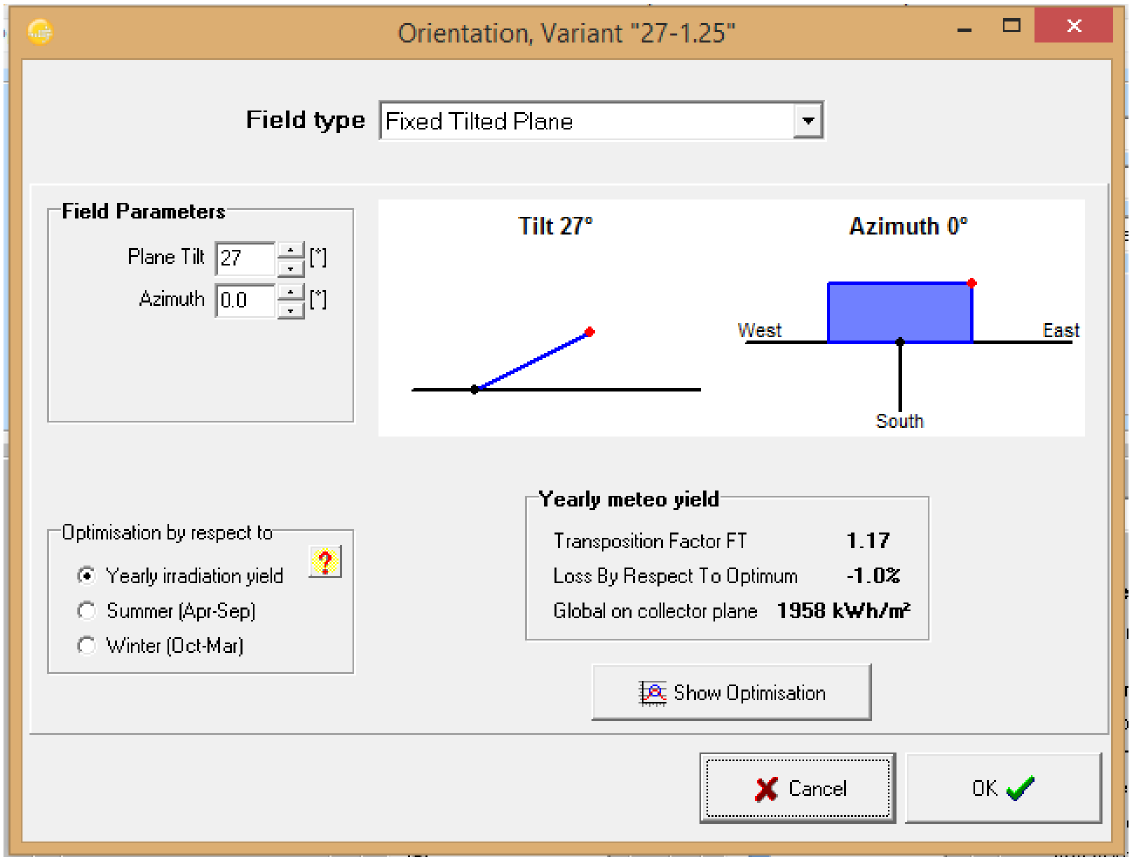
Tilt	**E taken from Grid (W)**
5°	9229387
10°	9219188
15°	9212036
20°	9207441
25°	9205309
26°	9205158
27°	9205092
28°	9205099
30°	9205353
35°	9207300
40°	9211244
45°	9217071
50°	9224883
55°	9235317
60°	9248361

Table 5: The tilt and the corresponding Energy taken from the grid (W)



Graph 3: The graph of the tilt and the corresponding energy (E) taken from the grid

The figure 6 is shown parameters been chosen of the orientation part by PVsyst.



Field type Fixed Tilted Plane

Field Parameters

Plane Tilt 27 [°]
Azimuth 0.0 [°]

Optimisation by respect to

● Yearly irradiation yield
○ Summer (Apr-Sep)
○ Winter (Oct-Mar)

Yearly meteo yield

Transposition Factor FT	1.17
Loss By Respect To Optimum	-1.0%
Global on collector plane	1958 kWh/m²

Figure 6 : Choosing parameters of the orientation by PVsyst

2.3. PV-System:

2.3.1. Selection the components: the PV module and the inverter

In this section I am going to define the main components of own-consumption PV system, which include PV module and inverter.

Selection the PV module:

According to Sara Matasci (march 27,2018), SunPower solar panels are one of the best solar panel brand on the market with high efficient between 19.1% and 22.2%; a 25 year warranty and the price may higher than average solar panels but not too much[7]. In this case, I use solar panel named Sunpower_SPR-262J-WHTD from manufacturer 2012 with technology is Si-mono has nominal Power 262 Wp – 36 V. The solar panel has high efficiency approximate 21, 1%. The characteristics of a PV module have been shown on the table 6 below.

Model	**SunPower, SPR-262J-WHTD**
Data source	Manufacture 2012
Power	262 Wp
Technology	Si- mono
Open circuit voltage	51.4 V
Maximum power point voltage	43.3 V
Short- circuit current (Isc)	6.52 A
Maximum power point current	6.05 A
Efficiency (module area) for standard condition	21.1%
Fill factor	0.784

Table 6: The characteristics of a PV module of an own-consumption PV-system

Selection the inverter:

For the inverter, I choose from manufacturer Enphase named M250-60-230-S22-E which has input side(DC PV field) Maximum power point MPP Voltage from 15 to 48 V and maximum PV voltage 60V which suitable with PV module have maximum power point voltage 43.3 V and open circuit voltage is 51.4 V; output side (AC grid) has nominal AC power 0.250kW with grid Voltage 230 V connected by monophased. The efficiency is 96.37%. The characteristics of a grid inverter have been shown on the table 7.

Model		**Enphase, M250-60-230-S22-E**
Data source		Manufacture 2015
Input (PV array side)	Operating mode	MPPT (Maximum Power Point Tracking)
	Minimum MPP voltage	15 V
	Maximum MPP voltage	48 V
	Maximum PV voltage	60 V
	Nominal PV power	0.35kW

	Maximum PV power	0.35kW
Output (AC grid side)	Grid voltage	230 V
	Grid frequency	50Hz
		Monophased
	Nominal AC power	0.25kWac
	Maximum AC power	0.26kWac
	Nominal AC current	1.09 A

Table 7: The characteristics of a grid inverter an own-consumption PV-system

2.3.2. Design the PV system:

- *The unit of PV system:*

To design the PV system, I have to find the right power for the PV system. To easy to find, I choose unit which have small power so the power I need just equal power of the total units. The unit of PV system includes one solar panel SPR-262J-WHTD and one inverter M250-60-230-S22-E having AC power 0.250kW with grid Voltage 230 V connected by monophased at output side of inverter, have been shown on the figure 7.

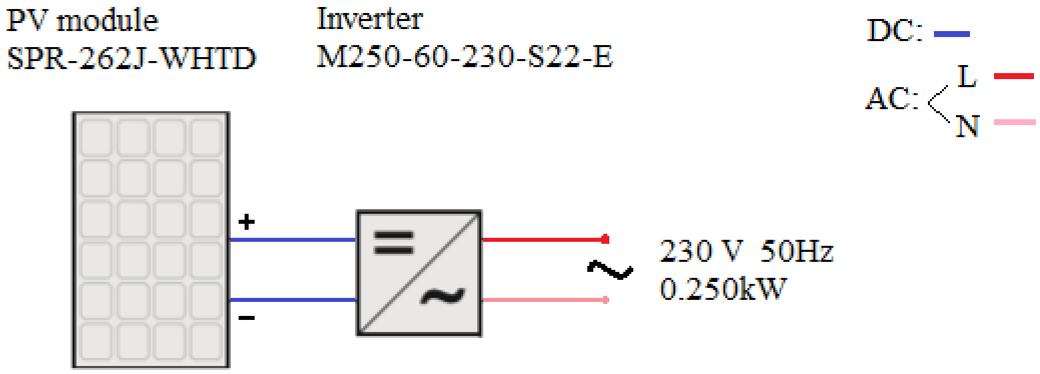


Figure 7: The unit of own consumption PV system

- *The design of PV system:*

The PV system includes number of strings units containing one PV module SPR-262J-WHTD and one inverter M250-60-230-S22-E in parallel and the power is 0.25kW per unit. To find the suitable power of PV system provide which mean to find the number of units in parallel, I have to balance the money spent for PV system and the money buying from electrical company and find the biggest money saving. Assume my PV system have 25 years old.

To more clearly, the starting point is that the user's needs must be covered; this energy must be provided by the PV system and by the grid. The PV energy is supplied to the user, the lack of energy is taken from the grid and the excess of energy is injected into the grid. The greater the PV power is, the less energy is buying to the electrical company but also mean the more energy is injected into the grid. The PV energy is cheaper than the electrical company energy. However, because the injected energy is given as a present to the electrical company, this energy is a loss of money. Therefore, I need to find the optimum power for my system, that means, the power that produces the maximum savings in comparison with the situation of no PV system.

First, I have to find the energy taken from the grid corresponding with the PV power to calculate the money buying from the electrical company which shown in the table 8 below.

PV Power (kW)	**Energy from Output of Inverter (kWh)**	**Energy injected into Grid (kW)**	**Energy supplied to the User (kW)**	**Energy need of the user (Load) (kW)**	**Energy taken from grid (kW)**
0	0.00	0.00	0.00	9843.57	9843.57
0.25	429.95	18.57	411.38	9843.57	9432.19
0.5	859.91	221.43	638.48	9843.57	9205.09
0.75	1289.86	495.55	794.32	9843.57	9049.25
1	1719.82	780.08	939.74	9843.57	8903.83
1.25	2149.77	1068.32	1081.45	9843.57	8762.12
1.5	2579.73	1363.73	1216.00	9843.57	8627.57
1.75	3009.68	1665.75	1343.93	9843.57	8499.64
2	3439.64	1970.06	1469.59	9843.57	8373.99
2.25	3869.59	2276.42	1593.17	9843.57	8250.40
2.5	4299.55	2584.72	1714.83	9843.57	8128.74
2.75	4729.50	2894.77	1834.73	9843.57	8008.84
3	5159.46	3206.69	1952.77	9843.57	7890.80

Table 8: The energy taken from the grid corresponding with the PV power

According to installers an average cost of a PV system could be, the price per power of each component has been shown on the table 9 below:

Components	**Price(€/Wp)**
PV panel	0.7-1
Inverter	0.5-0.7
Mounting structure	0.12
Other (wire,etc)	0.5
Total	2.12

Table 9: The average cost of a own-consumption PV system

The PV panel I choose from Sunpower having high quality so the price is 1 (€/Wp) and the inverter from Enphase having good quality so the price is 0.5 (€/Wp) so total price of PV system is 1+0.5+0.12+0.5 = 2.12 (€/Wp) which mean 2120 (€/kWp).

- *Formulation:*

$$\textbf{(1) Money buying from E Company}\ \left(\frac{€}{\text{year}}\right) = \mathbf{0.15}\left(\frac{€}{\text{KWp}}\right) \times \textbf{E taken grid}\ (\textbf{kW})$$

$$\textbf{(2) Money spent PV system}\ \left(\frac{€}{\text{year}}\right) = \frac{\textbf{PV Power (kW)}\times\mathbf{2120}\left(\frac{€}{\text{KWp}}\right)}{\mathbf{25}(\textbf{years})}$$

$$\textbf{(3) Saving}\ \left(\frac{€}{\text{year}}\right) = \mathbf{1476.54}\ \ (€)\ - \textbf{Money buying from E Company}\ \left(\frac{€}{\text{year}}\right) - \textbf{Money spent PV system}\ \left(\frac{€}{\text{year}}\right)$$

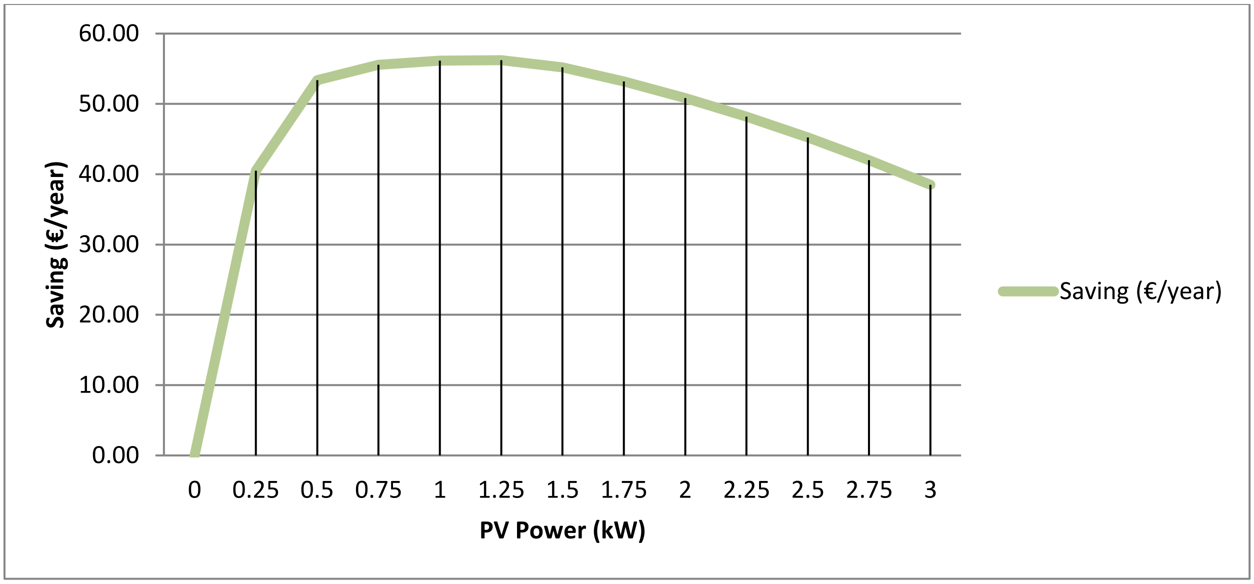
Note:

- 0.15 (€/kWp): is the price from the electrical company
- 1476.54 (€/year): is the money buying from electrical company without PV system

Follow the formulation, the table 10 and the graph 4 below shown the money buying from electrical company; money spent for PV system and saving money with corresponding PV power.

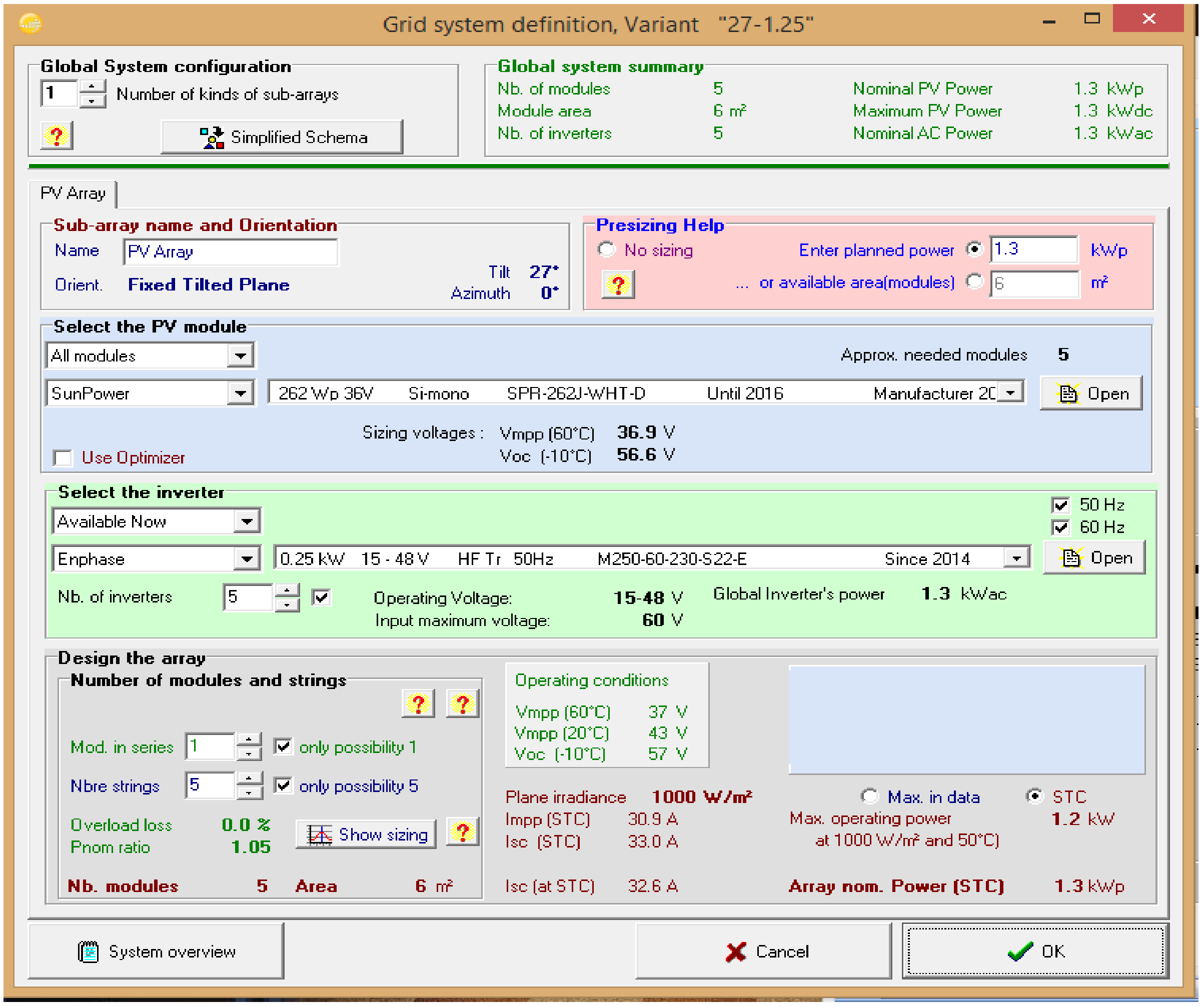
PV Power (kW)	**Money buying from Electrical Company (€/year)**	**Money spent PV system (€/year)**	**Saving (€/year)**
0	1476.54	0	0
0.25	1414.83	21.2	40.51
0.5	1380.76	42.4	53.37
0.75	1357.39	63.6	55.55
1	1335.58	84.8	56.16
1.25	1314.32	106	56.22
1.5	1294.14	127.2	55.20
1.75	1274.95	148.4	53.19
2	1256.10	169.6	50.84
2.25	1237.56	190.8	48.18
2.5	1219.31	212	45.22
2.75	1201.33	233.2	42.01
3	1183.62	254.4	38.52

Table 10: The money buying from electrical company; money spent for PV system and saving money with corresponding PV power



Graph 4: The money buying from electrical company; money spent for PV system and saving money with corresponding PV power

The suitable power for own- consumption is 1.25 kW which have the highest money saving per year is 56.22 € and for 25 years is 1405.5 €. The money I spent for PV system is 106(€/year) *25 years= 2650 €. The corresponding units is 1.25kW / 0.25kW=5. So we have 5 units of PV system in parallel.


Grid system definition, Variant "27-1.25"

Global System configuration
1 Number of kinds of sub-arrays

Global system summary
Nb. of modules 5
Module area 6 m²
Nb. of inverters 5
Nominal PV Power 1.3 kWp
Maximum PV Power 1.3 kWdc
Nominal AC Power 1.3 kWac

Sub-array name and Orientation
Name: PV Array
Orient.: Fixed Tilted Plane
Tilt 27°
Azimuth 0°

Presizing Help
○ No sizing
Enter planned power ● 1.3 kWp
... or available area(modules) ○ 6 m²

Select the PV module
All modules
Approx. needed modules 5
SunPower
262 Wp 36V Si-mono SPR-262J-WHT-D Until 2016 Manufacturer 2C
Sizing voltages : Vmpp (60°C) 36.9 V
Voc (-10°C) 56.6 V
☐ Use Optimizer

Select the inverter
Available Now
☑ 50 Hz
☑ 60 Hz
Enphase
0.25 kW 15 - 48 V HF Tr 50Hz M250-60-230-S22-E Since 2014
Nb. of inverters 5 ☑
Operating Voltage: 15-48 V
Input maximum voltage: 60 V
Global Inverter's power 1.3 kWac

Design the array
Number of modules and strings
Mod. in series 1 ☑ only possibility 1
Nbre strings 5 ☑ only possibility 5
Overload loss 0.0 %
Pnom ratio 1.05
Nb. modules 5 Area 6 m²

Operating conditions
Vmpp (60°C) 37 V
Vmpp (20°C) 43 V
Voc (-10°C) 57 V

Plane irradiance 1000 W/m²
Impp (STC) 30.9 A
Isc (STC) 33.0 A
Isc (at STC) 32.6 A

○ Max. in data ● STC
Max. operating power at 1000 W/m² and 50°C) 1.2 kW
Array nom. Power (STC) 1.3 kWp

Figure 8: Choosing parameters for own-consumption by PV syst

In figure 8, the parameters have been chosen. The number of module equaling with the number of inverter is 5 which are 5 units connected parallel together. The overload is 0.0% which means the number of the inverter is suitable for the system. In PVsyst, the inverter sizing is based on an acceptable overload loss during operation, and therefore involves estimations or simulations in the real conditions of the system (meteo, orientation, losses). The PVsyst criteria for an acceptable sizing are specified in the project's definition and the default values are in the table 11 below.

Overload loss	State
<0.2%	Suitable inverter sized
0.2%-3%	inverter slightly undersized, warning
>3%	inverter strongly undersized, prevents the simulation

Table 11: Values of overload loss affected to size inverter

Pnom ratio meaning the value of nominal power of array divide to nominal power of array has a value 1.05.

- *Scheme of the installation:*

Next scheme on figure 9 shows how different parts of the PV system are connected. At output side of inverter, using monophased which has line and neutral line connected with grid and house.

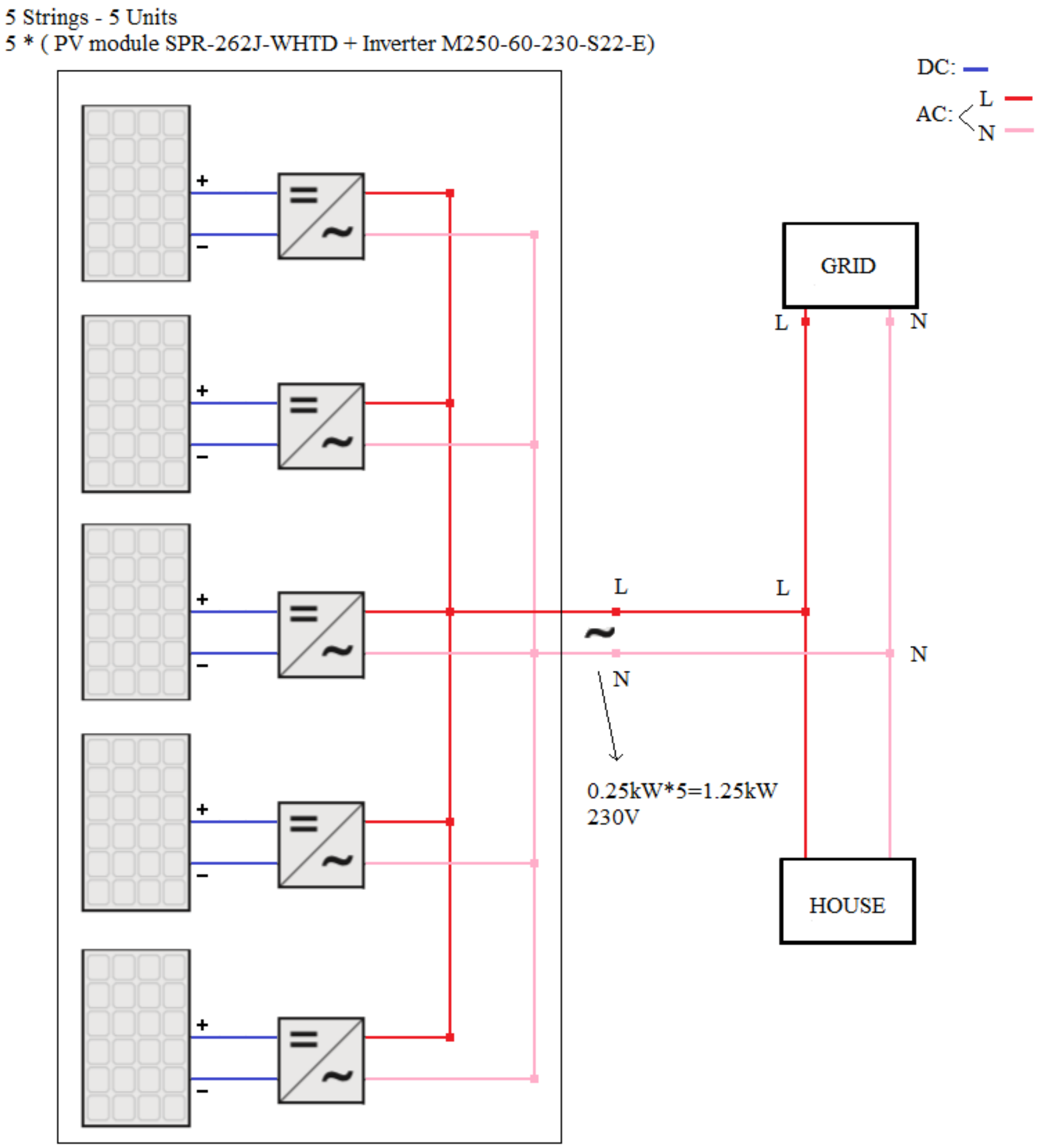


Figure 9: Scheme of the installation for the own-consumption PV system

2.4. Near shading:

No shadings have been defined for this simulation.

2.5. Economical value:

According to installers an average cost of a PV system could be, the price per power of each component has been shown on the table 12 below:

Components	Price(€/Wp)
PV panel	1
Inverter	0.5
Mounting structure	0.12
Other (wire,etc)	0.5
Total	2.12

Table 12: The cost of an own-consumption PV system

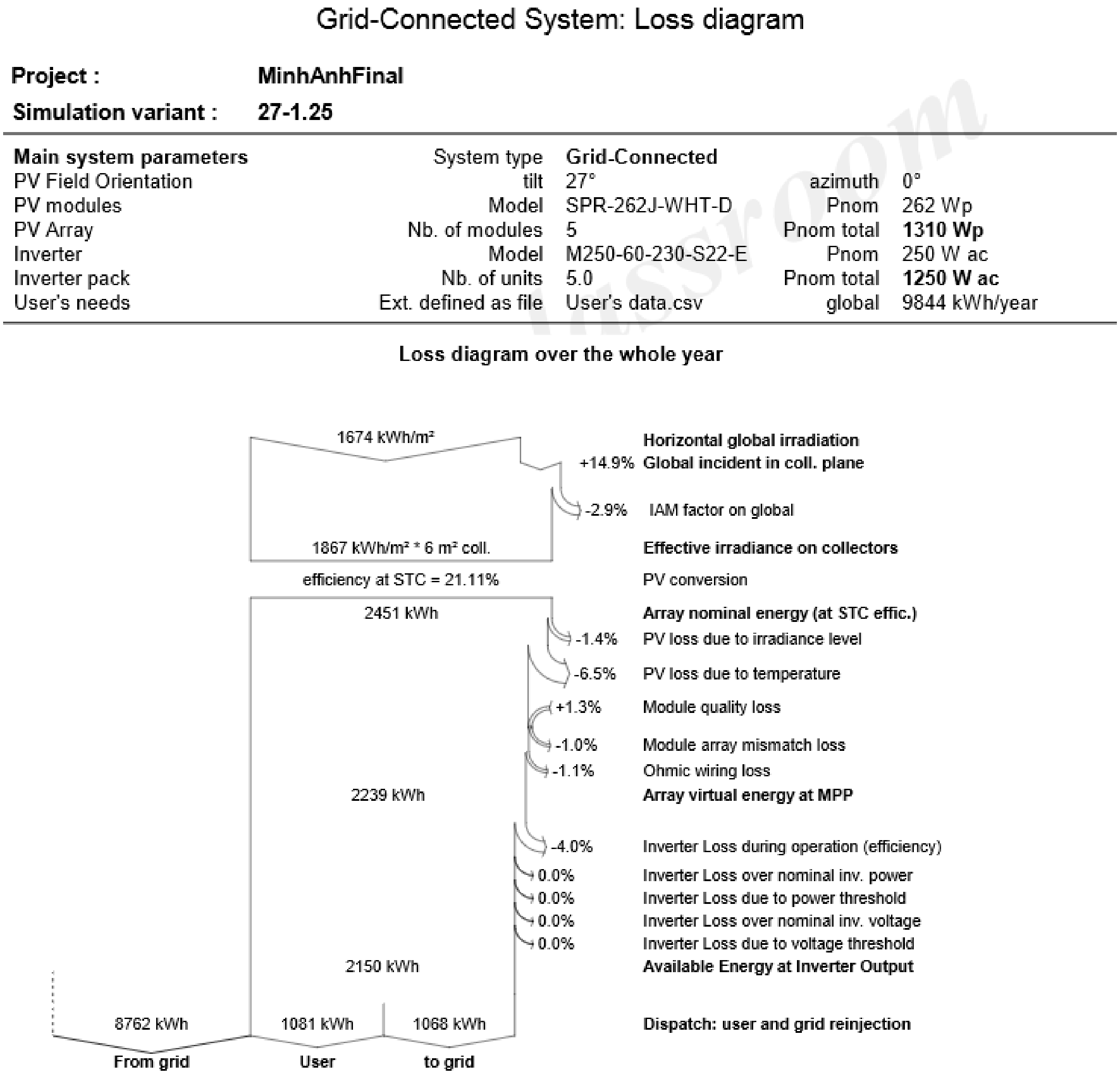
The total price of PV system is 1+0.5+0.12+0.5 = 2.12 (€/Wp) which mean 2120 (€/kWp). With PV power is 1.25kW, the price of PV system is 2650 €.

From table 10, for 25 years, the money saving including PV system is 56.22€*25years=1405.5€. The money I have to pay for energy from the grid without PV system for one year is 1476.54€. The money I have to pay for energy from the grid with PV system for one year is 1314.32€. The money saving not including PV system is 1476.54-1314.32=162.22 (€ / year). I want to find the number of years that I have to pay for my PV system cost 2650 € by dividing PV system cost to the money saving not including PV system per year: 2650(€)/162.22(€/year)= 16.34(years). So I recover my investment in 16.34 years and I have 8.66 years for using the PV system free, because of my investment for 25 years.

On the figure 10, the energy taken from the grid is 8762 kWh and the energy supplied for the user from PV system is 1081kWh. My system only produces the $\frac{1081}{1081+8762} = 10.98\%$ of the user's need due to behavior of user used a lot energy during the night hours. Because of this, I need 16 years in order to recover my investment. Although, I take a lot of time more than half of 25 years it prove not the best business but I recover my money and have 9 years to use free energy.

2.6. The loss diagram over the whole year from PV syst:

The loss diagram over the whole year is shown on figure 10. The available energy at inverter output is 2150KWh which have been minus 4% inverter loss during operation to the user is 1081KWh and energy injection to grid is 1068KWh. The energy taken from the grid is 8762KWh.



Grid-Connected System: Loss diagram

Project : **MinhAnhFinal**

Simulation variant : **27-1.25**

Main system parameters	System type	**Grid-Connected**			
PV Field Orientation	tilt	27°	azimuth	0°
PV modules	Model	SPR-262J-WHT-D	Pnom	262 Wp
PV Array	Nb. of modules	5	Pnom total	**1310 Wp**
Inverter	Model	M250-60-230-S22-E	Pnom	250 W ac
Inverter pack	Nb. of units	5.0	Pnom total	**1250 W ac**
User's needs	Ext. defined as file	User's data.csv	global	9844 kWh/year

Loss diagram over the whole year

Figure 10: The loss diagram over the whole year of an own-consumption PV system

3. A standalone PV-system:

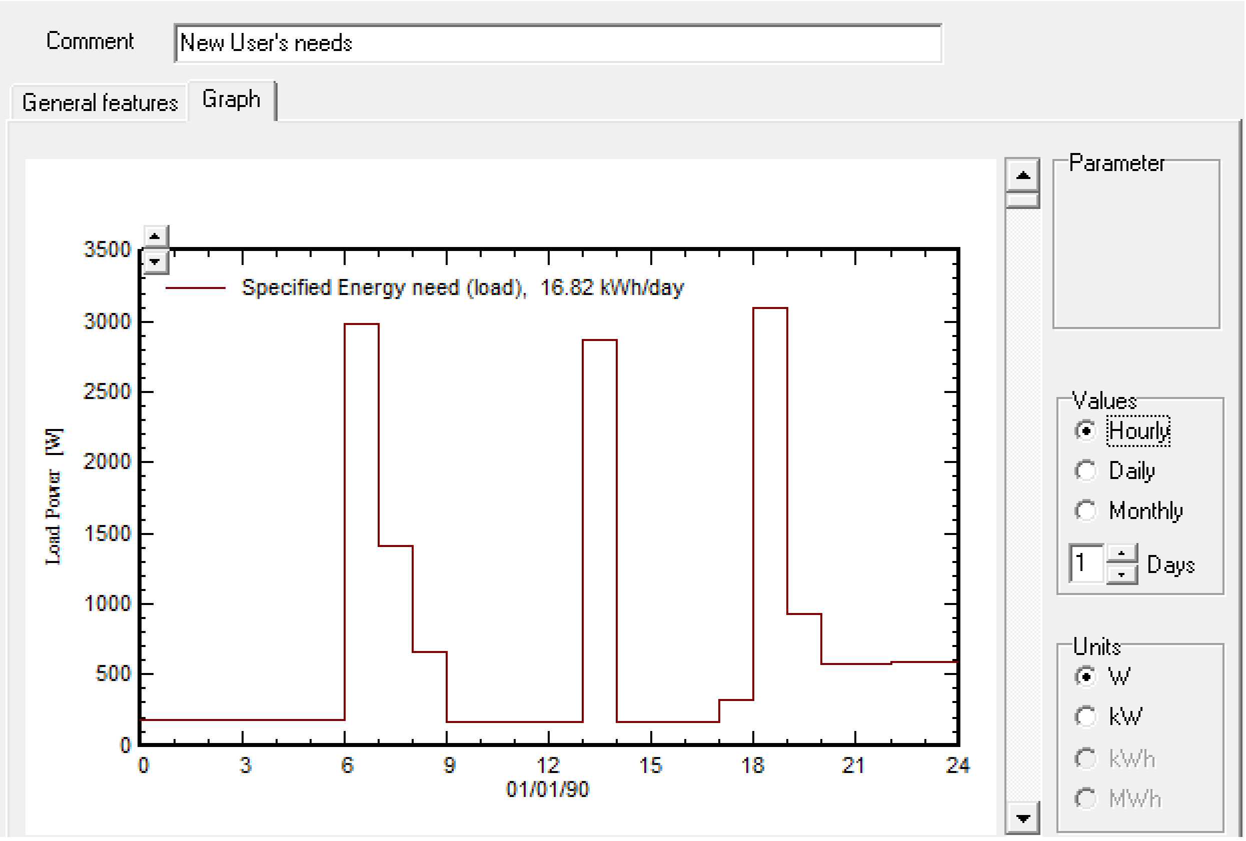
3.1. User's need:

The user's need data of standalone PV system have the same data of own-consumption PV system.

The daily profile in hourly values is performing in CSV. The table 13 and the graph 5 have been shown the example of daily profile in hourly values of one weekly day in winter which the total energy for that day is 16.82kWh and the total energy need of whole year is 9844kWh.

Date	**Load (W)**
1/1/2018 0:00	180
1/1/2018 1:00	180
1/1/2018 2:00	180
1/1/2018 3:00	180
1/1/2018 4:00	180
1/1/2018 5:00	180
1/1/2018 6:00	2981
1/1/2018 7:00	1412
1/1/2018 8:00	665
1/1/2018 9:00	165
1/1/2018 10:00	165
1/1/2018 11:00	165
1/1/2018 12:00	165
1/1/2018 13:00	2863
1/1/2018 14:00	165
1/1/2018 15:00	165
1/1/2018 16:00	165
1/1/2018 17:00	315
1/1/2018 18:00	3089
1/1/2018 19:00	926
1/1/2018 20:00	576
1/1/2018 21:00	576
1/1/2018 22:00	591
1/1/2018 23:00	591

Table 13: Data of user’s need for one weekly day of winter


Comment: New User's needs

Values: ● Hourly ○ Daily ○ Monthly, 1 Days

Units: ● W ○ kW ○ kWh ○ MWh

Graph 5: The specified energy need from the load for one weekly day of winter

3.2. Orientation:

For the orientation part, the field type and field parameters have been need to choose. For the field type, I choose Fixed Tilted Plane which similar with an own-consumption PV system. About the field parameter, the number has been analyzed.

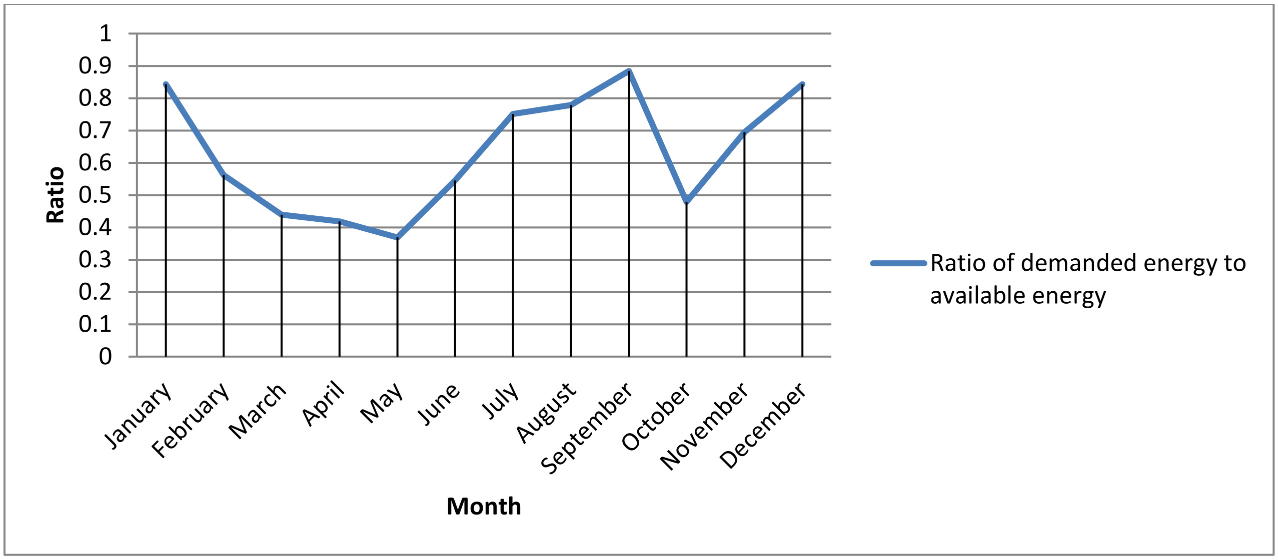
The location is Valladolid in Spain belonged to Northern Hemisphere, which led to in order to absorb the maximum irradiation from the sun; the panel must have to face the South. So we have Azimuth: 0° to the South.

To find the suitable tilt, I use method named "the worst month". The worst month is the month of the year which has the largest ratio of demanded energy to available energy. After finding the worst month, finding the largest available solar energy and unused energy (full battery) loss corresponding tilt which is the suitable tilt, is a next step.

To find the worst month, I choose the tilt 30° with the available energy 15.87 MWh per year, September is the worst month which has the largest ratio of demanded energy to available energy 0.884183 having been shown in the table 14 and the graph 6 below.

Month	**Available solar energy (kWh)**	**Energy supplied to the user (kWh)**	**Ratio of demanded energy to available energy**
January	717	604	0.84304
February	986	554	0.561866
March	1408	618	0.439134
April	1419	595	0.418999
May	1639	604	0.368798
June	1698	926	0.545194
July	1844	1386	0.751573
August	1779	1386	0.779033
September	1530	1353	0.884183
October	1261	604	0.47935
November	856	595	0.694579
December	733	618	0.84352

Table 14: The available solar energy, energy supplied to the user and the ratio between them with the corresponding month



Graph 6: The available solar energy, energy supplied to the user and the ratio between them with the corresponding month

To find the perfect tilt, I have listed the values of the tilts from 15° to 60° apart each other 5° with the corresponding available solar energy and unused energy loss. The tilt 40° has the large available solar energy and unused energy loss which is the suitable tilt, has been proved clear in the table 15 and the graph 7 below.

Tilt	Available solar energy (MWh)	Unused energy (full battery) loss (MWh)
15	1.437	0.039
20	1.477	0.069
25	1.508	0.089
30	1.530	0.111
35	1.542	0.123
40	1.545	0.126
45	1.539	0.120
50	1.524	0.110
55	1.500	0.086
60	1.466	0.052

Table 15: The available solar energy and unused energy (full battery) loss corresponding tilt

Graph 7: The available solar energy and unused energy (full battery) loss corresponding tilt

3.3. PV system:

3.3.1. Select the components: the batteries, the PV module, charge controller/ regulator and the inverter

PV system of a standalone includes the batteries, the PV module, charge controller/ regulator and the inverter. The PVsyst just have these components including the batteries, the PV module, charge controller/ regulator not inverter and I have to choose the inverter by myself and calculate the energy from output of the inverter.

Selection the inverter:

For the inverter, I have to find the inverter for standalone on the internet satisfied with the highest power that user need is 3228 W and the voltage system is 48 V, therefore Sunny Island 4.4M is suitable for this case. According the website, " The Sunny Island 3.0M / 4.4M is the perfect product solution for stand-alone and grid-connected systems with a power output range of 2 to 13 kW. With its high protection class, wide temperature range and overload capacity, the Sunny Island provides the kind of reliability needed for off-grid use. The intelligent load and energy management ensures operation even in critical situations, such as in the event of high inrush currents or harsh ambient conditions."[8] The efficiency of the inverter is 95.5%. The characteristics of an off- grid inverter have been shown on the table 16 below.

Model		**Sunny Island 4.4M**
Battery DC Input	Rated input voltage	48 V
	DC voltage range	41 V to 63 V
	Maximum battery charging current	75 A
	Rated DC charging current	63 A
	DC discharging current	75 A
	Battery type	Li-ion, FLA, VRLA
	Battery capacity (range)	100 Ah to 10000 Ah (lead) 50 Ah to 10000 Ah (li-ion)
AC Output	AC voltage	230 V
	Rated frequency / frequency range	50 Hz / 45 Hz to 65 Hz
		Monophased
	Rated power (for Unom / fnom / 25°C / cos ϕ = 1)	3300 W
	AC power at 25°C for 30 min / 5 min / 3 s	4400 W / 4600 W / 5500 W
	AC power at 45°C continuously	3000 W
	Rated current / short-circuit current (peak)	14.5 A / 60 A
General data	Maximum efficiency	95.5%
	Dimensions (width x height x depth)	467 mm x 612 mm x 242 mm (18.4 inches / 24.1 inches / 9.5 inches)
	Weight	44 kg (97 lbs)

Table 16: The characteristic of battery

Selection the batteries:

For choose right batteries, I have to determine the user’s need energy for a day, the values of autonomy days, depth of discharge, system voltage, battery type then calculate the size of batteries.

For the total energy for a year that the user need is 9843003 (Wh) with 365 days, so the average daily needs 9843003 (Wh)/365 days=26967(Wh).

The batteries are stored energy for the time during the load can be met with the battery alone, without any solar input, starting of course from a “full charged” battery state which called autonomy days. The values of autonomy days I choose for this project is 4 days.

For the battery type, I choose lead acid which is the cheapest option but they are big, heavy, require regular maintenance, short lifespan and only be discharge to about 50% of their capacity. The depth of discharge refers to the maximum amount of energy you can draw from a battery without greatly reducing its lifespan, is about 50%.

The system voltage is 48 V, the battery voltage is 2 V per cell. So I have the number of batteries in series are 48 V/2V = 24 batteries.

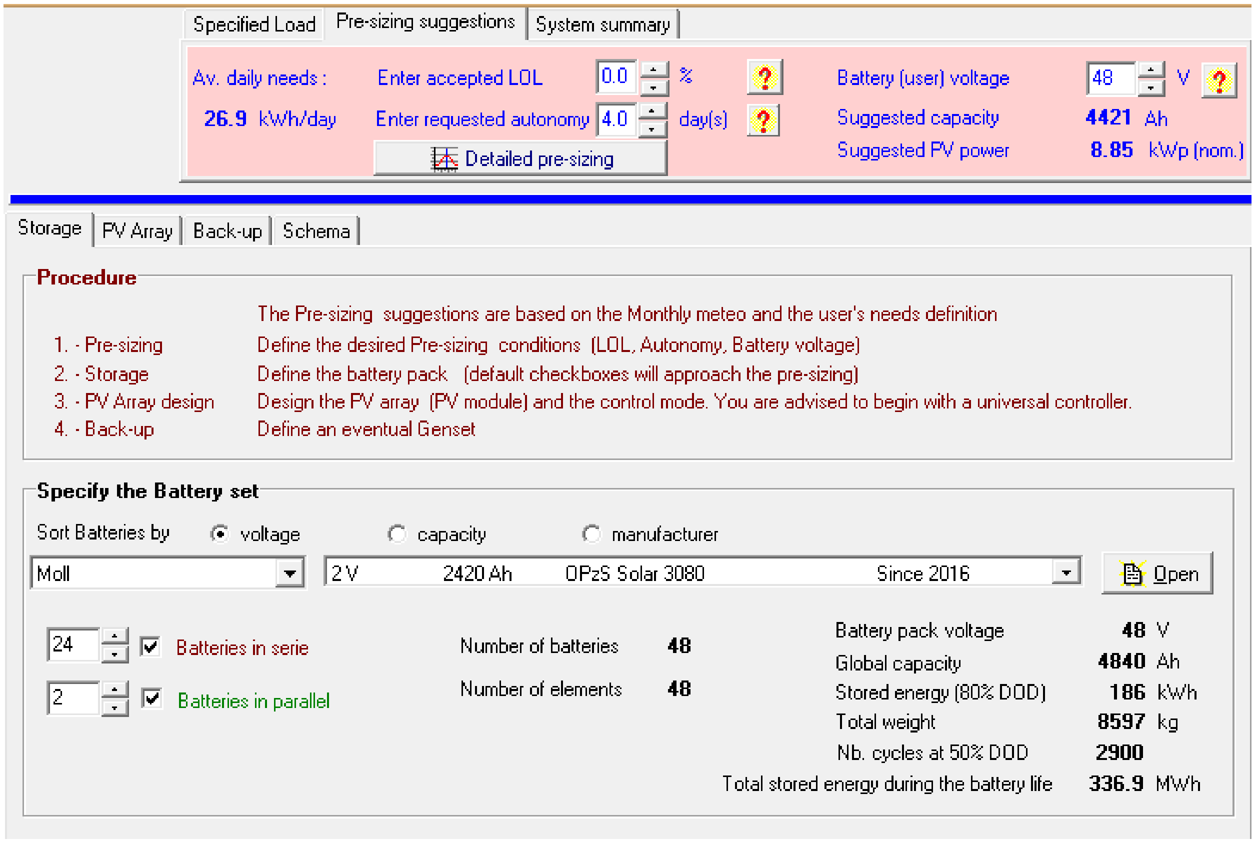
After having all the variables, next step is determining how much battery power user need by calculate in order.

- First, taking average daily needs divide by inverter efficiency : 26967(Wh)/0.955=28237(Wh);
- then multiply by number of autonomy days : 28237(Wh)*4=112950(Wh);
- next divide by depth of discharge : 112950(Wh):0.5=225900(Wh);
- Finally divide by system voltage: 225900(Wh)/ 48V=4706(Ah).

There is a different result by PVsyst in the figure 11, because of missing inverter so the capacity of batteries that PVsyst suggested just 4421(Ah). So I choose OPzS Solar 3080 from Moll Company which has nominal voltage 2 V and capacity 2420 Ah. I find a highest capacity of the batteries to have fewer strings due to batteries are charged by a charge controller, it’s easy for the charge controller to charge up the batteries if the voltage of one string remains constant as it charges. If two strings are present, the charge controller has to work harder to balance the voltages, and the strings can end up charging at different rates, meaning they will heat differently and their lifespans may be decreased. Therefore fewer strings are better. So in series there are 24 batteries with values of voltage is 24*2=48 V and capacity is 2420Ah; and have 2 strings in parallel which each string including 24 batteries, the voltage same value 48 V and total capacity is 4840 Ah. Therefore the total number of batteries is 24*2=48 (batteries). The table 17 is shown the characteristics of batteries.

Model	**Moll, OPzS Solar 3080**
Data Source	Manufacture 2016
Technology	Lead-acid
Number of cells	1 cell
Nominal voltage	2.0 V
Nominal capacity (at discharge rate of 10 hours)	2420Ah per cell 4.84kWh per battery
Internal resistance	0.1 mOhm/cell
Coulombic efficiency (without gassing)	97%
Reference temperature	20 C
Size (width x height x depth)	0.49 x 0.81 x 0.21m x m x m
Weight	179 kg

Table 17: Characteristics of batteries



Av. daily needs : 26.9 kWh/day

Enter accepted LOL 0.0 %

Enter requested autonomy 4.0 day(s)

Battery (user) voltage 48 V

Suggested capacity 4421 Ah

Suggested PV power 8.85 kWp (nom.)

Procedure

The Pre-sizing suggestions are based on the Monthly meteo and the user's needs definition

1. - Pre-sizing	Define the desired Pre-sizing conditions (LOL, Autonomy, Battery voltage)
2. - Storage	Define the battery pack (default checkboxes will approach the pre-sizing)
3. - PV Array design	Design the PV array (PV module) and the control mode. You are advised to begin with a universal controller.
4. - Back-up	Define an eventual Genset

Specify the Battery set

Sort Batteries by ● voltage ○ capacity ○ manufacturer

Moll

2 V 2420 Ah OPzS Solar 3080 Since 2016

24 ☑ Batteries in serie

2 ☑ Batteries in parallel

Number of batteries 48

Number of elements 48

Battery pack voltage	48 V
Global capacity	4840 Ah
Stored energy (80% DOD)	186 kWh
Total weight	8597 kg
Nb. cycles at 50% DOD	2900
Total stored energy during the battery life	336.9 MWh

Figure 11: Choosing battery bank by PVsyst

Selection the PV module:

For easy to comparison between 2 PV system, I use the same solar panel branch named Sunpower_SPR-200-BLK from manufacturer 2008 with same technology is Si-mono has nominal Power 200 Wp – 34 V. The solar panel has efficiency approximate 16.4%. The characteristics of a PV module have been shown on the table 18 below.

Model	**SunPower, SPR-200-BLK**
Data source	Manufacture 2008
Power	200 Wp
Technology	Si- mono
Open circuit voltage	47.6 V
Maximum power point voltage	40 V
Short- circuit current (Isc)	5.65 A

Maximum power point current	5.00 A
Efficiency (module area) for standard condition	16.4%
Fill factor	0.757

Table 18: The characteristics of a PV module

Selection the charge controller/ Regulator:

The charge controller or Regulator take care of batteries, which switch off the PV modules when batteries are fully charged, and may switch off the load to prevent the batteries from being discharged below a certain limit. So the charge controller has the same voltage with the batteries and inverter 48 V, also it is associated Lead- acid battery pack technology. Therefore Tristar TS MPPT 45 - 48V charge controller from Morningstar Company is suitable one which has characteristics from the table 19 below.

Model	**Morningstar, Tristar TS MPPT 45 - 48V**
Technology	MPPT converter
Nominal battery voltage	48V
Maximum input current	50A
Maximum output current	45A
Battery temperature compensation	External sensor
Associated Battery Pack technology	Lead-acid
Size (width x height x depth)	142mm x 290mm x 130mm
Weight	4.20kg

Table 19: Characteristics of a regulator

3.3.2. Design the PV system:

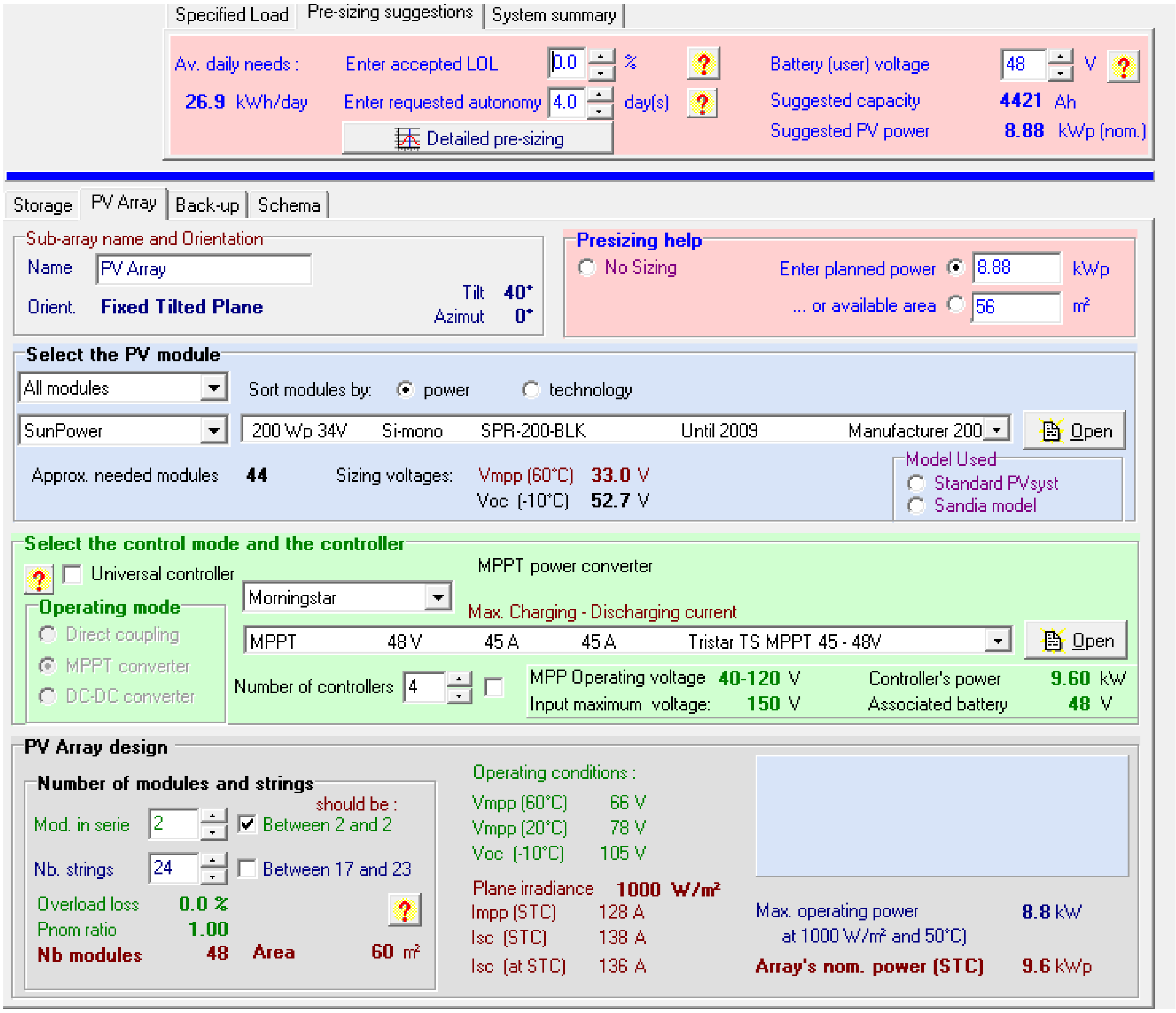
The design of PV system:

For design of PV system, I have to set up the number of each component and installation of each component.

First, I install the PV module and the charge controller. The PV module Sunpower_SPR-200-BLK has voltage range from 33.0 – 52.7 V and short- circuit current (Isc) 5.65 A. Connected with PV modules, the charge controller Tristar TS MPPT 45 - 48V has maximum input voltage 150 V and maximum input current 50A. As suggested PV power from PVsyst is 8.88kWp, the total number of modules is 48 connected have the power 9.6kWp with 4 charge controllers. Numbers of PV modules in series are 2, and 24 strings in parallel. I divide to 4 groups connected parallel together; each group has 12 modules and 1 controller. In each group, 6 strings connected parallel together and parallel with charge controller, each string has 2 modules in series. For PV modules, a string contain 2 modules in series has voltage range from 66-105 V and Isc 5.65A, 6 strings parallel have same voltage range 66-105 V and Isc 5.65 * 5=33.9A which match with charge controller having maximum input voltage 150 V and maximum input current 50A. Four groups connected in parallel has same voltage 48 V and the current is 33.9 *4=135.6A. The set up number of PV modules and charge controller can be seen in the figure 12.

Next, the battery bank has defined in the selection battery. In series, 24 batteries OPzS Solar 3080 connected together and 2 strings in parallel. The battery bank has the voltage 48V and the total capacity 4840Ah.

Final, one inverter Sunny Island 4.4M have input voltage 48 V and at output side, the voltage 230V with power 4400W connected with the load.



Av. daily needs : 26.9 kWh/day
Enter accepted LOL 0.0 %
Enter requested autonomy 4.0 day(s)
Battery (user) voltage 48 V
Suggested capacity 4421 Ah
Suggested PV power 8.88 kWp (nom.)

Sub-array name and Orientation
Name PV Array
Orient. Fixed Tilted Plane
Tilt 40°
Azimut 0°

Presizing help
○ No Sizing
Enter planned power ● 8.88 kWp
... or available area ○ 56 m²

Select the PV module
All modules
Sort modules by: ● power ○ technology
SunPower
200 Wp 34V Si-mono SPR-200-BLK Until 2009 Manufacturer 200
Approx. needed modules 44
Sizing voltages: Vmpp (60°C) 33.0 V
Voc (-10°C) 52.7 V
Model Used
○ Standard PVsyst
○ Sandia model

Select the control mode and the controller
☐ Universal controller
Morningstar
MPPT power converter
Max. Charging - Discharging current
MPPT 48 V 45 A 45 A Tristar TS MPPT 45 - 48V
Operating mode
○ Direct coupling
● MPPT converter
○ DC-DC converter
Number of controllers 4 ☐
MPP Operating voltage 40-120 V
Input maximum voltage: 150 V
Controller's power 9.60 kW
Associated battery 48 V

PV Array design
Number of modules and strings
should be :
Mod. in serie 2 ☑ Between 2 and 2
Nb. strings 24 ☐ Between 17 and 23
Overload loss 0.0 %
Pnom ratio 1.00
Nb modules 48 Area 60 m²

Operating conditions :
Vmpp (60°C) 66 V
Vmpp (20°C) 78 V
Voc (-10°C) 105 V
Plane irradiance 1000 W/m²
Impp (STC) 128 A
Isc (STC) 138 A
Isc (at STC) 136 A
Max. operating power 8.8 kW
at 1000 W/m² and 50°C)
Array's nom. power (STC) 9.6 kWp

Figure 12: Choosing the parameters of the standalone PV system by PV syst

The overload is 0.0% which means the number of the inverter is suitable for the system. Pnom ratio meaning the value of nominal power of array divide to nominal power of array has a value 1.0.

Scheme of the installation:

Scheme on figure 13 shows how different parts of the PV system are connected. At output side of inverter, using monophased which has line (L) and neutral (N) line connected with grid and house.

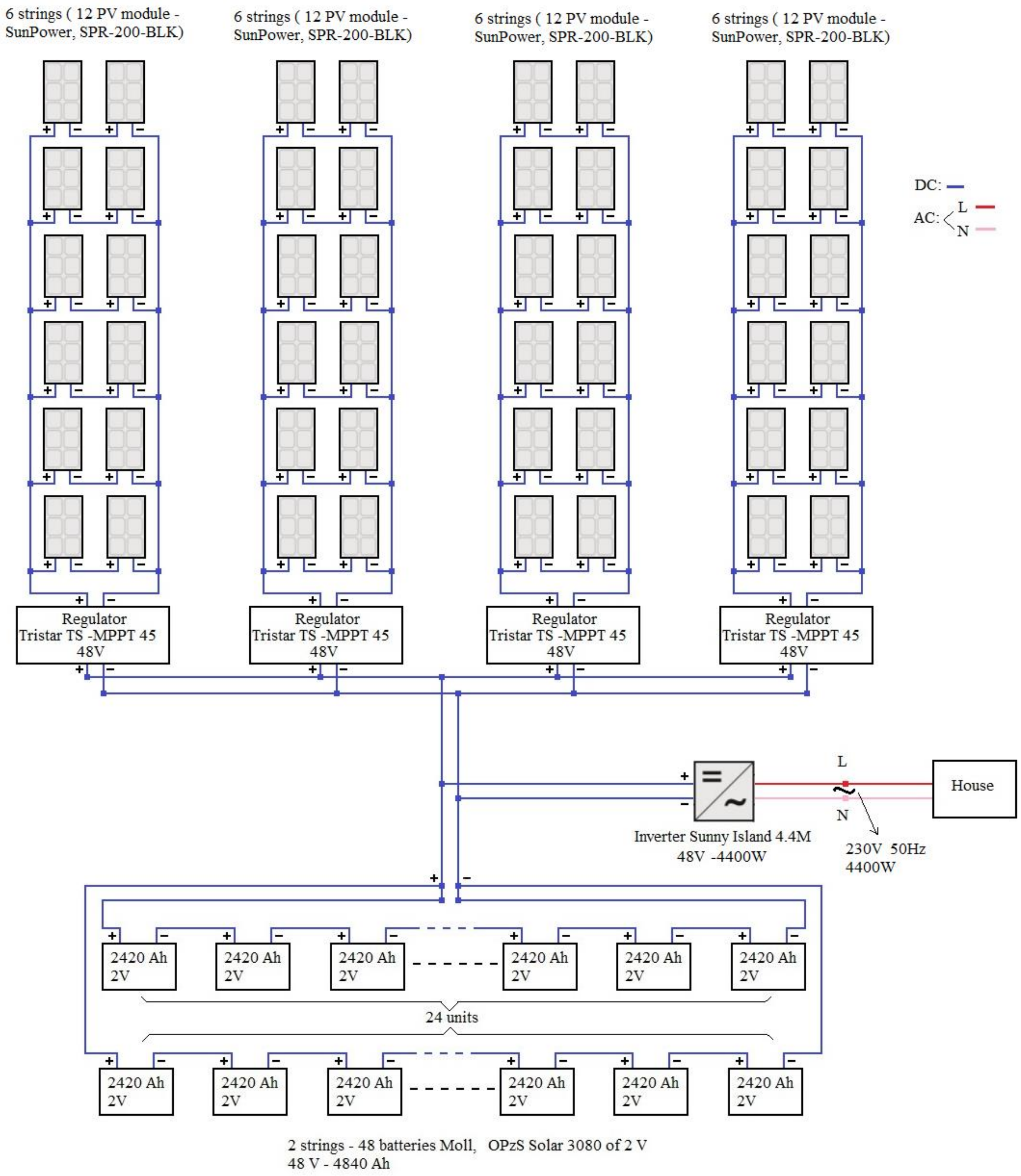


Figure 13: Scheme of the installation of standalone PV system

3.4. Near shading:

No shadings have been defined for this simulation.

3.5. Economical value:

According to installers an average cost of a PV system could be, the price per power of each component has been shown on the table 20 below:

Components	**Price(€/Wp)**
PV panel	0.7-1
Charge controller / Regulator	0.13
Inverter	0.5-0.7
Batteries (2 V)	0.25 (€/Ah)
Mounting structure	0.12
Other (wire,etc)	0.5

Table 20: The average cost of a standalone PV system

My panel from SunPower company which is high quality then the price is 1(€/Wp) with the high quality inverter so the price is 0.7(€/Wp). The total price of PV system without batteries is 1+0.13+0.7+0.12+0.5=2.45(€/Wp) means 2450(€/kWp). PV power is 9.6 kWp, the price of PV system without batteries is 23520 €. The capacity of batteries is 4840 Ah so the price of batteries is 4840Ah*0.25 (€/Ah) = 1210 €. The money I have to pay for standalone PV system is 23520 + 1210 = 24730 €.

In one year, the total energy that user's need is 9843.6kWh. If I have to pay to buy energy from the grid, for one year I have to pay: 0.15(€/kWh.year)*9843.6kWh=1476.54 € which is the money I can saving for one year not including my PV system cost; for 25 years, I can saving not including my PV system cost is 1476.54€ *25 years=36913.5 €. So the money I can saving after I pay for my PV system cost for 25 years is 36913.5-24730=12183.5 €. I want to find the number of years I can recover my investment for PV system by dividing the money I have to pay for standalone PV system to the money I can saving for one year not including my PV system cost : 24730/1476.54=16.75 years. So after 16.75 years, I have 25years-16.75years=8.25 years for using energy free.

3.6. The loss diagram over the whole year from PV syst:

The loss diagram over the whole year is shown on figure14. I have array nominal energy for whole year is 18,27 MWh but minus to PV loss due to irradiance level, PV loss due to temperature, module quality loss, module array mismatch loss, Ohmic wiring loss and unused energy (full battery) loss so the effective energy at the output of the array just 10.82

MWh. After loss during operation, the energy is 10.55MWh. Including 95.5% of inverter that PVsyst not have, the energy is 10.55*95.5%= 10.07MWh still the energy need of the user so no missing energy.

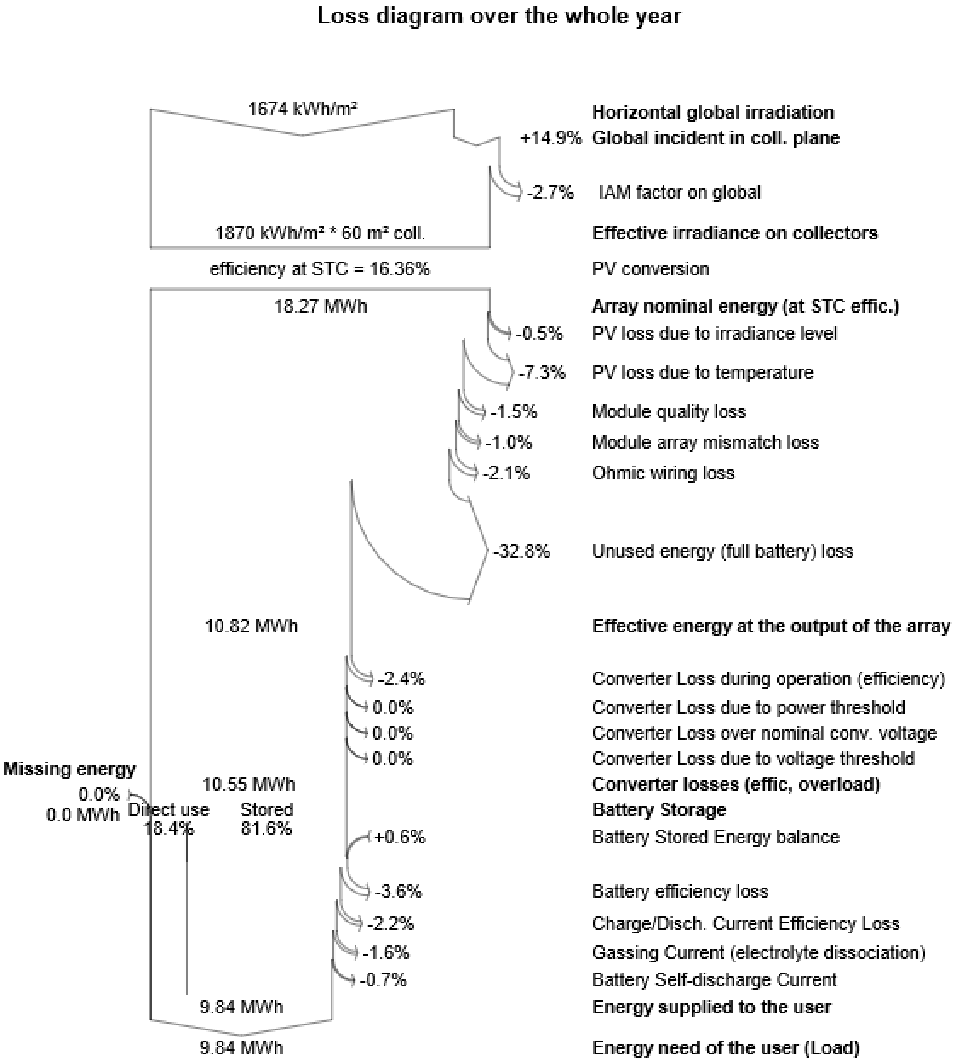


Figure 14: The loss diagram over the whole year from PVsyst

V. RESULTS AND DISCUSSIONS:

In this part, I will comparison two PV systems based on the information of previous part into four factors: how to set PV system, economy, environment, and regional to give a advice for customers what their priority are.

At first, setting each PV system is quite different between two PV systems because of their components. The own-consumption PV system has fewer components than standalone PV system; just two components are PV modules and inverter. The own-consumption provides energy when its daylight and sunny day not in nighttime, so missing energy is inevitable which have taken from the grid. Because of taken amount of energy from the grid, so the method is finding the optimum power to balance the energy between PV system produce and taken from the grid. The energy provides for daylight by PV system and for nightlife by the grid, therefore there is a huge advantage for the user if they only use energy for daylight. Different from the own-consumption PV system, the standalone PV system instead of be taken energy from the grid, it has battery to stored the energy. The components of the standalone PV system are PV modules, charge controller, inverter and battery. Because of having battery, the customers don't need to depend on another energy like the own- consumption PV system, they can produce the energy by their own. Before deciding the sizing of the battery and the PV module, the method has been used finding "the worst month". The power of standalone PV system is 9.6kWp lager than the power of own-consumption PV system just 1.25kWp due to stored energy to battery of standalone PV system, therefore the number of PV modules of standalone PV system is very huge (48 modules) in comparison with own-consumption PV system (5 modules).

Secondly, the economy of two PV systems is quite interesting. Because of component and the power of two PV systems are very different, so the prices of two PV systems are also different. The price of standalone PV system is 24730 €, higher 9.3 times than the price of own-consumption PV system is just 2650 €. However, the money can saving for 25 years including PV system cost of standalone PV system is 12183.5 €, also higher 8.67 times than of own-consumption PV system is just 1405.5 €. The number of years to recover investment of PV system cost is similar 16 years. The explanation for this is the behavior of user's need using mainly energy for night hours, although the money investing own-consumption PV system is small but the money to buy energy for the grid is high. For this household, the user should use standalone PV system because benefit of its economic is higher than own-consumption PV system. Assume that the quality of the PV system is not decreasing, the price of PV system not including any tax, vat and the price of energy by from electrical company not increasing for 25 years.

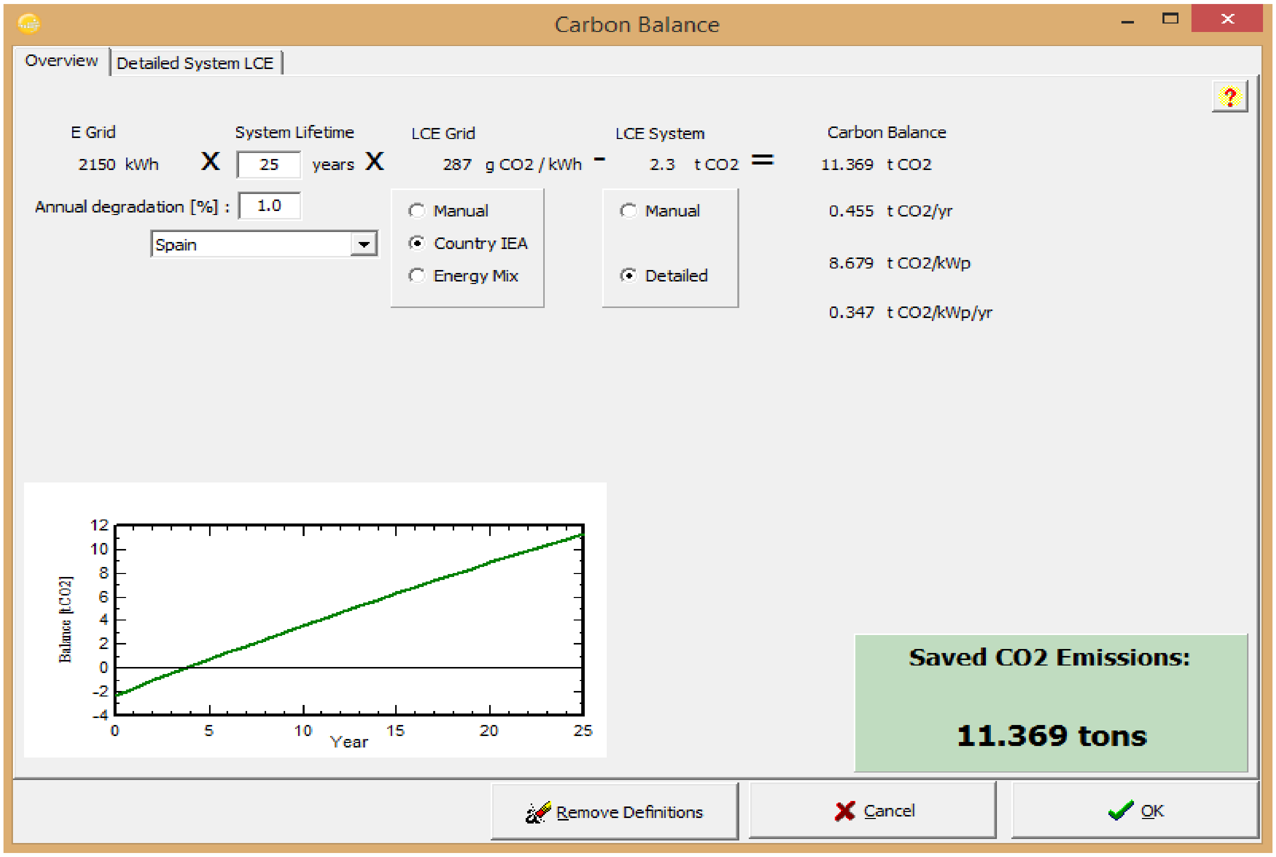
Thirdly, environment is the problem I care the most. Thank to PVsyst, I can calculate saved Carbon dioxide CO_2 emissions for the PV installation in 25 years by the Carbon Balance tool which have the formula:

$$E\ Grid \times System\ Lifetime \times LCE\ Grid - LCE\ system = Carbon\ Balance$$

Note:

- E_Grid: The System Production, or energy yield, of the PV installation for one year as computed by the PVsyst simulation. (Additionally, Annual Degradation, which is set to 1% by default, and which represents a yearly decrease of the energy yield due to aging of the PV components).
- System Lifetime: This is the lifetime of the PV installation given in years. It determines, together with E_Grid, the total amount of Energy that will be replaced by the PV installation.
- Grid LCE: It is given in gCO2/kWh and represents the average amount of CO2 emissions per Energy unit for the Electricity produced by the Grid.
- PV System LCE: It is given in tCO2 and represents the total amount of CO2 emissions caused by the construction and operation of the PV installation.

For own-consumption PV system, I can save 11.369 tons CO_2 emissions for 25 years which can be seen in the figure 15 below.



E Grid: 2150 kWh X System Lifetime: 25 years X LCE Grid: 287 g CO2 / kWh - LCE System: 2.3 t CO2 = Carbon Balance: 11.369 t CO2

Annual degradation [%] : 1.0

Spain

LCE Grid: ○ Manual ● Country IEA ○ Energy Mix

LCE System: ○ Manual ● Detailed

0.455 t CO2/yr

8.679 t CO2/kWp

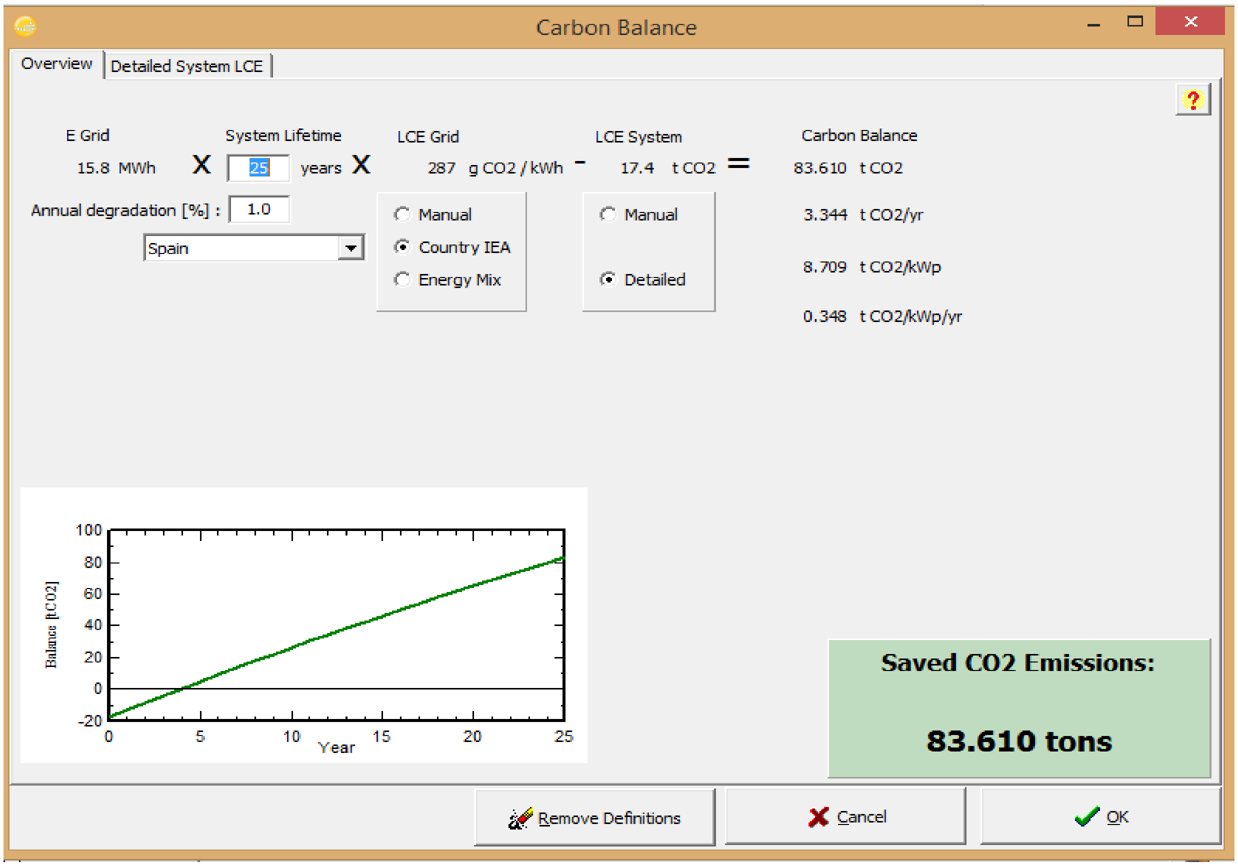
0.347 t CO2/kWp/yr

Saved CO2 Emissions:

11.369 tons

Figure 15 : Carbon balance from own-consumption PV installation

For standalone PV system, I can save 83.610 tons CO_2 emissions for 25 years which can be seen in the figure 16 below.



Carbon Balance

Overview | Detailed System LCE

E Grid 15.8 MWh X System Lifetime 25 years X LCE Grid 287 g CO2 / kWh - LCE System 17.4 t CO2 = Carbon Balance 83.610 t CO2

Annual degradation [%] : 1.0

Spain

LCE Grid: ○ Manual ● Country IEA ○ Energy Mix

LCE System: ○ Manual ● Detailed

3.344 t CO2/yr

8.709 t CO2/kWp

0.348 t CO2/kWp/yr

Saved CO2 Emissions:

83.610 tons

Figure 16: Carbon balance from standalone PV installation

The amount of CO_2 emissions saved from standalone PV system is higher 7.35 times than from own-consumption because of the emission from energy produced by the grid which own-consumption PV system still taken energy from the grid. The reason that energy from the grid can be taken from the fossil fuel, not to mention that in the transmission energy by the grid can be lost amount of energy which can be emitted amount of CO_2. Therefore, using standalone PV system can protect the environment more than using own-consumption PV system.

Last but not least, it depends on religion specifically the space that you can put PV panel on. For standalone PV system, producing a lot of energy so the number of panels are 48 modules take 60 m^2. For own- consumption, the number of panels are 5 modules take 5m^2. In this project, I assume that no limit for the area putting PV panel but in reality, installation PV standalone demand a lot of space so the own-consumption PV system can be one advantage. But the own-consumption PV system needing take energy from the grid so own-consumption PV system is suitable in high population density area or in city, land but standalone PV system is suitable for low population density area or in island.

VI. CONCLUSION:

In general, I have set up two PV systems which are own-consumption PV system and standalone PV system for one household by using PV syst software 6.6.2; after that I use the result from PV syst software 6.6.2 of two PV systems to comparison in four factor including how to set PV system, economy, environment, and regional. I have found that in term of economy, although the number of years to recover investment for PV system of two PV systems is the same as 16 years and have 9 years using free energy however the money saving of standalone PV system higher 8.67 times than of own-consumption PV system. In term of environment, the amount of saving CO_2 emissions from standalone PV system is higher 7.35 times than from own-consumption PV system. In term of area, the area of standalone PV system is higher 12 times comparing with of own-consumption PV system. For this project, I assume no limit area, so standalone PV system has advantage of economy and environment which suitable to use for this household.

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Valladolid, 11th July, 2018.

Minh Anh Pham

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IX. APPENDIX:

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