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"INSTALLATION OF SOLAR ENERGY IN SPAIN AND UK"

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INSTALLATION OF SOLAR ENERGY

IN SPAIN AND UK.

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ABSTRACT

The present projects has got the aim of construct and design a Solar photovoltaic cover connected to the electrician network and install in two places: One in Wales (UK) and the other in Navarra (Spain) to calculate the differences and compare the performance in each place.

Firstly I will describe the importance about the renewable energy in our life to reduce the pollution and save money .Also I will describe the different kind of them and which are more important and more useful .To make an approach to Solar Energy, I will explain some useful ideas in this one field to deal all the report.

Besides, I will design a solar photovoltaic cover to obtain the maximum performance with different materials and components.

If the installation obtain and extra energy it will be overturned to the grid to gain money and the amortization will be more quickly.

In this design I will calculate the budget and the amortization and next I will recommend or not.

ACKNOWLEDGEMENTS

Firstly, I would like to thank the University of Glyndwr for their support received during all the year and also my family because without them I could not be spending one year abroad.

I would also like to express my gratitude to all my friends, in special Tadeo Ciaurriz because they have been constantly helping and supporting.

Finally, I would like to thank the help of my supervisor Graham Smith for his guidance during the completion of this project.

LIST OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1: INTRODUCTION

During this report it will be developed a photovoltaic (PV) System in a semi-detached house with all my knowledge that I have acquired in my academic years. The study will be focus on two different climates, one in an area of Wales (Wrexham) and the other in an area of Spain(Navarra).Once done the different simulations will be compared the results and it will be seen in which is better to install.

In case of not supply with a PV system, it will be installed a small turbine wind to help the photovoltaic solar installation so that the house can be supply. If the installation gets extra energy I will design something to sell it to the Power Supply.

Firstly it will be done a research about the actual situation in Spain and UK, also the knowledge required for being able to design the installation.

1.1. – AIM

The main aim of this report is to develop a PV system calculating the cost of the installation and simulating the performance in both of the climates with the same characteristics like orientation and inclination of the modules, the same kinds of modules, and so forth.

With the results and knowing in how many years it will be redeemable, the installation will worth or not.

1.2.- OBJECTIVES

The objectives needed to develop and complete the report are presented below:

Research.

- Situation the Renewable energy in the world.
- Current Situation in Spain and UK.
- Photovoltaic s backgrounds.
- Information about the Solar energy.
- Kind of installation.
- Components required.

Design .

- Estimate and simulate the radiation solar.
- Estimate the consume of the house.

- Calculate the photoelectric cells needed depending the area available.
- Estimate and simulate the energy generation in each installation.

<u>Conclusion</u>

- In which area the performance is better.
- Profitable or not

1.3. – WORKING PLAN

In the following Figure1.1 describes the different steps to be completed in 28 weeks during the first and second semester. In the Table 1.1 is described the academic year 2009/10 in order to meet the objectives and subsequently to the final outcome

Academic Calendar 2009/10

This calendar is applicable to most undergraduate programmes, however there are exceptions (e.g. BA Primary Education with QTS and BN Nursing).

Timetable Week No.	w/c Monday	Notes	Teaching week No.
1	27-Jul-09		
2	03-Aug-09		
3	10-Aug-09		
4	17-Aug-09		
5	24-Aug-09		
6	31-Aug-09		
7	07-Sep-09		
8	14-Sep-09		
9	21-Sep-09	Induction/Enrolment for New Students[1]	
10	28-Sep-09	Teaching - Returning Students Enrolment	1
11	05-Oct-09	Teaching	2
12	12-Oct-09	Teaching	3
13	19-Oct-09	Teaching	4
14	26-Oct-09	Teaching/Reading Week[2]	5
15	02-Nov-09	Teaching	6
16	09-Nov-09	Teaching	7
17	16-Nov-09	Teaching	8
18	23-Nov-09	Teaching	9
19	30-Nov-09	Teaching	10
20	07-Dec-09	Teaching	11
21	14-Dec-09	Exams/Teaching	12
22	21-Dec-09	Vacation	
23	28-Dec-09	Vacation	
24	04-Jan-10	Vacation	
25	11-Jan-10	Teaching	13
26	18-Jan-10	Teaching	14
27	25-Jan-10	Teaching	15
28	01-Feb-10	Teaching	16
29	08-Feb-10	Teaching	17
30	15-Feb-10	Teaching/Reading Week[3]	18
31	22-Feb-10	Teaching	19
32	01-Mar-10	Teaching	20
33	08-Mar-10	Teaching	21
34	15-Mar-10	Teaching	22
35	22-Mar-10	Teaching	23
36	29-Mar-10	Vacation	
37	05-Apr-10	Vacation	
38	12-Apr-10	Vacation	
39	19-Apr-10	Teaching	24
40	26-Apr-10	Assessment	25
41	03-May-10	Assessment	26
42	10-May-10	Exams	27
43	17-May-10	Exams	28
44	24-May-10	Assessment	29
45	31-May-10	Assessment	30

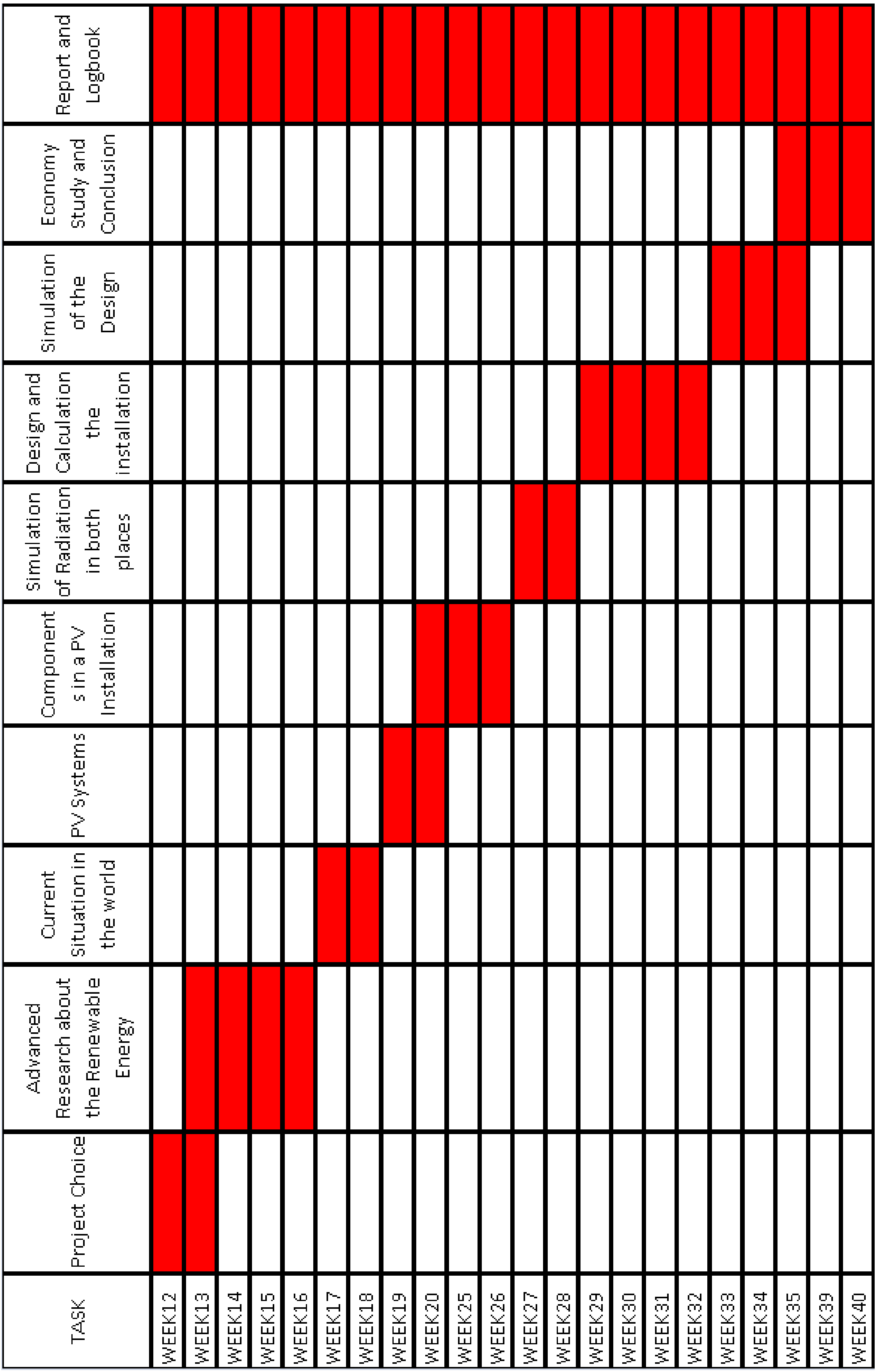


Figure1.1. –Working Plan

CHAPTER TWO

2.1. –THE RENEWABLE ENERGIES AND HISTORY OF PV SYSTEMS

Nowadays the energy represents a strategic factor for an economic growth, to get more employment and providing a better quality of live for people.

If a Country intent to develop something about the world of the renewable energy or improve their performance, it will be very positive for achieve a "clean economy" and Sustainable development and to fight against the Global Warming. In addition, the Kioto Protocol has been signed for some countries saying that they have to reduce the gas of greenhouse effect. One solution that some of them are using is the Renewable energy.

According to recent dates, the eighty five percent of all the energy emaciated in the world comes from the burning of fossil combustible. Also, A study developed by the International Energy Agency (2008) predicts that the "world primary energy demand grows by 1.7% per year on average in 2006-2030…an increase of 45%".

The resources have never exploited with this intensive rhythmic like this, so the scientific ´s world have warm to be conscious about the problems that we could have.

Solar energy is one that is having a faster growth in its capacity in the latter years as we can see in the following picture. This fact should not surprise since the Sun is our main source of energy.

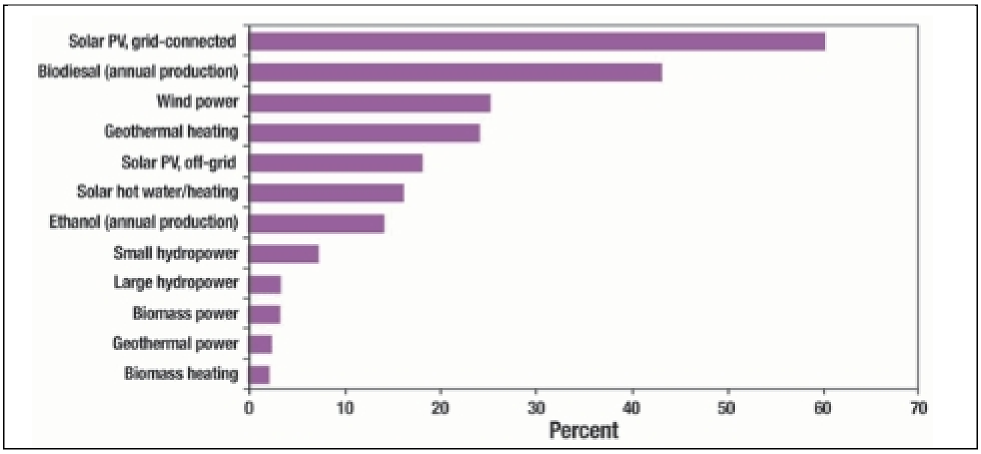


Figure 2.1.–Percent of Renewable [05]

Now it will be described how was discover the Solar Energy.

A physical phenomenon of PV effect was discovered in 1839 by the French physicist Alexander Edmond Becquerel, who found the photocurrent while experimenting with metal electrodes and electrolyte.

During 1873 and 1876 William G. Adams and Willoughby Smith made the first report about photoconductivity. In 1954 the silicon was introduce as a solar cell material and since then, it was made the first solar cell capable of converting energy of the sun into enough Power to run electrical equipment.

In the late 1950s there was a intensive space research and without this studies would have been impossible going to the space if not for solar cells.

With the time goes by, a new material was develop with better performance and less costly solar cell made that they were able to compete in situation where electricity was needed but the power lines were far away.

Since their discovery, solar cells and its technology have been developed a lot, making possible the fact that the PV systems can be seen in our environmental.

2.2 – CURRENT SITUATION

2.2.1. – ACTUAL SITUATION IN THE WORLD

Respect the world production, The year 2007 this sector grew very much, 40% respect 2006.For example in 2000 there were installed only 1.482 MWp and in 2007 8.700 MWp, so we can see the main change that was produced in the world of the PV systems. German is one the countries with more power install, followed by Spain

Being Conscious the importance that the PV systems has had in the world, In Figure 2.2 is shown the countries which more photovoltaic cells have made.

Traditionally, the manufacture of cells and photovoltaic panels has been concentrated in three zones: Japan, United States and Europe, but in these last years China has started to be important due to a Silicon´s factory was built in 2006 with a capacity of 10.000tm per year. United Kingdom was the fifth world manufacturer of PV modules after Germany, Japan Spain and USA

In 2007 Europe was making 30 % of the components of the photovoltaic facilities, of which 20 % was in Germany.

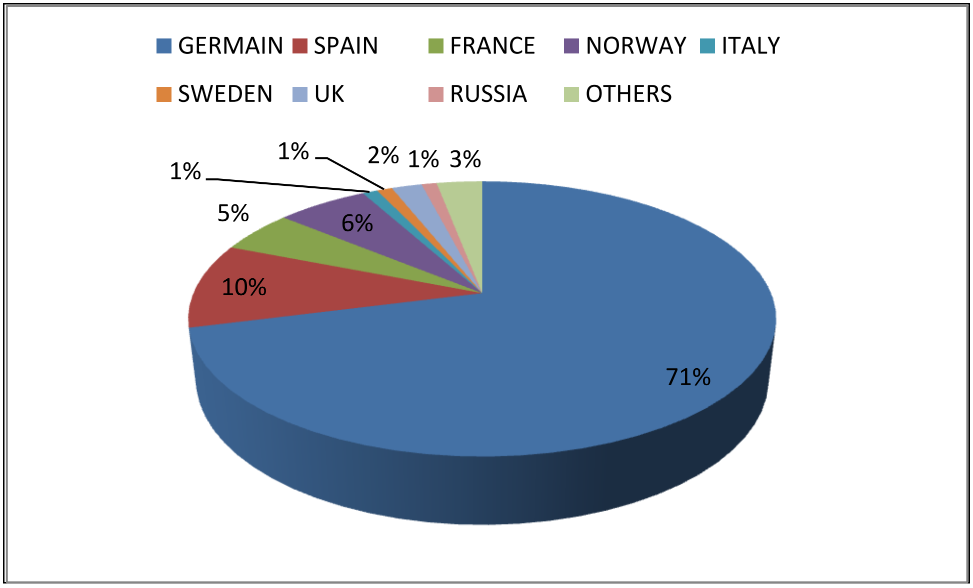


Figure 2.2 – PV module production in % by country in 2007[01]

2.2.2. – ACTUAL SITUATION IN SPAIN

Spain is one of the countries of Europe which most radiation received, nearly 1500 Kw/h in a year by squared metro. It will be calculated the installation in the area of the North-East of Spain which receive per media 3.8 Kw/h by squared metro.

Spain is under the PER (PLAN OF RENEWABLE ENERGIES 2005-2010),which main mains are:

- Achieve the 12% of the total consume of primary energy in 2010 with renewable energy.
- From 2005 to 2010 The Government has bet strongly with the Solar Energy. The helps are being increased for this type of installation to 43 million of Euros
- The most advantages of this plan have been: Generation of 9200 employments and reduction de emissions of dioxide the Carbone

It is described below that in 2005 Spain only had achieved el 6% of Renewable Energy and is a little far for fulfilling the aims marked by the Kioto´s Protocol, because exists a high dependence of the consumption of fossil origin.

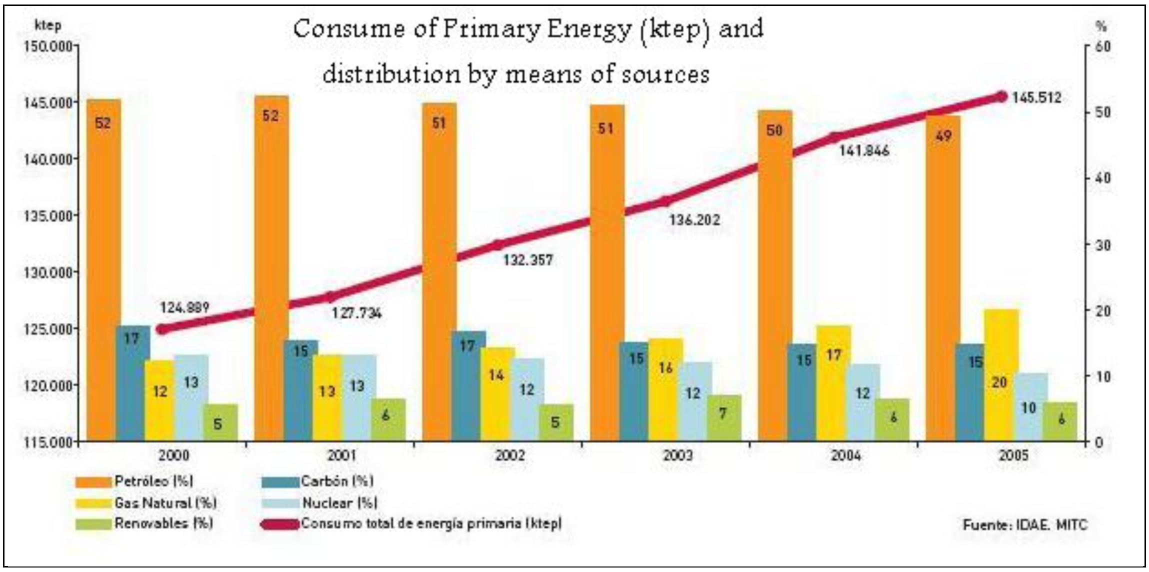
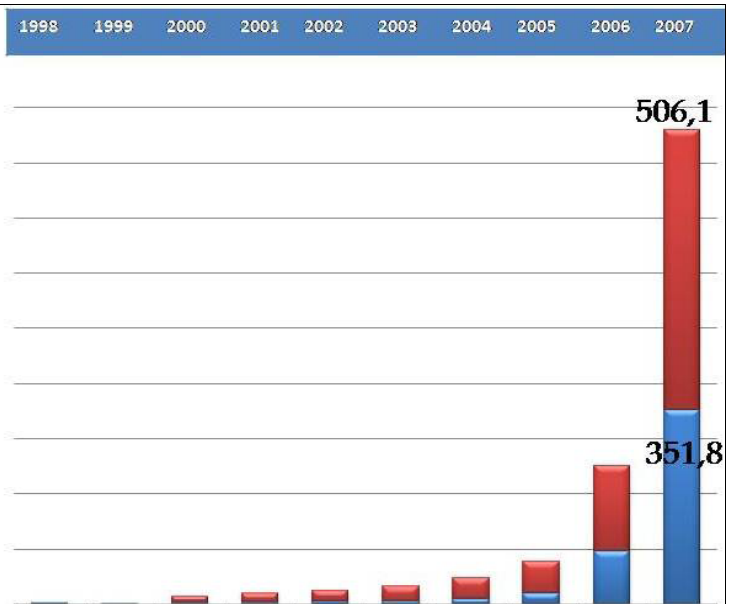


Figure2.3.-Evolution of the Consume and Production of Renewable energy[07]

From 2005 the government bet strongly with the PV installation and in 2006, Spain had achieved a consumption of 7.11% the Renewable Energy.

In 2007 Spain produce more than the 3% of the world production and in 2008 the objective of the PER has been achieved.

In the following display we can see the evolution until 2007



	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
ACUMULATED POWER	0	0	11,8	15,6	20,5	27	37,4	57,6	154,3	506,1
PV POWER INSTALL IN 2007	2,3	1,2	2,4	3,6	4,9	6,5	10,4	20,3	96,6	351,8

Figure 2.4.- PV Power install in 2007 in Spain[07]

Respect the world production, in the year 2007 this sector grew a lot , 40% respect 2006. For example in 2000 there were installed only 1.482 MWp and in 2007 , 8.700 MWp, so we can see the main change that was produced in the world of the PV systems.

2.2.3. – ACTUAL SITUATION IN UK

United Kingdom, like Spain, has the obligation of complying with the Kyoto Protocol and EU Directive. Thus, the UK government, wishing to reduce the country dependence of fossil-fuel stores and to cut carbon dioxide emissions for that achieve a 10 per cent of their energy from renewable sources by 2010, rising 15 per cent by 2020.In the following graph is shown the evolution of the renewable energies .These last years the renewable energy has increase a lot like the expectations are.

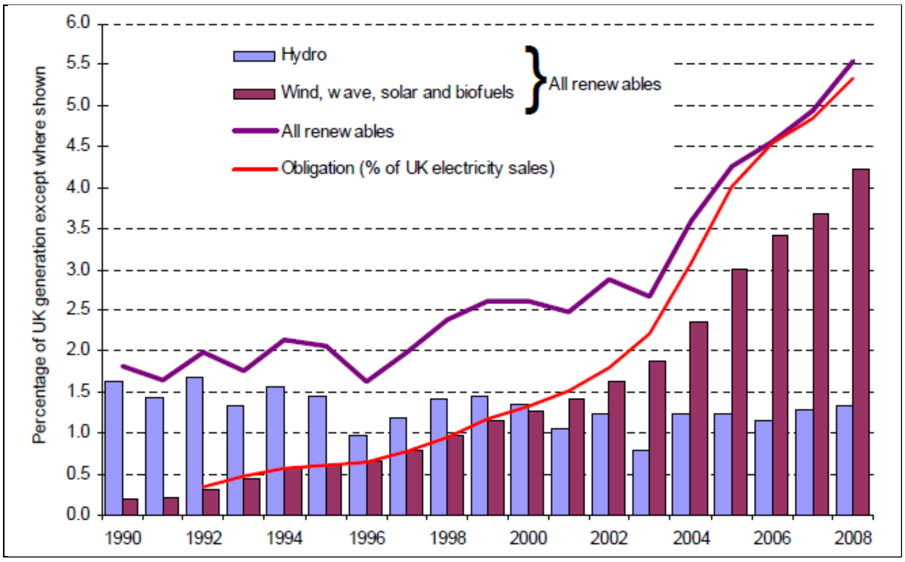


Figure 2.5.-Growth in electrical generation from renewable sources since 1990[24]

There have been significant increases in capacity and generation of PV systems in recent years due to the increased Government support.

New policy changes related to small-scale clean electricity are coming, since although the United Kingdom has a different energy policy compared with other European countries (since does not use the aforementioned FIT system), this is about to change. The British Department for Energy and Climate Change announced on July 2009 the measures taken to meet its carbon reduction targets. These included a proposal for the beginning in April 2010 of the Feed-In Tariff system.(FIT)

In addition this FIT system is different because consist on having two different tariffs: One of generation and other for export. The price of the generation tariff changes depending on the technology used to generate electricity. In the case of PV there are different prices represented in the Table 2.1, and it compares with another tariff that was used before, the Renewable Obligation Certificates (ROCs).

		Proposed initial tariff (p/kWh)	Approx ROC equivalent
PV	<1 KW(new build)	31	7
PV	Stand Alone System	26	6
PV	100KW-5MW	26	6
PV	10-100KW	28	6
PV	1-40 KW	31	7
PV	<1KW (Retrofit)	36	8

Table 2.1.- Tariff for first year of FITs compared with ROCs[05]

Thanks of the application of ROC system in 2002 the PV experienced a large increase. Grid Connected distributed reach nearly 22.000 KW in 2008.This kind of installation has been more installed than stand-alone non-domestic or stand alone domestic.

The department of Trade and industry reports that domestic energy has increased by 32 per cent since 1970 and 19 per cent since 1990.

2.3. – SOLAR POWER

2.3.1. – INTRODUCTIÓN

The sun, source of life and Origen of the rest of energies that the man has used since the prehisotory.The human could satisfy all the needes if learn how to take advantage of the sunshine which are continue coming to the planet.

It would be no rational if we do not use the advantage of this energy.This Energy resource is free, clean, and inexhasustible which could definetly to get out of the petrol or another alternatives contaminan.

However ther are some problems that we have to confront and overcome. Also we have to know this energy changes a lot depending in which season we are, indeed the sun´s rays are less intense in the time period which we need more, winter.

Due to this ideas among others we realized that is so important to continue developing this energy to achieve being competitive.

What is obtained from the solar energy?

Basically, collecting in a good way , anyone could obtain electricity and warm.The latter is possible thanks to the thermical´s collecting and the electicity by means of the photovoltaic´s modules.Both of them use different technology and maintenance.

2.3.2. – CHARACTERISTIC AND BASIC CONCEPTS

The photovoltaic system is based in the properties of the semiconctor material, which trasform the energy from the sun in electricity without chemical reactions, termodinamic cycles or process which required renovable parts.

The operation´s condition of a photovoltaic modul depends on different external changeable like solar radiation, the temperature of work, orientation and inclination of the modules…

Doing a design of a photovoltaic solar install needs to know the radiation of the place, in my case, Spain and UK.

The most relevant factors will be the irradiation and the diary demand. Like a general rule this energy will be said in KJ/m2.Bellow we can see a map of Europe with the radiation solar in each area.

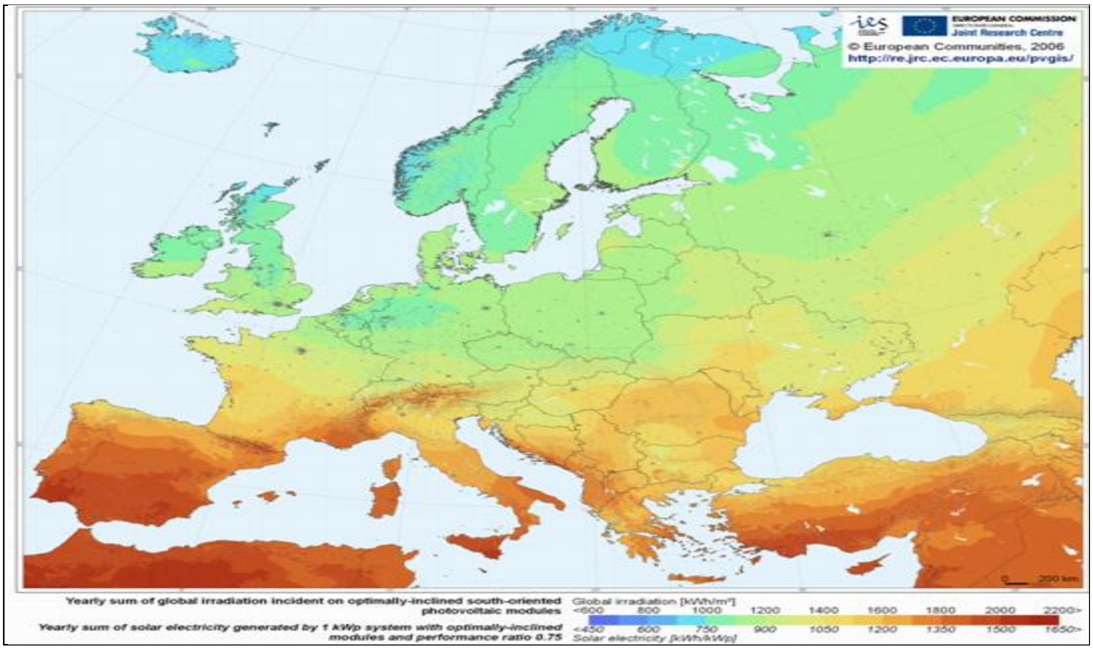


Figure 2.6 Solar Irradiation in Europe[03]

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The process to transform solar power to electricity by itself is thanks to an element semiconductor which is called Photovoltaic cell (explained in the section 2.6)

The connection of some photovoltaic cells with their encased and framed later gets like a result the photovoltaic modules or panels to generate electricity.

The photovoltaic installations are characterized by:

- Their simplicity and easy installation
- To be modular
- To have a large useful life(more than 30 years)
- The maintenance is low.
- Not produce any type of environmental pollution
- To have a silent working.

For achieve the solar power like a complement solution of the traditional system of the electric´s supply, is needed overcome some difficulties like:

1) ECONOMICS: Insisting of the reduction of theirs costs of manufacture and final price of installation, we will know in how many years the installation will be recouped. Depending on the performance of the photovoltaic cell and also of the economy in a large scale that takes place the purchase.
2) ESTHETICS: To incorporate the photovoltaic elements in the building having careful in not brake the design of the houses.
3) FINANCIALS: Getting acceptable financial conditions for do the inversion.
4) ADMINISTRATIVES: Getting the maximum support from the civil service

2.4. – SOLAR RADIATION

24.1. – DATES OF THE SUN

The sun is the star about which turns the system of planets included the land.It is the nearest for our planet and, therefore, the principal light source and heat.Some interesting dates of the Sun are:

- Ratio of the Sun: 700.000 km(109 times more than the land)
- Mass of the Land:300.000 times more than the land
- Age of the Sun: Approximatly,5000 millions of ages
- Life of the Sun: Approximatly,8000 millions of ages more

The energy that radiate comes from nuclear reactions of fusion in which the hydrogen atoms are fusion and make atoms of Helio. This process liberates a lot of energy in all possible directions.

The distance between the earth and the sun is 150 millions of Km, and due to the light travel a speed of 300.000 km/seg, the different radiations came in 8min.It has been calculated that the power of the radiation is 4*10exp23 KW, approximately 200*10exp12 times more than the energy of the centrals which are working nowadays.

2.4.2. – THE MAIN PARAMETERS OF THE POSITION OF THE SUN

The radiation solar is constant power before enter in the atmosphere.

- LATITUDE→Is the angle which form the vertical of the geographic point that we are going to study and the plane of the equator. The date of the latitude is basic for know another dates about the reference of the position of the sun.
- LENGTH→Is the angle between the vertical of the geographic point to study and the vertical´s projection of a point which is situated in the same latitude but in a axe called “Meridian of Greenwich”

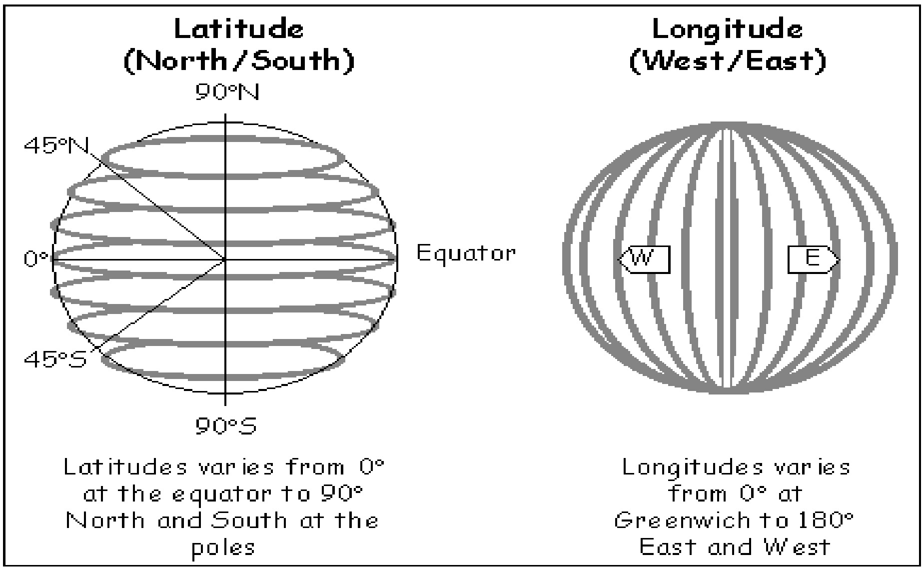


Figure 2.7-latitude and longitude [08]

- AZIMUT→Is the angle between the lights of the sun over the tangent plan of the land surface and the geographic south. Azimuth 0 is when the sun is the geographic south and says that is 12:00

- SOLAR HEIGHT→ Is the angle that forms the beams of the sun when they crash with the earth

The solar height changes during the day and it reach a different height in each day of the summer. The maximum is 42N (71º) and the lowest is near 25º.

It is important bear in mind once knowing that the earth tour on around the sun creating a ecliptic where the sun is the focus with a maximum separation(4th of July) and the minimum distance (31th of December), whereas the medium separate between the two stars is 144.600.000 km

By the other hand, the earth turns on its own axis which is inclinator 23º30´with regard to the plane of the ecliptic.

Because of this inclination in each point of the terrestrial orbit, the situation of a place with regard of solar rays is different. This fact makes the rays that throw a different thickness of the atmosphere. In winter is bigger than summer

2.5. – TYPES OF PHOTOVOLTAIC SYSTEMS

There are three kind of using electricity when is generating by photovoltaic effect:

- STAND-ALONE SYSTEMS
- GRID-CONNECTED SYSTEMS
- HYBRID SYSTEMS

In the first all the powers is stored in the batteries for then use it. In the second, the generated energy is sent to the power supply. There are different applications and some advantages of one to another that I will talk about now.

2.5.1. – STAND-ALONE SYSTEMS

These system are used in the different places that there are no possible to connect a power supply because is cheaper to install a photovoltaic system.
Like the photovoltaic’s cell only produce electricity at the hours of sun, is needed a battery ‘s system to store the electricity.
The quantity of the energy that it is necessary to accumulate is calculate depending on climatic conditions of the area and the consumption of the house. In such a way that in an area where there are many sunny days per year,

there will be necessary to accumulate little energy. If the period without light is not enough long, it is needed to accumulate more energy.
The simplest possible connection scheme for this application is to connect directly the output of the solar panel to the load, but this scheme is only used in hobby projects, rechargeable battery chargers and other simple applications.

Others devices, such as clocks or calculators, that are a bit more complicated that the mentioned previously, use a voltage regulator between the output of the solar panel and the load in order to achieve the proper operation of them, generating a constant output voltage, different from the input voltage and independent of voltage variations of the panel itself.

The number of photoelectric cell to install will change depending on:

- The energy demanded in the months more unfavorable
- The technical ideal conditions of orientation and inclination depending on the place of the installation. If we use electrical appliance and lighting of low consumption will be better.

To optimize the system is necessary to calculate correctly the specific demand for not over size the installation. IF the user uses electrical appliance and lighting of low consumption it will get a more economic installation.

- ELEMENTS:

  These kinds of installation are formed by:

  1) Photovoltaic Generator: Transform the solar energy in electricity
  2) Regulator of Load: It controls the load of the battery preventing it to produce a overcharges or excessive unloads which diminish the useful life of the accumulator. It can incorporate a system of follow-up of the point of maximum power. This is a device that increases the performance of the installation
  3) System of accumulation: The different batteries accumulate the energy delivered by the photovoltaic cells. When produce a consumption the batteries feed to the loads and no the photovoltaic panels.
  4) Inverter: It transforms the DC current in AC current.

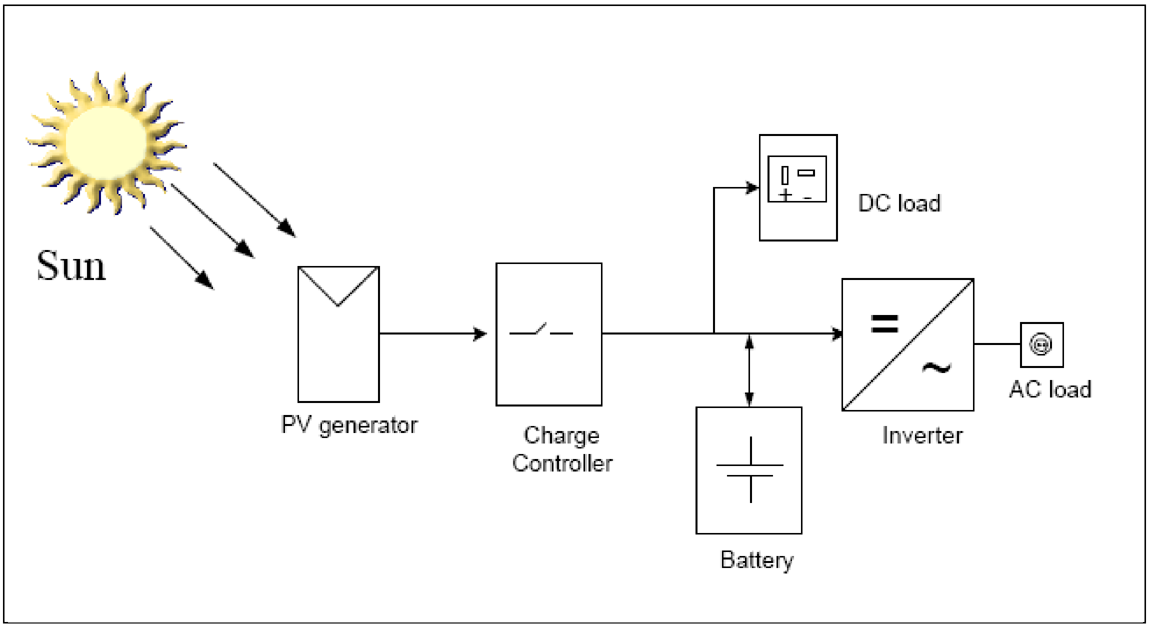


Figure 2.9.- Stand-Alone Systems[10]

2.5.2. – GRID-CONNECTED SYSTEMS

If it is possible to connect the instalation to the power supply , it will be positive becouse the emition of dioxide of Carbon will be reduced.This aplication adjusts very well to the curve of the demand of the electricity.The moment in which the panels generate more energy is when there is solar light coinciding when more electricity is demanded.

In order to these facilities are technically practicable is needed:

- The existence of a electric line nearby wit aptitude to admit the enrgy produced by the photovoltaic installation.
- The determination of the point of connection with the company.
- Do the installation with the protection needed according to the force legislation

In order to design a installation is necessary to know the investment initial, the available space and the minimum profit that the user wants to get. Is important to remind that the consume is independent of the energy generated by the photovoltaic panels. The user buys to the company the electricity that he consumes in the established price, and in addition the owner sells KW/h a top price to the grid.

-The elements are:

- Photovoltaic Generator: Transform the solar energy in electricity which is send to the net.
- Electric Panel board: It contains alarms, protections….
- Investor: It transform the DC current in AC current with the same characteristic of the power supply.
- Meters: There will be two. One to measure the consume of the photovoltaic cells and other for measure the energy which is sent to the power supply

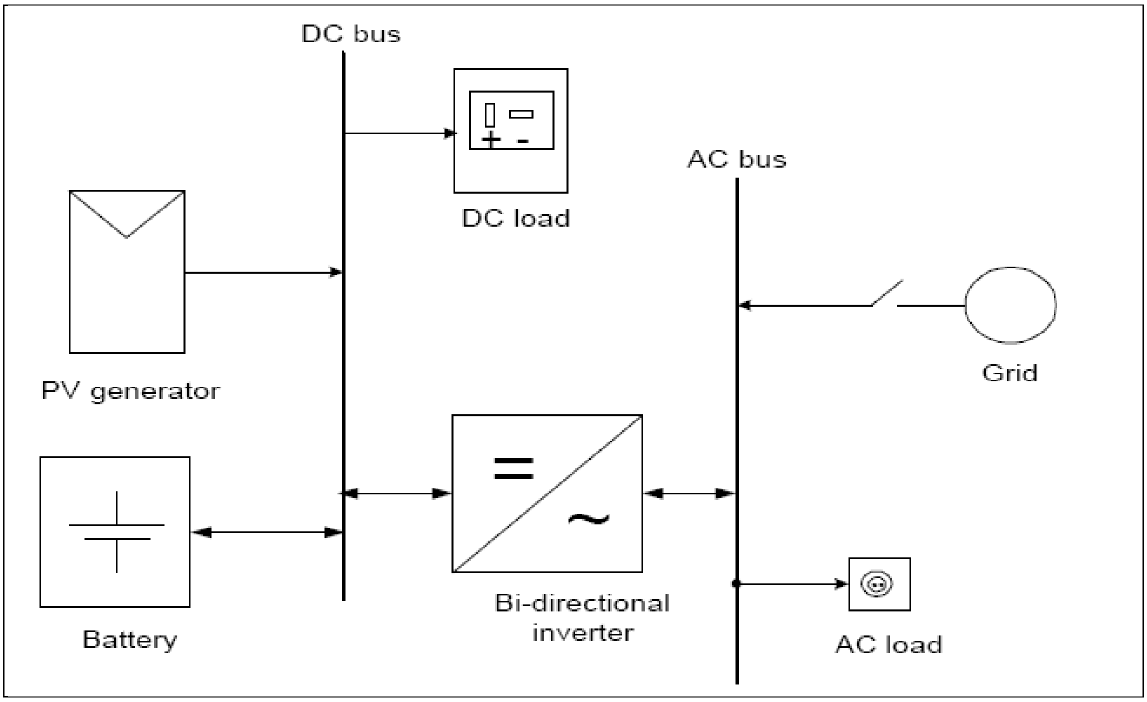


Figure2.10.-Grid Connected Systems[10]

2.5.3. – HYBRID SYSTEMS

Hybrid systems are those which have, in addition to solar energy, other systems of generating electricity such as small wind turbines or electric generators connected to combustion engines.In this case, the systems complement each other to deliver the amount of energy needed to load or to cover all required hours of use.

The wind turbines generation system behaves similar to the PV system, hence the energy produced should be used to charge the battery bank or to sell everything to the grid. Some commercial regulators have double entries: solar panel and wind generator.

In the case of generators with combustion engines, which produce alternating current, is needed a switch circuit that allows the sharing of power supply (battery to generator group and vice versa) without interruption of the supply.

2.6. – PHOTOVOLTAIC EFFECT

The semiconductor materials have got the property to convert the solar radiation directly in electric energy with an overall efficiency between 16% and 18% for a single monocrystalline.

When a photon of the light come into contact with semiconductor materials, suppling to the electrons a cinetic energic.

The photovoltaic cells generally consists of two regions, one abothe the other, each with specially added impurities called dopants.So is obtained two differents regions called “type n” and “type p” with excess of electrons and excess of positive holes respectivily.

Thus, the area next to the frontier between regions, N side and P syde, making a P-N junction, creating a potencial barrier that prevents that the process of electron flows past indefinetly.

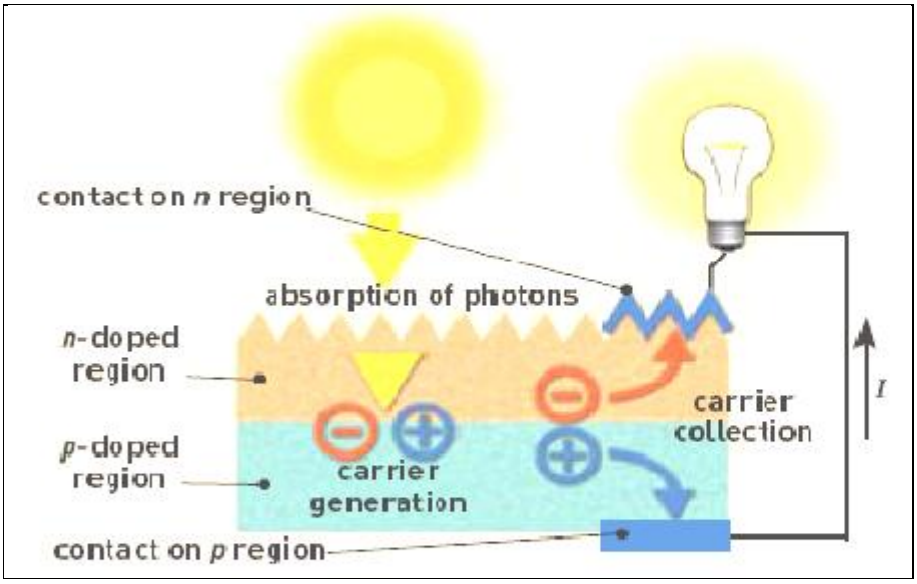


Figure 2.11. - Photovoltaic Effect [04]

The Photovoltaic cells were developed in 1954 by Bell Laboratories and since then have improved rapidly.Silicon is the material tahy still dominate the market at present.There have been an evolution and are described bellow three differents generations.

FIRST GENERATION:

PV cells take up around 89% of the present market.The Production of these cells is very labour intensive and requires a lot of energy to produce, ant the purity of the silicon will produce a high cost.

These cells have large areas with high quality single juncition deveces, and their theorical efficiency limit is 33% wher after the silicon can not be purified any further.Now are described the most common

a) *Mono-crystalline*

This sort of cells was the first to be industrially produced and the classic manufacturing process is known as Czochralski method.Their characteristics are:

- atomic structure very tidy
- Performance between 21% and 25%.The most efficience
- Hight price due to there is a difficult construction.
- The most expenseive

b) Polycrystalline

The manufacturing process changes because now the atomic structure is not as tidy as monocrystalline cells. The structure of this type of cells is tidied for separated regions, consisting of multiple small silicon crystals.

- The efficiency is lower than the monocrystalline cells.Between 18 and 21%.
- They are more economic than the monocrystalline cells.

c) Amorphous silicon

This group differs from other crystalline structures by introducing a high grade of disorder in the structure of atoms, producing a large number of structural and link defects.

- The performance is down 10%
- The manufacture of this kind of cells are more simple
- A typical aplication could be instruments of low power like calculators, clocks...

SECOND GENERATION:

PV cell types appear to have a promising future.So called thin film cells are most cost effecctive in terms of production process but have efficience less than 18% at present.

Material used includes cadmiun telluridde (Cdte), copper indium gallium selenide (Cigs/Cis), amorphous silicon cells, micromorphous silicon...

Thin film cells get their name from the method of coating a supportin structure such as cllas or ceramics with the matterials described above.Thus thin film cells use less material, producing a thiner cell as well as lowering the cost.

THIRD GENERATION

These cells are the as same as second generation while aiming to increase the efficiences to 31-41%.Low cost materials are used while increasin the outpus several ways.

The highest efficiency is due to these cells absorbs each color of light with a material that has a bond gap equal to the photon energy

CHAPTER THREE: PHTOVOLTAIC SYSTEM

3.1. – COMPONENTS OF PV SYSTEMS

All the components required to have a photovoltaic system will be explained in the following section:

3.1.1 PHOTOVOLTAIC PANEL

This is the most important element because it converts the radiation solar in continuous current like direct form.

A photovoltaic module is encapsulated between a tempered glass and some coat of plastic. The whole is reinforced with an aluminum metallic profiles which makes an external mark providing strength and protection against the weather conditions.

Usually a photovoltaic panel is formed by association of 33 and 36 cells in series with a nominal voltage of 12 Volt.cc.

There are three different possibilities to connect the solar cells that will be explained later:

- Connection in Series : Usually, is used this configuration to get low voltages of 12 or 24 V, in autonomous electrification installations, from 96 to 144 V, in grid-connected System or for supply a frequency variation to direct pump .
  It should be known that working with voltages upper than 48 V in continuous current is dangerous for the humans.

- Connection in Parallel: Normally is used to obtain until currents of 20 or 25 A, in automatic installations of electrification and upper in grid-connected system of high power.
  One reason of not being used a lot is because the losses will be upper due to the circulation of more current.

- Mixed Connection: Is the most useful because in solar power installations is needed a specific voltage, so it will achieved if are connected in series a number of modules which are connected in parallel.

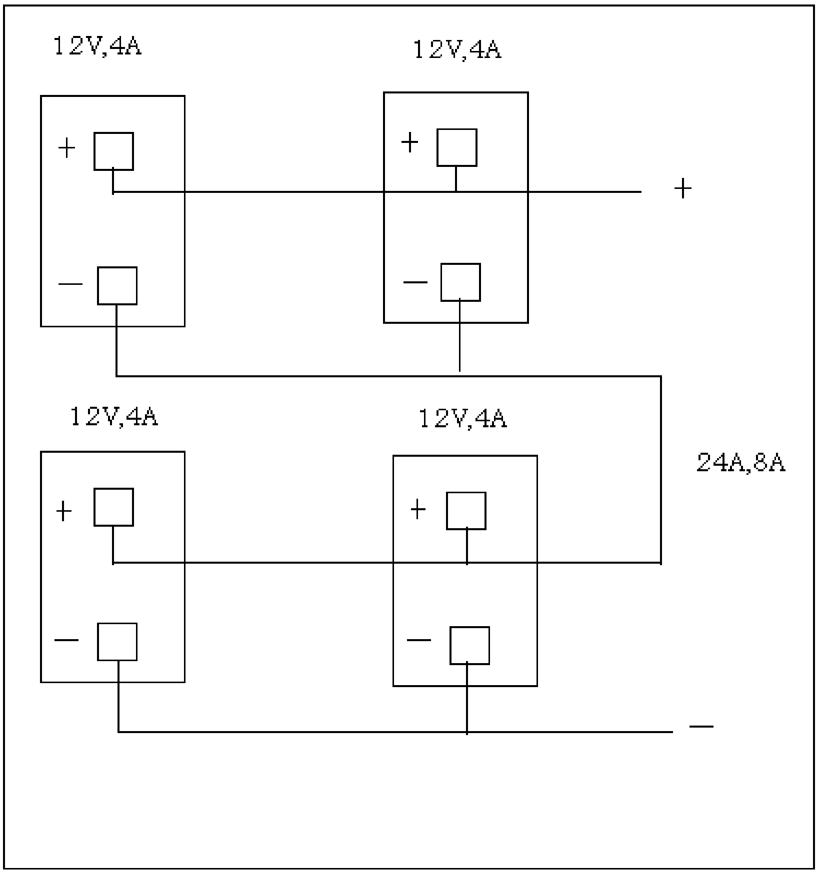


Figure 3.1. - Mixed Connection [10]

Usually, the combination of these modules is known as a photovoltaic or solar panel (PV). The PV modules inside the solar panel can be connetion in in series to increase the available output voltage, in parallel to increase the available output current or a combination of both procedures aforementioned.

In the same way as PV modules use bypass diodes so as to assure the proper operation of itself, solar panels may use anti-return diodes and blocking diodes to do the same.The anti-return diodes are used to prevent the current flow through one module to other modules connected in parallel. Blocking diodes avoid the current generated flowing through the modules in the opposite direction as well as to avoid battery discharges over them.

Later it will be described the curve of PV panel under specific constant conditions of irradiance and temperature I-V curve.

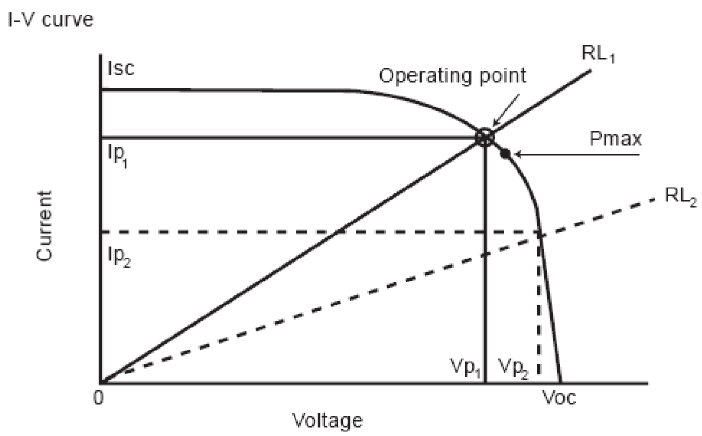


Figure 3.2-Characterisctic I-V curve[11]

POWER MAXIMUM→ We will obtain this value with specific values of VO and Io. It is difficult to work in the maximum conditions due to the fact that of the resistance of the external circuit is set by itself.We could achieve the pair of points using electronic devices but ther are not used in small systems because of their cost.

OPEN-CIRCUIT VOLTAGE (V_{oc})→ It is the maximum voltage in open conditions, so we coud say that we have ideally infinite load.

SHORT-CIRCUIT –CURRENT ($I_{sc)}$→ this measure correspond to the situation in which the resistance is cero, making a short-circuit.

It is important to know that the curve I-V admits variations when the solar radiation and the temperature of the cell. Later, it is represented the graphic I-V, depending on the variation of the temperature and solar radiation. A continuous aspect is that is not worthy to have higher temperature because the performance will down.

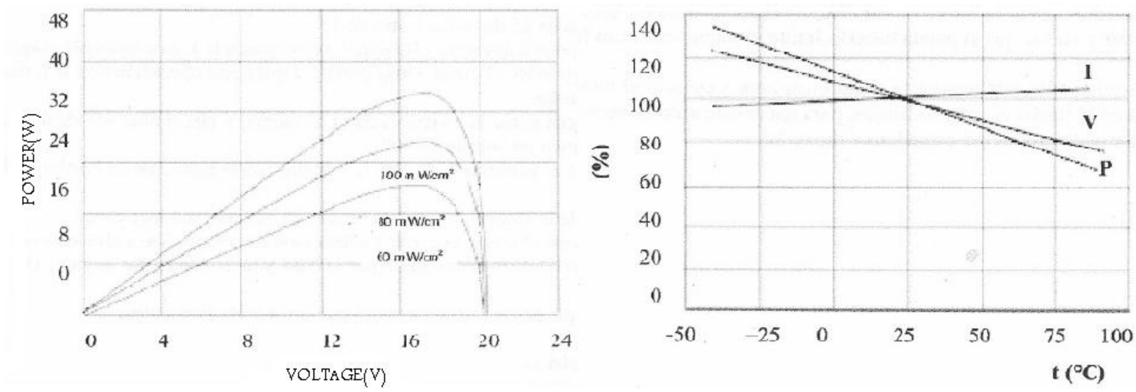


Figure 3.3. - Characteristic of the PV cell dependsing on T and Voltage [12]

It has been demostrated in the previous graphic that if it is wanted to achieve a good performance is important to have a good orientation and correct inclination.Later it is said some advices for get the best inclination.

- Installation to use in Winter: Latitude place +20º
- Installation with grid-connected system, inclination: Latitude of place
- Installation working specially on Summer: Latitude of the place -10º
- Installation of Semester Use; Complementary angle to the solar high of epoch in use.

These back lists are some tips of people who have been working in the installation of PV modules

Now are described the components which a Photovoltaic module is conformed:

1. External Cover:

   The main function is to protect it against the atmospheric agents. The material used is the tempered glass because presents a good protection against the hitters and it has got an excellent transmission of the solar radiation. The common thickness is 4 mm

2. Encapsulated Layer:

   The different layers have got the aim to surround the cells and electrical connections. The material most used is EVA, which has got an excellent transition of solar radiation and is not deteriorate with ultraviolet rays.

   Also provide flexibility to the whole module, so in case of having an external strong vibration the PV module does not break.

3. Back Protection:

   Its mission consists of being a barrier against the dampness. These materials are white so that improve the performance thanks there are an important reflect which produces the cells.

4. Frame of Support:

   This is the Aluminum part which the PV module gets mechanic hardiness and allows the whole structure to install with more PV modules.

   The whole structure has got some holes to allow other modules be connected. Some of them has got a current connection too, so is needed to make here an external connection

3.1.2. – SUBSYSTEM OF ENERGY STORAGE

This will be required for stand-alone installations but not for grid-connected system.

Every self-governing installation is necessary to store the energy during the hours of sun to use it when there is no radiation solar. The main characteristic of the storage is the capacity of continues loading and unloading.

The basic functions of accumulators in solar installations are:

-Supply a higher power of the PV modules

-Maintain stable the voltage of the installation

-Supply Energy in absence of radiation solar.

Although there are batteries with different technology, like the alkaline batteries of Nickel-Cadmium, the accumulators which are used in solar power the 99% of the cases is acid lea. They are formed by a few electrodes of lead as a basic material, immense in a solution electrolytic.

To the set that a pair of electrodes form (positive and negative) has the main characteristic of maintain a different voltage nominal of 2V.

By the group of pair of electrodes we can obtain different voltage of (6, 12, 24,48V)

This nominal voltage it is because goes in a battery of 2V nominal from 1.85 V (unloaded) to 2.4 V (loaded).

The capacity of accumulation of a battery is measured in A*h and it is calculated multiplying the current and the time.

The process of unloaded in a battery is different if is wanted to maintain a calm level (100h) or a quickly download (5h).The problem come if it is get downs times the capacity will fall too.

3.1.3. – BATTERY CHARGE CONTROLLER

A battery charge controller is a device which protects the batteries in a solar electric system from being overcharged or being over-discharged. Is very important to protect the batteries because is one of the components which more suffer degradation since they endure charge and discharge cycles daily. The most basic controller simply monitors the battery voltage and opens the circuit, stopping the charging when the battery voltage rises to a certain level.
The parameters more important to get one or other are:

- The voltage: The value will be the same to the battery (12, 24, 48V).
- The maximum current. Always this value will be 10% more than the maximum current that we could obtain from a PV module.

3.1.4. – SUBSYSTEM DC/AC CONVERSION

This is possible with a DC-AC inverter which is electronic devices used to produce ´mains voltage` AC power from law voltage DC energy. This makes them very suitable when is needed AC power tools, nearly always because the majority of electrical appliances work with 220 alternating voltage.

In the following picture we can see an electronic circuit to know how works it.

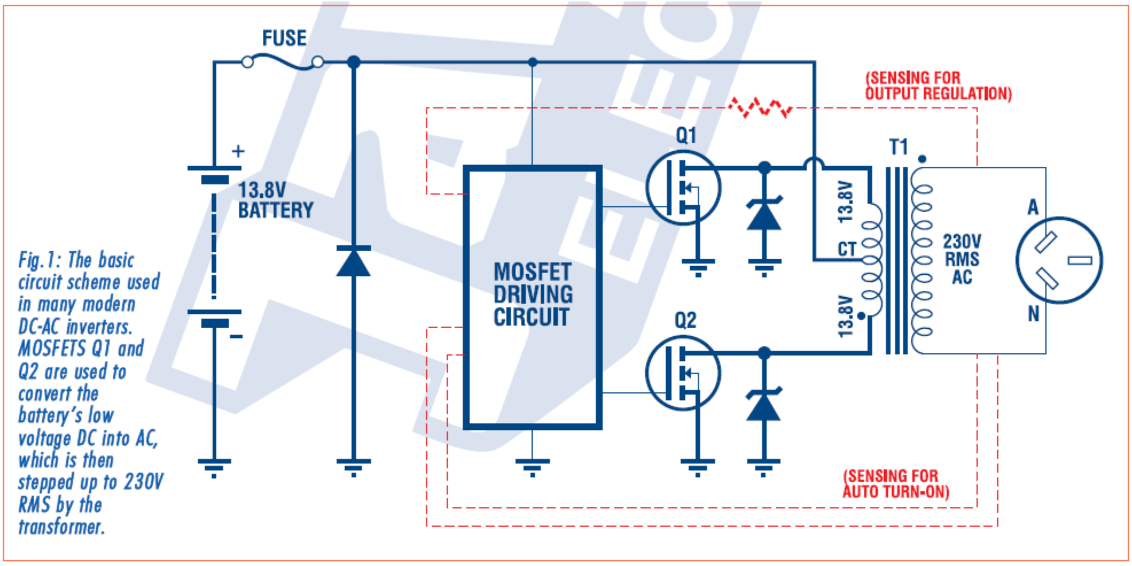


Figure 3.4. - Basic Scheme of the inverter [14]

The power stage presents a configuration in a single phase bridge, using like semiconductors of power MOSFET transistors. The inverter has a control system that allows completely automatic functioning. The generated voltage by the inverter is sinusoid and it is obtained by the modulation technique of width of pulses. A microcontroller determine the kind of wave that it will be generated according with a values which are in the auxiliary memory of the system

The main control makes a following very sensible with any change of the net. This allows introducing the needed corrections each 10 milliseconds. The control of the net is done by analogical circuit which allows adjusting of the systems, measures of the voltage, current and factor of power. The synchronization is done when the invertors stars and it spends a time to be synchronized to the net, so it is needed to be connect to the net.

To get a good performance of the installation, the control system of the inverter works detecting every time the point of maximum power of the characteristic Voltage-Current of the PV modules. This point changes depending on the solar radiation and temperature.

If there is a mistake in the net, a voltage out of the range or a frequency out of the limits, the inverter will open working like a protection

3.1.5. – SUPPORT STRUCTURE

Sometimes the study is focus on the photovoltaic modules and it is forgotten the importance of chosen the correct structure.

The weight of a photovoltaic module is not heavy though its surface is wide, and it causes an important barrier to the wind that can generate huge efforts, so in a windy day, if the structure is not enough holed, some modules can be found destroyed.

To choose one structure the user has to decide the followings aspects:

1. The material: The best are stainless steel or aluminum. Some installations uses iron or wood as well but the useful life worse.
2. Screws and elements to fix them: Is better to use stainless steel but if it is not possible and are in contact different materials will be used some products to avoid the corrosion
3. Points of subjection: Depending on the available area will be done but it is preferable in concrete structures by metallic raw.

Another aspect useful of the structure is the possibility to obtain the correct inclination. In case of install the modules over the roof are not possible to have this kind of structure because the angle will be constant and will be used another structures like it is explained in the PV design.

Figure 3.5.-Image of a Solar Famulus structure[12]

3.1.6. – ORIENTATION AND ANGLE

In order to maximice the energy obtained, the inclination and the angle is an exential factor to obtain the maximuous incident irradiance. The more perperndicular light falls on the module, the more energy is produced. The more important parameters are the angle of inclination on the horizontal and the panel orientation, it is to say the azimuth.

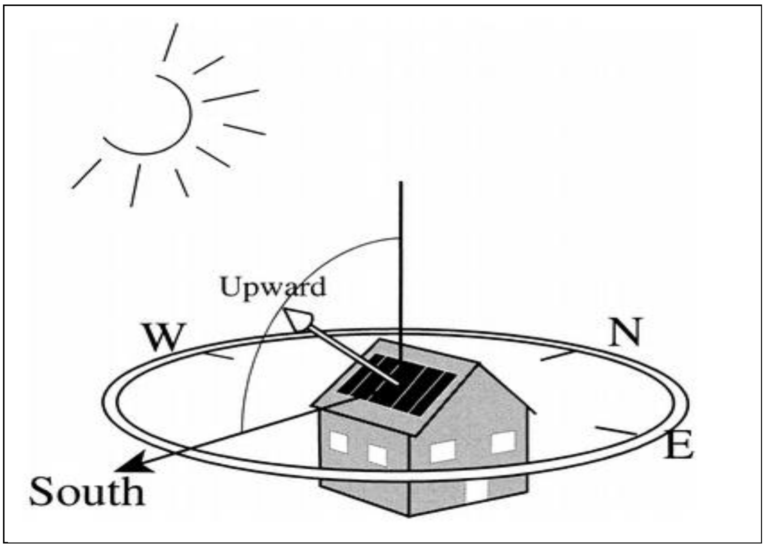


Figure 3.6.- Solar panel orientation and inclination [13]

If the installation is situated in the North Hemisphere, the modules should be oriented towards the south, however in Southern Hemisphere, the orientation should be north. The orientation depends on the situation of the house but normally should be north or south geographically.

The inclination depends on the latitude at which the panel is located. The closer to the Ecuador, the smaller the angle should be. Manufacturers of solar panels provide some clues for the correct selection of the angle.

The angle of inclination of a photovoltaic module has to be a specific one to get the maximum energy. In this installation, it is not possible to change this value, so in winter and summer has to be the same.This value depends on the situation where is installed the PV module.

Another alternative could be having at leaste two inclination angles, one for summer and the other one for winter.

On the study, it should be bear in mind the surrounded buildings, trees or whatever obstacle able to produce a shadow following by a dicrease in the performance. To solve this problem, in the Design is not necessary because it will be suposed to be alone the cottage.

CHAPTER FOUR: PV SYSTEM DESIGN

4.1. – DESCRIPTION OF THE HOUSE

4.1.1. – CHARACTERISTIC OF THE HOUSE

Below it is described the house where is going to be installed the PV design. This house has got the good characteristics of having a large roof in the left side and the inclination of 30º to install the PV modules. Later, in the simulation it will shown that the inclination of the roof is the optimum for having a good performance in the installation

It is represented a cottage where it is thought principally to spend the weekends and summers. It will be situated in an area where the house will be surrounded by a garden, so it there were not any obstacle able to produce shadow.

In the Figure 4.1, it is represented an outside view of the house which it does not have a wide useful surface, only 135 square meters. The planes of the house are shown in the Annex A.

The first floor of the ground floor it is formed by a kitchen, a living-room, a room, a bath and a small terrace. The second floor has only two rooms and a terrace as well.

Figure 4.1.-External view of the house[15]

4.1.2. – SITUATION AND CLIMATE

As previously mentioned, the photovoltaic system has been designed to be installed at two places in the cottage which has been described in the previous apartment. These two places are known of having different climates weather like are described below.

One of the situations will be in Wrexham where it is situated in the north of Wales and the other location chosen is Pamplona (Navarra), situated in the north of Spain.

Their coordinates are :

WREXHAM	Latitude: 53º3'00'' N Longitude: 3º0'0'' W	PAMPLONA	Latitude: 42º5'00'' Longitude: 1.4º0'

The climate of the United Kingdom is clasified as a mid-latitude oceanic climate with warm summers, cool winters and plentiful precipitation. Wales has the sort of climate often described as "temperate". This means that it never gets very hot or very cold. May, June, July and August are the suniest and driest months, but even in the winter a raincoat and sweater will usually be enough to cope with the worst that the weather can offer.

On the other hand the climate of Navarra (Spain) is characterized by the contrast that exists between the rainy north, with temperatures regulated by the influence of the Atlantic Ocean, and the South, greatly drier and warmer. Regardless, the step from one to onether zone is realized of gradual form.

The climate of Pamplona has a sub Mediterranean (moderate-cold) type full of contrasts and that different from one year to other one.

Focus on the study of the solar energy, it is shown a table with the number of Sun's hours monthly in the both places.This datas facts are significant to realize the energy study.The energy produced in the PV installation of Pamplona will be more bigger than Wrexham due to there is an important difference between the annual hours.In Pamplona nearly 637 hours more of sunny days.

	HOURS OF THE SUN	
	WREXHAM	PAMPLONA
JANUARY	54	102
FEBRUARY	66	162
MARCH	121	143
APRIL	180	201
APRIL	190	177
JUNE	194	251
JULY	192	329
AUGUST	188	292
SEPTEMBER	153	221
OCTOBER	74	137
NOVEMBER	68	101
DECEMBER	49	51
ANNUAL	1529	2166

Table 4.1.- Hours of the Sun in Wrexham and Pamplona [16][17]

4.1.3. – CONSUME

4.1.3.1. – Needs to cover

This point is required to know the power of the PV installation in case of using this energy to supply the cottage like a Stand Alone system. Later it is explained that this project will focus on the study of a grid connected system because the pay back period will be earlier.In case of finish these helps the PV installation will supply the cottage, therefore is going to be calculated the consume of the cottage approximatly.

First of all, it is represented differents consumes in the table of the electrical appliance that could be in a house. The typical consume of the electrical appliance of using no continuos consume is produced when it is used during some hours per day or per week. The energy consumed per day is equal of the product by the power (W) and the time (h).

ELECTRICAL APPLIANCE	POWER(W)	ELECTRICAL APPLIANCE	POWER(W)
Light bulb	25-100 (60)	Extractor far	5-70
Energy efficient light bulbs	9-20 (12)	Vacuum Cleaner	300-600
Fluorescent	4-58 (36)	Iron	800-2000
Halogean lamp	15-300	Video	30-45
Televisión	50-150	Computer	100-250
Radio	10-25	Laptop	200-300
Cassette	35-50	Printer	15-25
Water pump	70-500	Phone modem	15-30
Hairdryer	500-2000	Toaster	500-1000
Air Vent	25-50	Microwave	500-700
Electric cook	2000-7000	Juicer	30-160
Electric Oven	1500-2500	Washing machine	2200
Blender	200	Dishwasher	1500
Deep Fryer	1400-2100	Hairdryer	3200
Mixer	200-300	fridge	800-1500
Electronic Coffee	600-1100	Freezer	650-800
		Amplifier Aerial	125-250

Table 4.2.- Consumes of each electrical appliance[04]

In a PV installations it is recomended not to supply electronic appliances which has got electronic resistances like the oven, electronic radiators, dishwasher, washing machine.These machines has the the characteristic of having a high consume and low efficience.

In the following table it has been stimated the needed consume.The diary energy depends on the number of electronic appliances which the house is formed, the power of them and the time of use.

ENERGY NEEDED				
Electronic Appliance	Number	Power(W)	Time (h)	Energy(Wh/dia)
Energy Efficient Lights bulbs	12	10	6	720
Fluorescent	5	58	4	1160
Television	3	80	2	480
Video	1	50	1	50
Vacuum Cleaner	1	500	0.10	50
Computer	2	100	2	400
Toaster	1	800	0.1	80
Microwave	1	800	0.12	96
Mixer	1	300	0.10	30
Extractor	1	250	2	500
Dishwasher	1	2200	1	2200
Printer	1	25	0.5	12
Juicer	1	50	01	5
Washing machine	1	2200	0.5	1100
Freezer	1			130
Fridge	1			200

CONSUME TOTAL	5233 W

Table 4.3.-Energy Needed [04]

4.2. – CHOICE OF THE PV SYSTEM

The main decision is about doing a grid-connected system or stand-alone system, so here it is described which solution is the best.

The idea of all the projects is to make profitable the installation as soon as possible to obtain a bigger profit, so the choice will be Grid connected system like is explained bellow.

Like it has been in the point 2.2.2 and 2.2.3 , both countries has different politics about the renewable energies and their tariffs of buying each kwh.

In the case of Spain the bonus obtained is regulated by the "Real Decreto 1578/2008,25 the Septiembre" where comments that all the PV installations situated over the roofs, the front of the houses or buildings will receive a bonus during 25 years depending on the power installed in it.

After 25 years it will be paid the actual prime in that moment in case of having anyway. In this project it will be consider the same price,0.3346 €/Kwh.

POWER	BONUS OF KWH
< 20KW	0.3346€/Kwh
>20KW	0.30€/Kwh

Table 4.4.- Bonus of each Kwh [20]

In the case of UK is more complex like it has been explained in the chapter two. The Feed-in Tariff consists of a fixed payment per KWh generated from eligible renewable. In Spain the economic income is only obtained if the generated electricity is exported to the distribution network, but the British FIT system is a bit different since it proposes the idea of a generation tariff and an export tariff.

The generation tariff consists of receiving money for the simple fact of generating electricity. The price that is paid for each Kwh and the annual degression depends on the kind of energy used to obtain the electricity. For the case of PV systems the price of the Kwh for the first and the second year is 36.1 p/Kwh and the annual degression can be calculated approximately. For this case is 8.5%.

However, The export tariff entails a guaranteed minimum payment per KWh exported to the distribution network, 3p/kwh.

Bellow is shown the table where the different prices for the 11 first years and can be calculated the annual digression.

Technology	Scale	Tariff level for new installations in period (p/kWh) [NB tariffs will be inflated annually]											Tariff lifetime (years)
	Scheme Year	1 1/4/10 – 31/3/11	2 to 31/3/12	3 to 31/3/13	4 to 31/3/14	5 to 31/3/15	6 to 31/3/16	7 to 31/3/17	8 to 31/3/18	9 to 31/3/19	10 to 31/3/20	11 to 31/3/21	
Anaerobic digestion	≤500kW	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	20
Anaerobic digestion	>500kW	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	20
Hydro	≤15 kW	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	20
Hydro	>15-100 kW	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8	20
Hydro	>100 kW-2 MW	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	20
Hydro	>2 MW – 5 MW	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	20
MicroCHP pilot*	≤2 kW*	10*	10*	10*	10*	10*	10*	10*	10*	10*	10*	10*	10
PV	≤4 kW (new build**)	36.1	36.1	33.0	30.2	27.6	25.1	22.9	20.8	19.0	17.2	15.7	25
PV	≤4 kW (retrofit**)	41.3	41.3	37.8	34.6	31.6	28.8	26.2	23.8	21.7	19.7	18.0	25
PV	>4-10 kW	36.1	36.1	33.0	30.2	27.6	25.1	22.9	20.8	19.0	17.2	15.7	25
PV	>10-100 kW	31.4	31.4	28.7	26.3	24.0	21.9	19.9	18.1	16.5	15.0	13.6	25
PV	>100kW-5MW	29.3	29.3	26.8	24.5	22.4	20.4	18.6	16.9	15.4	14.0	12.7	25
PV	Stand alone system**	29.3	29.3	26.8	24.5	22.4	20.4	18.6	16.9	15.4	14.0	12.7	25
Wind	≤1.5kW	34.5	34.5	32.6	30.8	29.1	27.5	26.0	24.6	23.2	21.9	20.7	20
Wind	>1.5-15kW	26.7	26.7	25.5	24.3	23.2	22.2	21.2	20.2	19.3	18.4	17.6	20
Wind	>15-100kW	24.1	24.1	23.0	21.9	20.9	20.0	19.1	18.2	17.4	16.6	15.9	20
Wind	>100-500kW	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	20
Wind	>500kW-1.5MW	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	20
Wind	>1.5MW-5MW	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	20
Existing microgenerators transferred from the RO		9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	to 2027

* Note the microCHP pilot will support up to 30,000 installations with a review to start when the 12,000th installation has occurred

Table 4.5.- Generation tariffs for the first year of FIT´s (2010-2011) [05]

Once knowing the tariff´s countries, in the followings chapter will be present the simulation of the PV installation and the economic Assessment for a grid Connected System. The case will be study with these tariffs relying on not having changes..

4.3. – COMPONENTES CHOICED

4.3.1. – PHOTOVOLTAIC MODULE

As before was mentioned, this dissertation includes a comparison of two weather climates having the same installation.

The model I_75G of Isofoton has been chosen because its characteristics are more appropriate for this study and the software PVsyst 5.2 works with this model. Although their characteristics can be seen in Appendix C, their main important values are shown in the table 4.6.

ELECTRICAL DATA	Rated Power	75Wp(± 10 %)
	Open Circuit Voltage	21.6 V
	Short Circuit Current	4.67A
	Voltage at maximum	16.2V
	Current at maximum	4.34 A
	Module efficiency	Between 80-90 %
MECHANICAL DATA	Cell Type	SI monocrystaline
	Module connection	
	Dimensions	1224×545×39.5 mm
	Weight	9 kg
	Connection Type	

Table 4.6.- Characteristic of the PV module

4.3.2.– INVERTER

The inverter chosen is PVI 5000 of the Manufacture Kaco. The catalogue of the inverter can be seen in the Appendix C but in the following picture is presented the main values to know respect it. The catalogue of the inverter can be seen in the Appendix C though here are represented the main values:

DC INPUT	**Rated DC power**	6800 W
	Maximum DC current	18 A
	MMP voltage range	350V-600V
	Maximum DC voltage	800V
AC OUTPUT	**Rated AC power**	5500
	Nominal AC current	23.9A
	Frequency	50 Hz
	Voltage	To local requirements
PERFORMANCE	**Stand-by consumption**	11W
	Night-time	0W
	Maximum efficiency	96.3 %
	European efficiency	95.3 %
	Cos phi	1
OTHER	**Degree of protection**	IP54
	Ambient temperature	From 20º to 60º
	Dimensions	600×340×220 mm
	Weight	30Kg

Table 4.7.-Main characteristics of PVI 5000

4.3.4. – SUPPORT STRUCTURE

For this installation where the roof has the optimum angle (30 degrees) has been chosen the universal structure for sloping roof SUNTOP II of AET. This system is set by modular profiles of high flexibility of the installation, one element of subjection of the roof and different elements like is shown in the figure 4.2

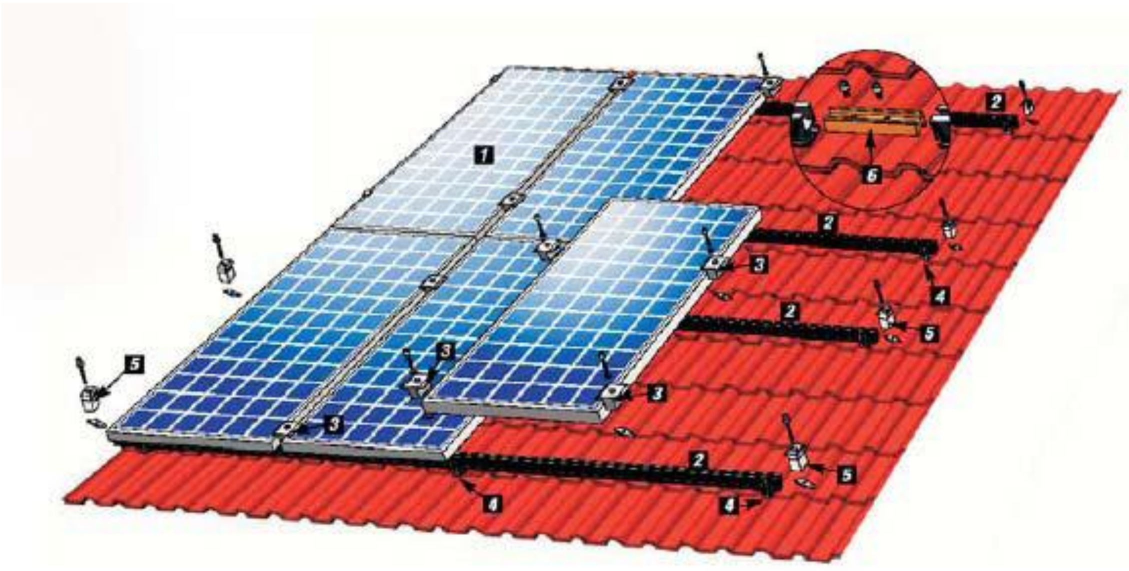


Figure 4.2.-Structure de support SUNTOP II.[31]

This system has got a good capacity of adapt in whatever PV module and guarantee quickly staging and their characteristics are shown in the table 4.9

CHARACTERISTIC	DESCRIPTION
LOCATION	OVER SLOPING ROOF
TYPE OF ROOF	UP TO 60º
Maximum Height of the building	20m
Load of snow	1.4KN/m2
PV modules	With mark
Compensation of irregularity	<40mm
Distance between hooks	2 m at maximum
Law	Din 1055
Profile of support	Stainless Steel

Table 4.9.- Características Técnicas estructura SUNTOP II.

4.3. – ELECTRICAL APPLIANCES

The interconnection between the generation and the net will be done by an automatic switch where the system of protection and maneuver works.

The interconnection consist on the followings elements:

1. Power Circuit: In the single line diagram is defined the different elements which configure the power circuit of interconnection.

2. Protections: The electrical protections have as aim to assure the protection of the people and machines, also support the quality level of the service of the network. For it, they will arrange a set of elements destined for such a purpose that they will operate on switch of interconnection. The installation and the protections will be chosen according to the actual low and the particular rules establish by the company

Through the DC and AC magnetothermic will circulate a current equal to 9.24 A, so the nominal current will be immediately upper, in this case it has been chosen 10 A. One of the magnetotermic has been of 2 poles for DC and 3 poles for the AC. Bellow are written the two codes of the brand ABB.

- S251NAICP-M10□ 2 POLES
- S253NAICP-M10□3 POLES

Respect the differential, the current that through it is 9.24 A, so the value of the nominal current upper is 25A.The sensibility has been chosen 30 ma and the brand is ABB as well. Bellow is written the code of differential:

- F204A-25/0.03□ 3 POLES

3. Measure: There will be two electricity meters, one to sell and other to buy like it is represented in the figure 4.3.

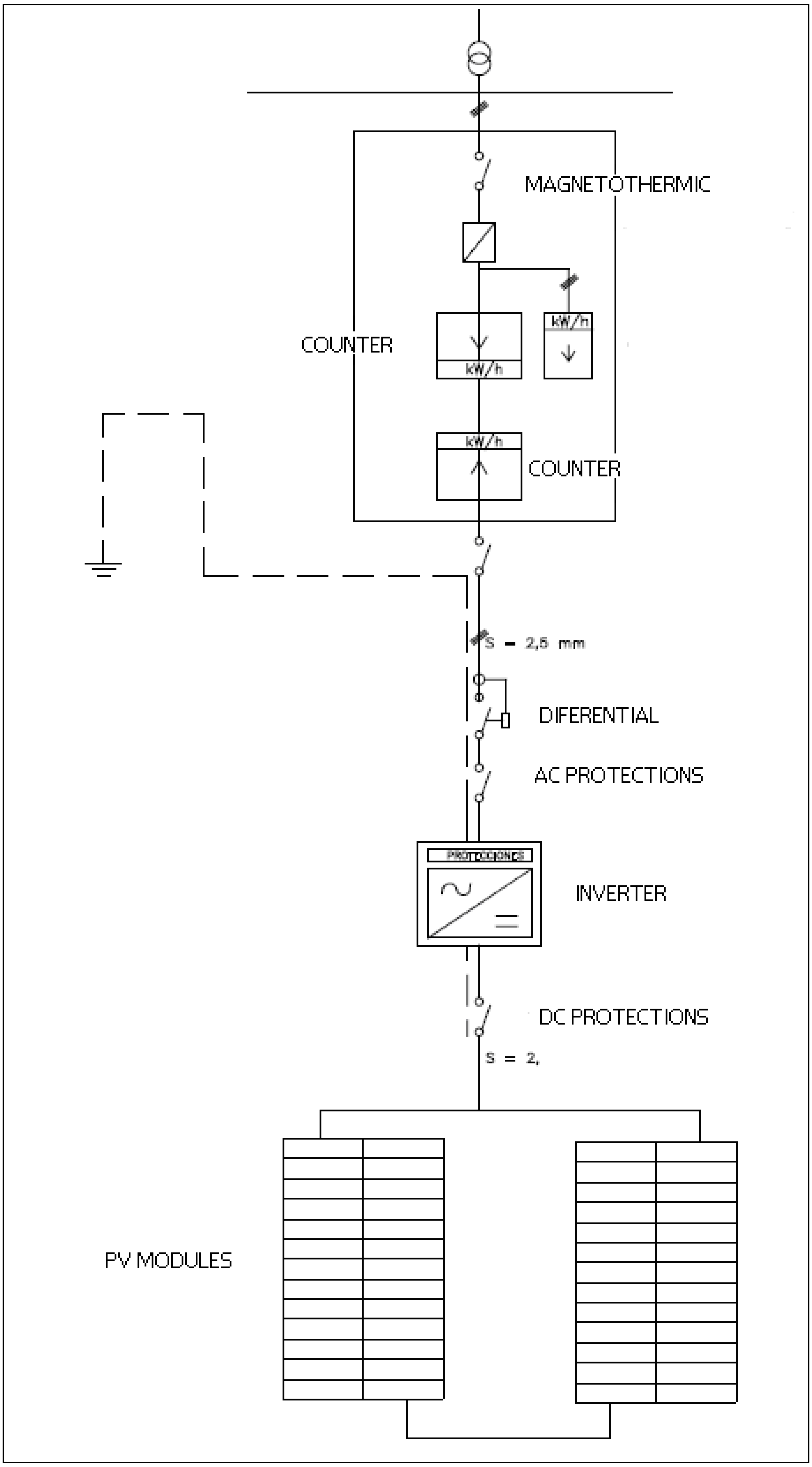


Figure 4.3.- Electrical Scheme of the Pv installation

4.4. – ENERGY STUDY OF THE PV SYSTEM

4.4.1 SOLAR RADIATION

Firstly, to calculate the average annual production of the system is necessary to determine which the incident solar radiation on the PV panel is.

In this case the estimation of incident solar radiation has been achieved by the database of the software PVsyst 5.02.

The main sources that uses are:

- Meteonorm → Monthly and hourly values irradiance data are available for about 1200 "stations" with the main European countries. Data for any other site may be obtained by interpolation.
- Satelight → Provides real measured data in hourly values, over 5 years (1996-2000) for any pixel of 5*7 km^2 in Europe.
- Heliocrim→ Provides data in hourly values, measured by Meteosat, since February 2004.But these data are not free. Nevertheless the year 2005 is available for test.
- NASA-SSE→ Hold satellite monthly data for a grid of 11km covering the whole world.

The table 4.10 represents the Global Horizontal and diffusion Horizontal radiation monthly and their temperatures.

The first conclusion is that it will be easier to have a better performance in Pamplona than Wrexham knowing only that the solar radiation in Pamplona is nearly 400 kWh yearly more than in Wrexham.

	PAMPLONA		WREXHAM	
	GLOBAL HORIZONTAL(KWh/m2)	T. Amb(ºC)	GLOBAL HORIZONTAL(KWh/m2)	T. Amb(ºC)
January	45.5	5.7	20.2	5.7
February	61.4	6.10	33.9	5.5
March	105.6	10.10	70.1	6.8
April	135.5	11.30	102.9	8.3
May	174.8	15.60	138.0	11.5
June	202.9	19.90	146.1	14.7
July	202.1	20.70	142.0	17.1
August	172.2	21.40	124.0	17.1
September	126.6	18.40	87.9	15.20
October	81.8	14.60	51.2	11.60
November	51.8	8.60	26.1	8.20
December	42.2	5.80	14.9	6.90
TOTAL	1402.6	13.23	958.0	10.75

Table 4.10.-Solar Radiation in Pamplona and Wrexham

4.4.2. – ESTIMATION OF THE ANNUAL ENERGY GENERATED

The energetic study has been carried on with the software PVsyst 5.02, so in this apart will be described the different steps needed to obtain the simulation with this software.

Now, it is presented a short review about the software.

PVsyst 5.02 is a PC software package for the study sizing, simulation and data analysis of complete PV systems. This software is from 2009 and was made by the University of Geneva and so far, it is one of the most comprehensive photovoltaic simulations.

It is divided in three main sections; Preliminary design, project design and tools. The option used has been PROJECT DESIGN where the user can choose among the grid connected, stand alone, pumping systems and DC grid-connected systems. Like it has been explained before it has been chosen grid-connected system where is needed to sign in the different steps explained bellow:

FIRST STEP: Is necessary to introduce the coordinates of the place, where the installation will be installed and the values of the solar radiation monthly like has been shown in the previous point.

The theory value for incident solar radiation of the PV system is obtained multiplying the tables of solar radiation and a correction factor like can be seen in the appendix B.

SECOND STEP: The user has to decide the inclination of the PV cells and the azimuth.

In this case like it has been explained before, the angle will be the inclination of the house, 30º, due to be nearly the point of the best performance.

Respect the azimuth has been chosen 0º and the cottage will be orientated to the South.

<u>THIRD STEP</u>: There are different tools to simulate the real place where the cottage is surrounded. In this case there are some trees and another building but far away of the house, so is not necessary simulate nothing because there will not been looses due to the shading.

<u>FOUR STEP</u>: This is the last step where the user has to introduce the followings parameters, where it can see in the appendix B.

Available Area

Brand of PV modules

Brand of inverter

Array of PV series

Array of PV in parallel

Array Global Power

From now on these parameters will be calculated:

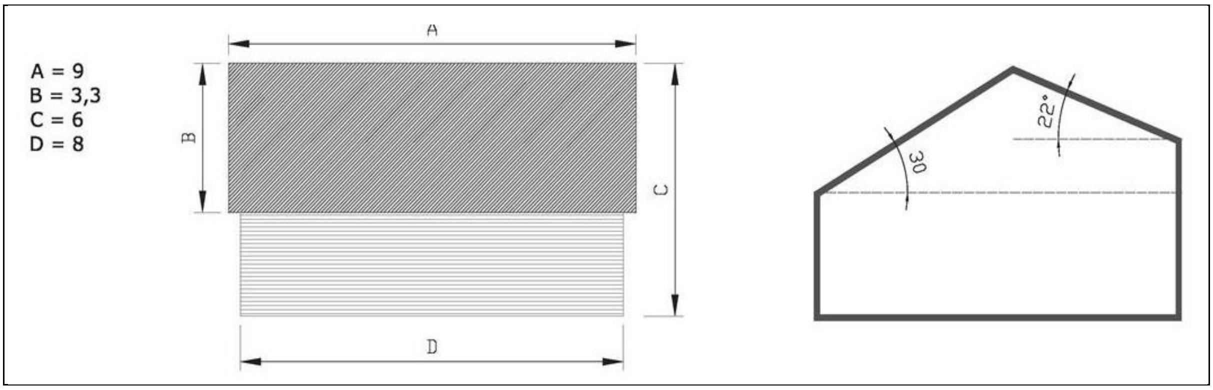


Figure 4.4: Representation of the house

Sen. & = h/ä→ a=h/ Sen. &

- **How many PV modules?**

Z=Number of PV modules in vertical =a/high module=6.6/1.224=5.3

Y=Number of Pave modules in horizontal= D/ (width+e_1) =8/(0.545+0.02)=14

Maximum Number of PV modules=Z*Y=70

Due to the experience of the manufacturer are going to install only 56 modules in 11 rows and 5 lines, like can be seen in the Appendix A.

Knowing the PV modules installed, will be calculate the different currents, voltages ant the Array energy produced by the PV installation.

Vinv = Ns x Vp = 28x 16.2 = ***453.8 V***

WHERE
- Ns: number of modules in series
- Vp: Voltage maximum of a PV module (V)
- Vinv: The voltage of the inverter (V)

Idc = Pin / Vinv = 6000/ 453.8 = **13.2** ***A***

WHERE
- Idc: Input current in the inverter (A)
- Pin: Input Power in the inverter (W)
- Vinv: Input Voltage in the inverter (V)

Once knowing the current generated by the modules, it is possible to concrete the number of PV modules in parallel depending the characteristic of inverter that it has been chosen.

Np = Idc / Im = 13.2 / 4.62= 2.8 → 2: Array PV in parallel

After connected 2 strings of Parallel is obtained a current in the input of the inverter equal of 9.24 A like it has been demonstrate behind.

*Inst. = Np x Im = 2*4.62 =* ***9.24 A***

Following the recomendations of the manufacturer, it will be installed 2 array in parallel where each array has got 28 modules.With these data is possible to calculate the value of the Power Nominal

Pinst = Inst. x V inv = 9.24 x 453.8 = ***4,200 Wp***

This values can be verified on the Appendix B, and also the the power of the installation is similar value, 4.2kw.

Having these values the user has only to introduce them and the estimation of energy generated is obtained in the following table.

	PAMPLONA	WREXHAM
	E.array (kwh)	E.array (kwh)
January	225,4	102,1
February	292,8	154,8
March	446,1	295,8
April	505,3	379,2
May	588,6	467,2
June	638,4	478,7
July	645,5	460,4
August	594,3	431,4
September	494,1	349,2
October	361,5	239,6
November	264,7	138,8
December	231,7	70,9
TOTAL	5288,7	3568,3

Table 4.11.- Energy obtained from the system

The results of the table above are graphically represented in the following figure. This system shows the estimated quantity of electricity than can be produced monthly for the PV system considering some parameters which have been explained before.

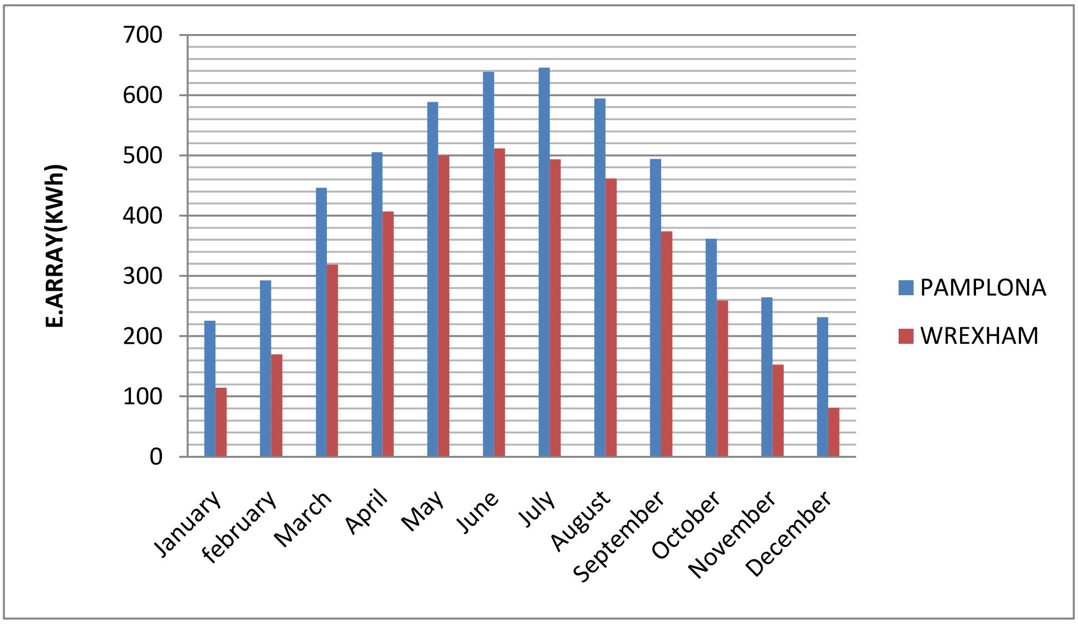


Figure 4.5.-Results of the simulation

In each month the solar radiation is higher in Pamplona than Wrexham like was explained in previous chapters, so now it is clearer where the performance will be better, because comparing both systems the difference in energy is1720 Kwh.

In this simulation has been considering the correspondent looses that will be estimated in the next point

4.4.3. – STIMATION OF POWER LOSSES

In this point it will be demonstrate the value of the losses that the software has provided which can be seen in the Appendix C.

4.4.3.1. – LOSSES DUE TO POWER SCATTERING

According to the manufacturer the losses are between 2 and 5%, (see datasheet in Appendix C) depending on the connection, because it is not the same in series or parallel.

This values changes because is not the same if the current throw more modules in series or parallel. An approximation value comparing with other studies could be 3%.

4.4.3.2.– LOSSES DUE TO CELLS TEMPERATURE

The open circuit voltage, Voc, of these cells was found to decrease linearity with increasing temperature, with a temperature coefficient dVoc / dt in the range – (1.40,-1.65) Mv/k in the temperature regime between 10º and 60ºC.

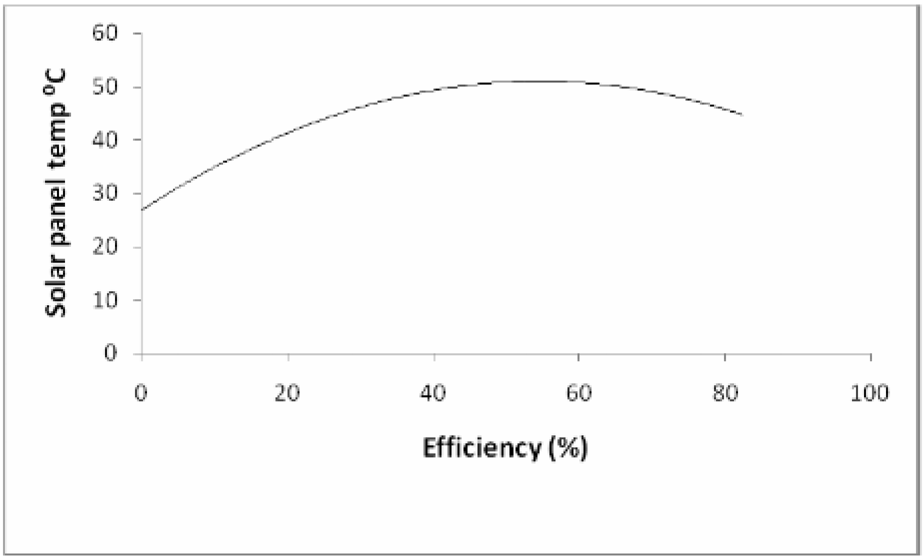


Figure 4.6. - Solar Panel Temperature and efficiency [13]

We can realize that the best performance is achieved approximately with 45º of the solar panel and is not proportional with the temperature.

The energy Agency (IEA) carry out a study of 18 selected grid-connected PV systems of different countries where the types of mounting were grouped in 4 main types: Façade (integrated), Sloped roof , Freestanding and Flat roof.

In this dissertation the PV installation is classified in the group of integrated where the study said that the losses were between 5.3 and 6.4, so the value provided of the software PVsyst 5.02 is correct (5.3%).

4.4.3.3.– LOSSES DUE TO OHMIC WIRING.

Always when there are conductors and the current flows through it, it is produced some looses due to of heating and it is called Joule Effect.

The expression to calculate this lost energy it can be calculated by the formula:

$$P_{JE}=I^2*R \quad [4.1]$$

where

- I: current flowing through the cable [A]
- R: cable resistance [Ω]
- PJE: power losses due to Joule effect [W]

The resistance of the conductor can be calculated with the following expression :

$$R=\rho*l/A \quad [4.2]$$

Where

- ƿ: electrical resistivity [Ω mm2/m]
- L: length of the cable [m]
- A: sectional area [mm2]
- R: cable resistance [Ω]

In the following table it has been estimated the longitude of the different conductors in Dc and Ac as well.

KIND OF CURRENT	LONGITUDE(m)	SECTION(mm2)	RESISTANCE(Ω)
DC	50	2.5	0.34
AC	7	(3*) 2.5	0.1428

Table 4.12. - Cable section and length used for the PV system.

Sustaining this values in the expression [4.1] we obtain that the loosed power by Joule effect is 55 W, almost 0.7% of the total energy generated, and the losses of the simulation is 0.9% so the approximation is correct.

4.4.3.4.– LOSSES DUE TO INVERTER

The manufacturer don´t provide any values of the losses but according to different studies of some universities in the inverter the value will be among 6% depending on the power of the inverter.

The software estimate the losses in 5.8%, so it can said that it is correct the value of this approximation.

4.4.3.6.– LOSSES DUE TO THE INCLINATION OF THE PV CELLS.

In the previous chapter has explained the inclination of the PV modules chosen due to the characteristics of the house. The best performance is achieved approximately with 32º, 2º more than the inclination of the roof. The software PVsyst 5.02 calculates these losses like it can be seen in the following picture and the value is nearly 0%.

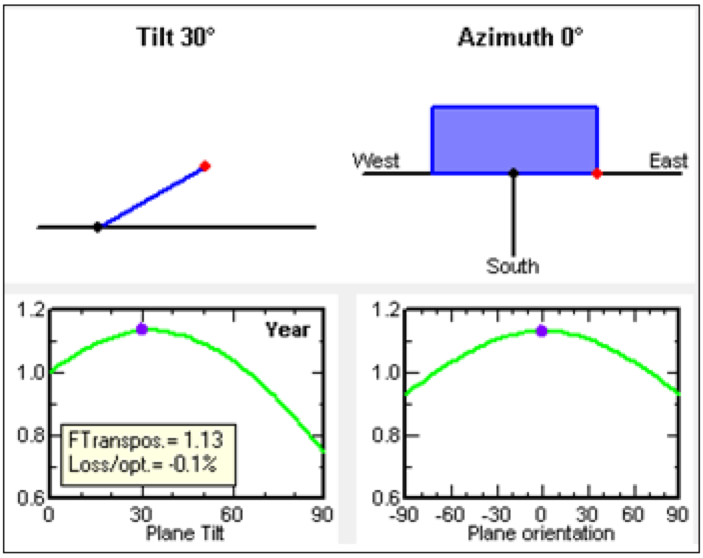


Figure 4.7. - Losses depending on the angle of the PV cells

4.4.4.– ENVIROMENTAL IMPACT

Having a Pv installation provide an important economic benefit and also respet the enviroment.All kwh generated by othe kind of sources where it is produced a huge cantity of pollution, so there will be an important reduction of emisions using renewable enrgies like solar installations.

Due to the combustion, some gases are produced causing the greenhouse effect and the main important parameter to stop it is using renewable energies.The gas most harmgul for it is the CO_2, generated in all kind of carboned materials.

The general director of FOTOSOLAR Says that for 1MWh the Pv energy generated are wasted 400 Kg of CO_2.Also, there are other emissions like SO_2 and Nox where are written the equivalences bellow:

16.52 t Son / Gwh

5.83 t Nox / Gwh

In the next table is possible to know this savings:

	PAMPLONA	WREXHAM
ANNUAL RODUCTION	5288Kwh	3843.8kwh
CO_2	2115 kg	1537.52
SO_2	0.087kg	0.064
Nox	0.032kg	0.023

Table 4.13. - Dates of annual reductions [28]

CHAPTER FIVE: ECONOMIC ASSESSTMENT

In this chapter it will be carry out on a economic study knowing that the prices of the elements will be consider the same for the installation situated in Spain and UK.

The difference will be in the ages of repayment, where later will be analyzed.

5.1. – BUDGET

In the following tables are presented the assumption of the installation where some values have been stimated like it has been explained there.

ELEMENT	UNIT PRICE(€)	UNITS	AMOUNT (€)
PV MODULE	500	56	28,000€
INVERTER	3200	1	3,200€
STRUCTURE AND SUPORTER	950	1	950€
DC Protections	35	1	35€
AC Protections	46		46€
Wiring	10		10€
Counter	45	2	80€
Differntial Interruptor	100	1	100€
Magnetothermic Interruptor	45	1	45€
Civil Work	0.32 €/Wp	4200	13,44€
TOTAL			33,810€
General Cost (10%)			3,381€
Industrial Benefits (6%)			2,028.6€
VAT (5 %)			1,690.5€
TOTAL COST OF THE INSTALLATION			40,910.1€

Table 5.1. - Budget of the installation

The relation between euro and pound is varying these months between 1.1 and 1.14, so aproximatly, it will be get 1.12.Thus the total cost of the installation in pounds is **£ 36,000.88**

5.2. – INCOME

Here it will be presented the stimated income of the PV system.The energy produced and the bonus per kWh is higher in Pamplona, so the benefit will be better like it will be demostrate later.

In the next table are presented the differents incomes for the first year according to the explanation of the point 4.2.In the case of Wrexham there will be the following incomes:

- **Generation Tariff**

  36.1 p/ Kwh*3568.3 = 1288.15 £

- **Export Tariff**

  3p/kwh * 1685 kwh (Quantity of energy that is sold to the grid) =50 £

- **Saved Money**

  10p / Kwh *1883.3 kwh (Consumption of the house)= 183 £

	PAMPLONA		WREXHAM	
	E. array (kph)	**INCOME(€)**	**E. array (Kwh.)**	**INCOME(£)**
TOTAL(1º YEAR)	5288,7	1769,5	3568,3	1521.2

Table 5.2.- Annual Income

To obtain the difference more clearly, the income will be expresed in pounds, so in the case of Pamplona, the total income for the first year is £1,557.16 and for Wrexham £ 1,521.2.

It is important to realize that this income in Wrexham is only for the first year because for the rest of the years there is a annual degression of 8.5 % for the Generation Tariff.

5.3. – PAYBACK PERIOD

In this section, it has been calculated one of the most important point because it will be possible to know if it is profitable or not the PV installation. For that it has been used RETScreen v4.1 sotware which main characteristcs are described bellow:

In RETScreen Version 4, the software's capabilities have been expanded from renewable energy, cogeneration and district energy, to include a full array of financially viable clean power, heating and cooling technologies, and energy efficiency measures. The international appeal of this decision supporting tool has been improved through the expansion of climate data, required by the tool, covering the entire surface of the planet, including central-grid, isolated-grid andoff-grid areas, as well as through the translation of the software into 35 languages that cover roughly 2/3 of the world's population.

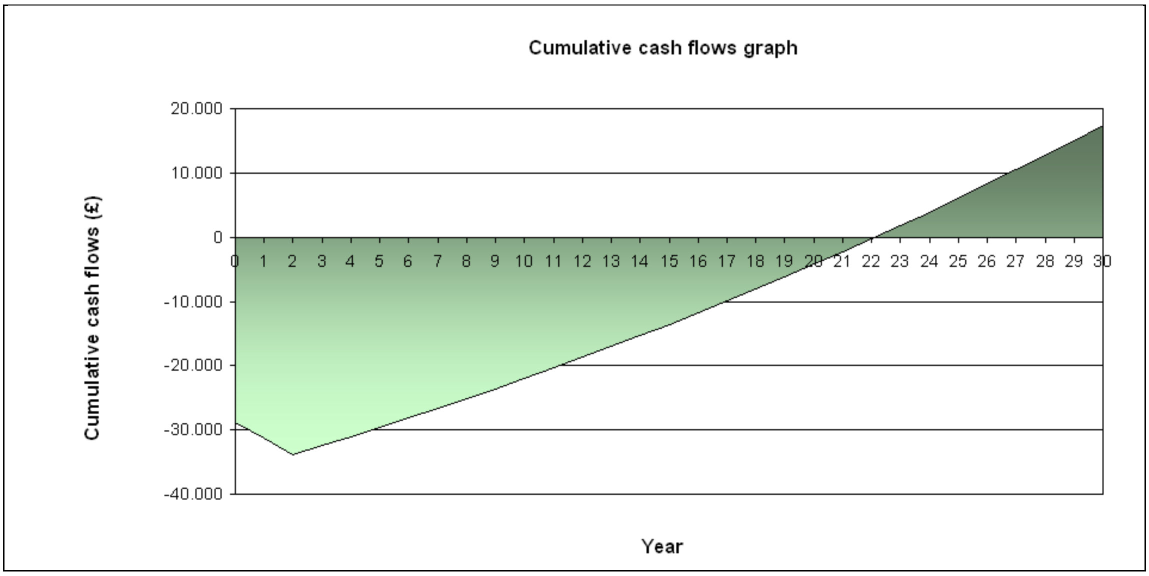
To calculate the Payback period the values more outstanding will be the energy generated and the price per kwh sold to the net.Also the following common aspects have been needed:

- INFLATION RATE =2%-→ looking the previous years, this value has choosen by aproximation
- PROJECT LIFE=30 YEARS → According to the manufacturer and previous intallations, it is common this value
- Debt Ratio =20 % → This is the quantity of the total cost of the installation that the user obtain like a credit with an intereste rate of 5% during two years
- Annual Cost =36 → This value is an aproximation due to it is very difficult to know.According to previous users this value could works.

Respect the value of the Export Electricity rate, it has been obtained different for both installations:

For the case of Pamplona, during 25 years all electricity will send to the net at the same price of 0.3346 €/kwh (0.2475 £/kwh), and for the next 5 years has consider the worst case, sell the electricity a low tariff equal to 0.10 € /kwh (0.088£/kwh).Thus the medium Export Electricity rate for Pamplona is consider **217.94 £/Mwh**.

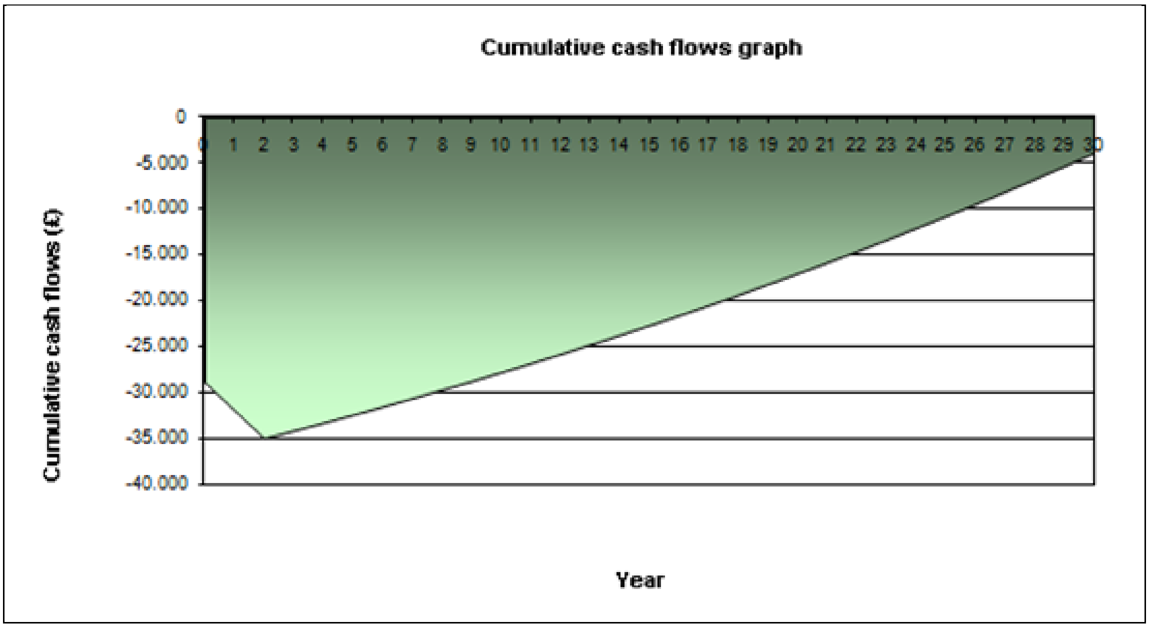
Like it is shown in the Picture 5.1, the payback period is during 22 years, thus this installation is profitable and it could take place.



Picture 5.1.- Payback period of Pamplona

However in the case of Wrexham it is different because every year there is an Export Electricity rate different due to there is a annual degression of 8.5%.The average of the 30 years for the final value of the Export Electricity rate for Wrexham is **170 £/Mwh.**

According with the point 5.2, it has been considered an annual extra income of £233 (£183 =Saved Money and 50 £= Export tariff) apart of the Generation Tariff liket can be seen in the Appendix C.



Picture 5.2. - Payback period of Wrexham

Even so, the important matter is that the payback period is much longer than the project life, resulting that either of the PV system designed are not cost-effective.A solution for the case of Wrexham will be analyzed in the next chapter

CHAPTER SIX: DISCUSSION

6.1. – CHOICE OF THE KIND OF PV SYSTEM

At first glance it is difficult to know which option is the best, mainly because the grants could change in the future and energy study is only a stimation.The best way to decide the profitable option is to calculate how it is possible to obtain more profit, so in the next points it is going to be demostrated for both places:

PAMPLONA

- PRICE Kwh =11.473 cent €/ Kwh
- Consume of the house=5233 Wh per day → 1833.8 Kwh per year
- **Annual Cost Stimate of Elecricity :** 11.473 cent €/ Kwh*1833.8 Kwh per year=***217 €***

If the system was Stand Alone System, the Total annual Income would be 217 €, because the house would be connected directly to the PV installation and the user wouldn´t sell nothing to the grid.

From the beginnig in this project has been done the study with a grid-connected system and in the the apart 5.2 it has been stimated the total Income equal to 1,769.5 €.

Knowing that the payback period in Pamplona is lower than the project life, and the total benefit in a grid-connected system is nearly 8 times more than a stand alone system, it is not difficult to realize that the best way to have more profit is with the solution studied, GRID-CONNECTED SYSTEM.

In case of finishing the grants or changes the prices per kwh causing losses of money, the grid-connected System can be changed to a Stand alone system with a few changes:Adding a group of batteries and a regulator of load apart of some electrical configuarations.

WREXHAM

- PRICE Kwh =9.842 pence per Kwh
- Consume of the house=5233 Wh per day → 1833.8 Kwh per year
- **Annual Cost Smtimation:** 9.842 pence per Kwh *1833.8 Kwh per year=***181 £***

According with the apart 5.2, the stimate of annual income is £1,521, so at first glance it looks better to choose a Grid Connected System like in Pamplona but here there is a problem.

This problem it is because the total energy generated in the installation situated in Wrexham is low and the price per kwh is not enought.Due to these factors the pay-back period is higher than the project life like it has been demostrated in te apart

5.3.It is logical that the project is not possible to do because the user will loss money.

In the following point there is an interesting solution for Wrexham where it will be demostrated that there is a better way.

6.2. – PAYBACK PERIOD

The results of the payback period has been explained in the apart 5.3 for both places.

For the case of Pamplona (SPAIN) results were not as it was spected because normally it is around 15 years depending highly on the situation.In Pamplona it is normal 22 years because it is situated in the North of Spain and the solar radiation is not like Mediterranean area or the South of Spain where are installed the majority of the installations.

In the case of Wrexham it is different and more complicated because the project is not possible to make due to the payback period is bigger than the project life (round 33 years).

Here it will be presented a solution to have a profitable installation.It will be considered a hybrid installation between the previous PV installation and a small wind turbine.

6.2.1. – HYBRID INSTALLATION

As it has been explained in the point 2.5.3, a Hybrid System is formed by a wind turbine and a PV installation.So in the case of the installation calculated to Wrexham the only element needed is the small wind turbine and change the power of the inverter.

The simulation has been done with the software called Homer where a short explication is presented later.

6.2.1.1. – COMPONENTS

First of all will be presented the two new elements mentioned before:

SMALL WIND TURBINE:

The small wind turbine choiced is **INCLIN 3000 NEO** because the price is not really high and it works correctly with the speed wind in Wrexham.Bellow it is described the main values of the small wind turbine and more imformation can be seen in the Appendix C.

Technical Data	INCLIN 3000 NEO
Number of Blades	3
Rotor diameter(m)	3.7m
Out- in(start) wind speed	3.5 m/seg
Max wind speed	50 m/seg
Output Voltage	48V
Weight	112KG

Table 6.1 Representation of the main parameters[29]

INVERTER

In this case the brand is the same that has been choiced in the PV installation, due to this increase in the power the price has changed as well.

The catalogue of it can be seen in the Apendix C

6.2.1.2. – SIMULATION

The simulation has been done by the software called Homer which a short explication is presented now:

Homer started in 1993 to meet the renewable energy industry´s system analysis and optimization needs.HOMER is a computer model that simplifies the task of evaluating design options for both off-grid and grid-connected power systems for remote, stand-alone, and distributed generation (DG) applications. HOMER's optimization and sensitivity analysis algorithmss allow the user to evaluate the economic and technical feasibility of a large number of technsology options and to account for uncertainty in technology costs, energy resource availability, and other variables. HOMER models both conventional and renewable energy technologies

Principally, the data needed to the simulation has been the solar resource and the wind resource.

In the solar resource it has been used the same data as the software PV Syst used for the PV installation in Wrexham. These values are the solar radiation monthly, coordinates of the place, azimuth and inclination of the PV modules…

Respect the wind resource it has been needed the wind speed monthly which it has been got from the weather station in Wrexham. In the table it can be seen the window of Homer where has been introduced all the values.

Month	Wind Speed(m/s)
January	7.4
February	6.7
March	7.1
April	6.1
May	6.8
June	5.7
July	5.4
August	5.9
September	5.9
October	6.4
November	6.2
December	7.1
Annual Average	6.394

Table 6.2 Values of the wind speed [17]

Once having the main values and filling in some necessary dates like the Anemometer height, the Weilbull K, Diurnal pattern strength, hour of peak wind speed, Homer is ready to do the estimation of the hybrid system.

6.2.1.3. – STIMATION OF THE ENERGY PRODUCED

In the next table is presented the results of this study where the wind turbine produced the 64 % of the total energy and the PV installation a 36%.

PRODUCTION	KWH /YEAR	%
Pv installation	3743	36
Wind Turbine	6702	64
Grid purchase	0	0
TOTAL	10,444	100

Table 6.3 Energy produced yearly by the Hybrid System

In the next picture can be seen the representation of both energies monthly where curiously the wind turbine produce more in winter, exactly the opposite of the PV installation where the maximum values are achieved in the months of summer.

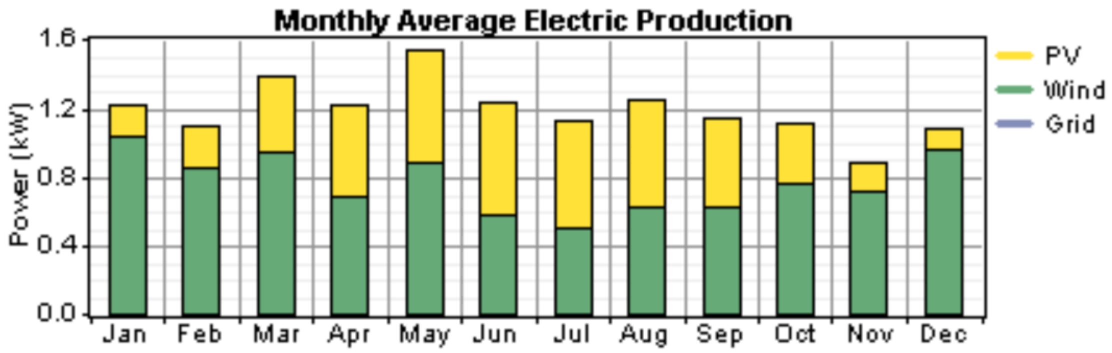


Figure 6.2 Monthly Average Electric Productions

From now on it will be presented the main things to know if the hybrid system could replace the PV installation in Wrexham or not.

6.2.1.4. – BUDGET

This point is similar because only there are some changes. The price of the wind turbine, the structure of it and the new inverter which it will be installed with more power

ELEMENT	UNIT PRICE(€)	UNITS	AMOUNT (€)
PV MODULE	**500**	**56**	**28,000€**
WIND TURBINE	**6,000**	**1**	**6,000€**
Structure Wind Turbine	**1,820**	**1**	**1,820**
INVERTER	**4,425**	**1**	**4,425€**
STRUCTURE AND SUPORTER	**950**	**1**	**950€**
DC Protections	**35**	**1**	**35€**
AC Protections	**46**		**46€**
Wiring	**10**		**10€**
Counter	**45**	**2**	**80€**
Differntial Interruptor	**100**	**1**	**100€**
Magnetothermic Interruptor	**45**	**1**	**45€**
Civil Work	**0.32 €/Wp**	**7200**	**1544€**

TOTAL	**43,055 €**
General Cost (10%)	**4,305€**
Industrial Benefits (6%)	**2,583.3€**
VAT (5 %)	**2,152.7€**
TOTAL COST OF THE INSTALLATION	**52,096 €**

Table 6.4 Budget for the Hybrid System

The Total cost of fhe installation it will be expressed in pounds due to the the economy study will be done in pounds as well, so 52,096 € is equal to £45,844.5.

6.2.1.5. – INCOME

On this part, it will be presented the estimated income of the Hybrid system.Now the energy produced and the bonus per kwh is different because there are the production of the wind turbine and the Pv installation.The energy of the PV installation is almost nearly of the calculated in the PV syst like it can be seen in the following table.

In the next table are presented the differents incomes yearly according to the explanation of the point 4.2

	TOTAL INCOME (£)	
	WIND TURBINE 6702 Kwh.	PV ISNTALLATION 3743Kwh
Generation Tariff	6702kwh*26.7 p/ Kwh. = 1789.5 £	3743kwh*36.1p/Kwh. 1351.2 £
Export Tariff	6702kwh*3 p/Kwh= 201 £	1910 kwh*3p/ kwh=57 £
Saved Money	1833.3 Kwh. 10 p/Kwh=183	
TOTAL INCOME (1º YEAR)	1789.5+201+1351.2+57+183= **3581.7 £**	

Table 6.5.- Total income for the first and the second year in Wrexham

The total income for the first year will be £2648.7 but for next years it is different because there will be a annual digression of 8.5 % for the PV installation and 3 % for the Wind turbine. This aspect will be considered in the next point, the payback period.

6.2.1.6. – PAY BACK PERIOD

Like it has been explained in the point 5.2, it will be calculated for the hybrid installation.The olny parameter that has changed is the useful life because for the wind turbine is 25 years.

Knowing this aspect, the study has been done for 25 years, thought it is interesant realize that the Pv installation will be working 5 years more, producing an income aproximatly of £5,000.

In the Figure 6.3 it is represented the payback period of the hybrid installation which it is paid in 17.8 years. The total income of the installation is approximately 24000 £ plus 5000 £ due to only has been considered 25 years for the PV installation in such of its useful life of 30 years.

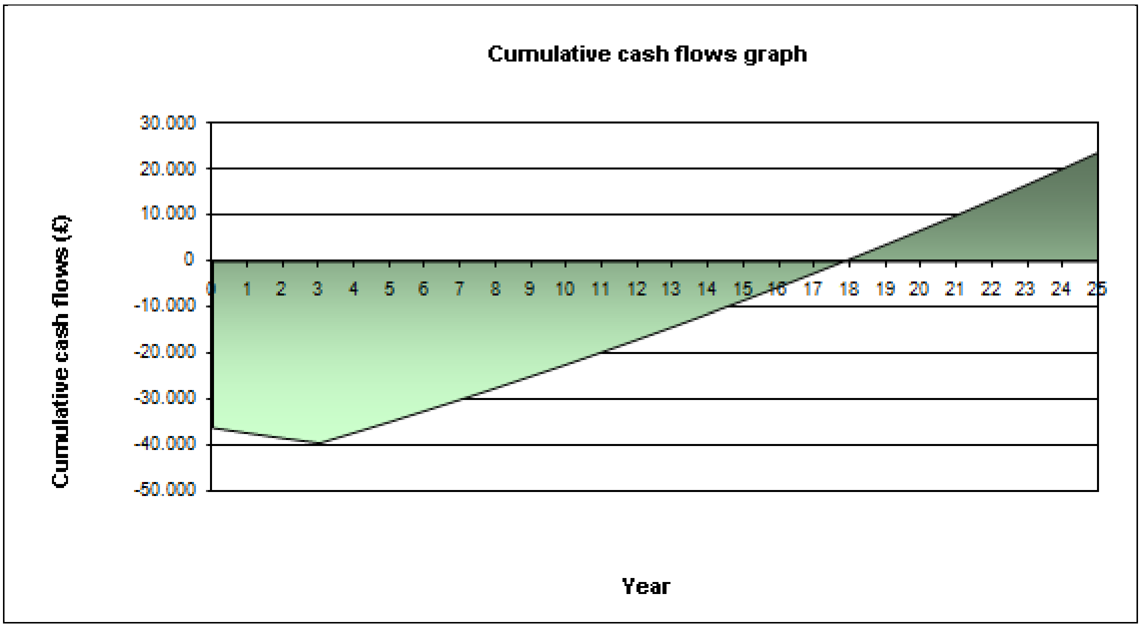


Figure 6.3 Pay back Period for the Hybrid System

Like it can be seen in the up Figure the installation in Wrexham is profitable and only adding a small wind turbine the pay back period has changed from 33 years to 17.8 years. The only disadvantage is that the initial investmend has changed logicaly.

CHAPTER SEVEN: CONCLUSION

In this Project has been demonstrated that grants from the government of each country is really important to reduce the years of the pay back period. In Spain the tariffs are kept whereas United King has start to increasing it respect the last year because of the Feed-in Tariff (FIT) system.

A positive consequence of the FIT system could be the increase of PV installations with the disadvantage that depending on the area, they are not still profitable like the case study in Wrexham.

The analysis carry out in this project for Pamplona shows that the pay back period is completed from the 21th year, having a total income of 15,000 £ approximately.

For any person with a normal purchasing power, 36000 £ is an important inversion due to 21 years paying suppose an important risk in case of be braked the installation from different causes like a beam in a summer storm or a bad weather…

Once doing this inversion is better to make sure that the pay back period is shorter doing the installation in a place with more solar radiation like it happens in the South of Spain or the Mediterranean cost.

In the case of Wrexham it is better to study another renewable energy sources like the example of the small wind turbine explained in the chapter Six. In this case, the Hybrid installation is paid in 17.8 years, more than 15 years before than the PV installation, so a solution for Wrexham could be install a Hybrid installation with a total income of 22000 £ approximately in such a PV installation.

Before installing a wind turbine it is necessary to be sure that there is no any problem with the noise, height, vibrations and the social opinion.

<u>Recommendations for further work</u>

- Use another kind of house with more useful surface to build a bigger PV installation, so that the energy generated will be higher in comparison of the investment.
- Do a deep study for Wrexham about the hybrid system or install only the small wind turbine due to the wind has got a good characteristic to have a good performance in the installation.
- Redesign the PV system using instead of a fix support structure, a solar tracker (1 axis and 2 axis) in order to produce more electricity. Study the cost-effectiveness and disadvantages and advantages of using this kind of structures
- Redesign the PV system using the PV cells of the Third generation explained in the Apart 2.6 due to have a high performance in comparison with the mono-crystalline cells used.

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APPENDICES:

APPENDICES:

Appendix A : Plans

Appendix B: Simulations

Appendix C : Catalogues

APPENDIX A: PLANS

Figure A1: Situation of the House in Pamplona

Figure A 2: Sitution of the House in Wrexham

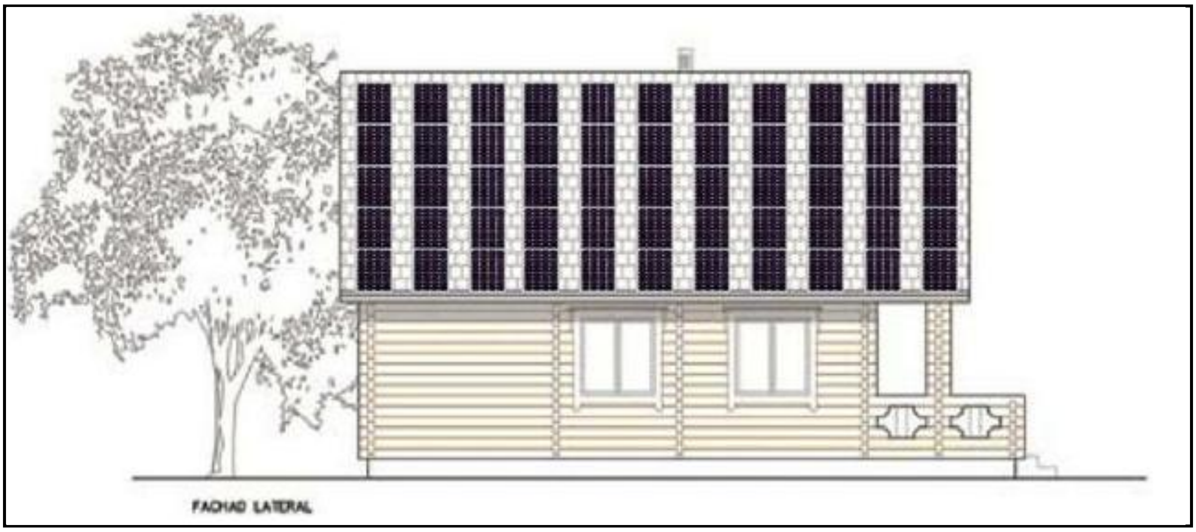


Figure A 3: Distribution of the PV modules over the roof.

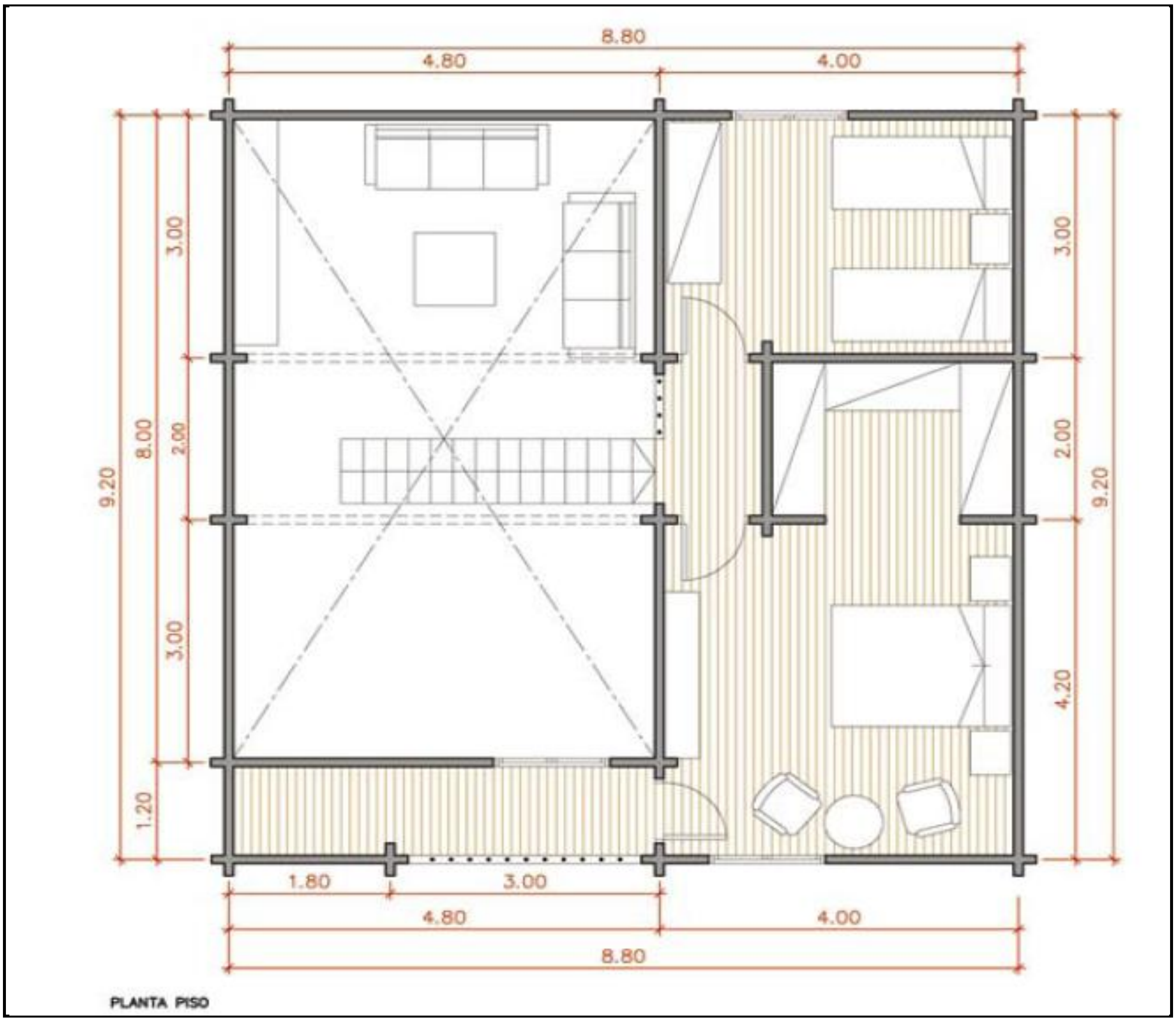


Figure A 4: Plan of the second floor of the house

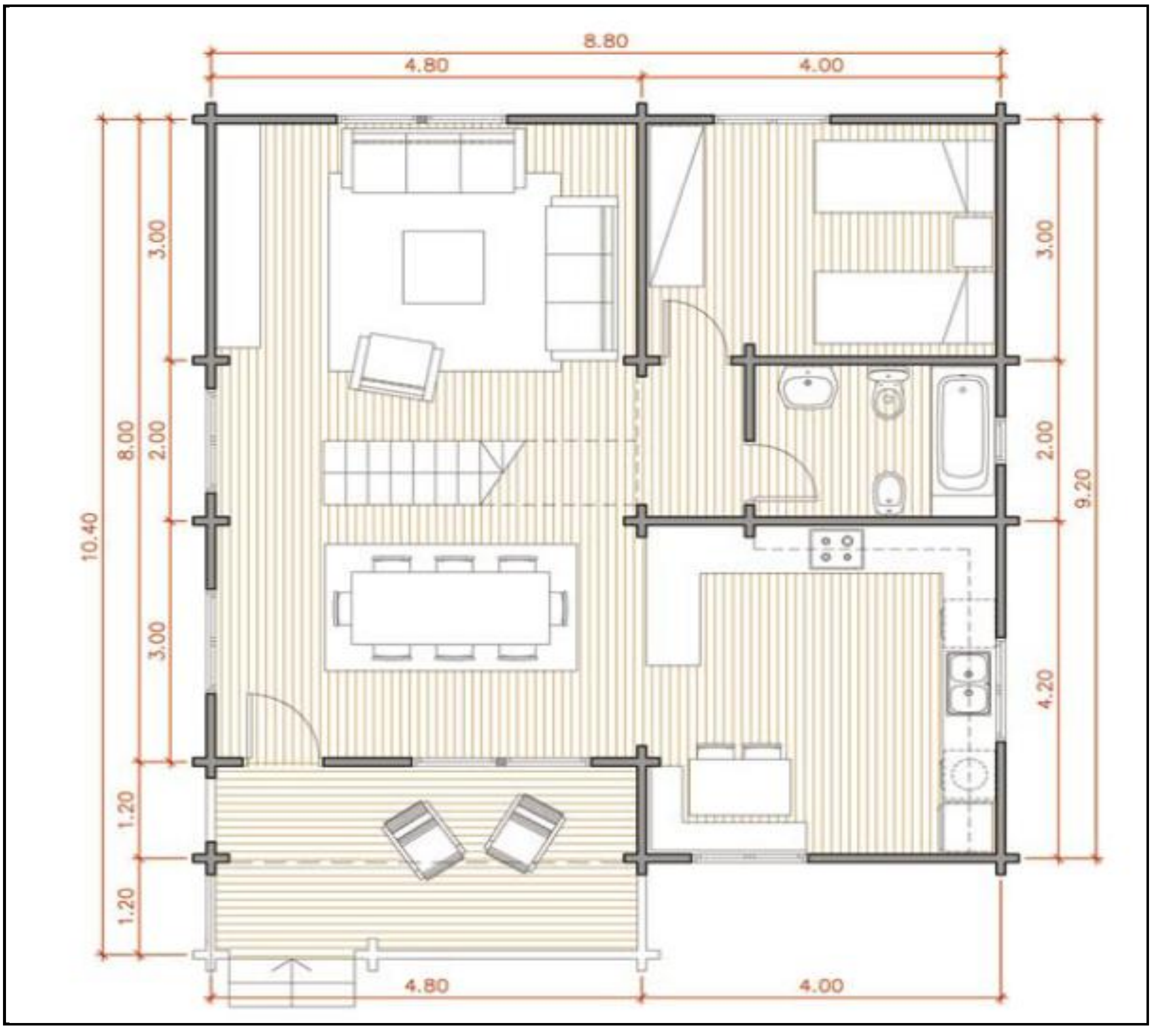


Figure A 5: Representation of the first floor of the house

APPENDIX B : SIMULATIONS

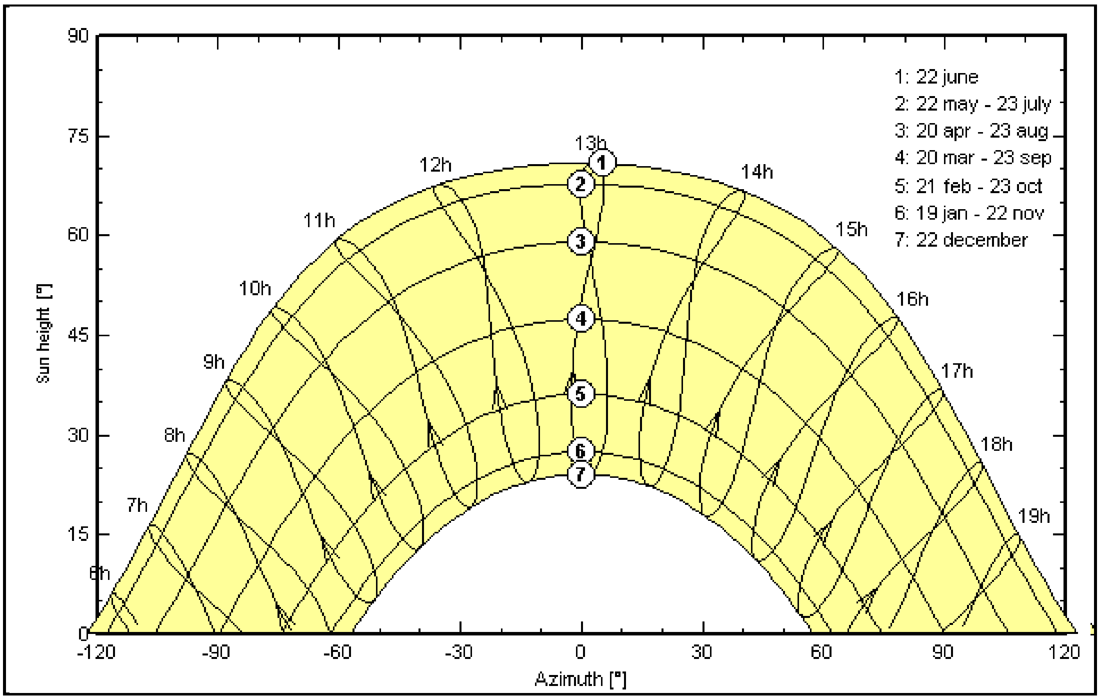


Figure B1:Solar Path at Pamplona

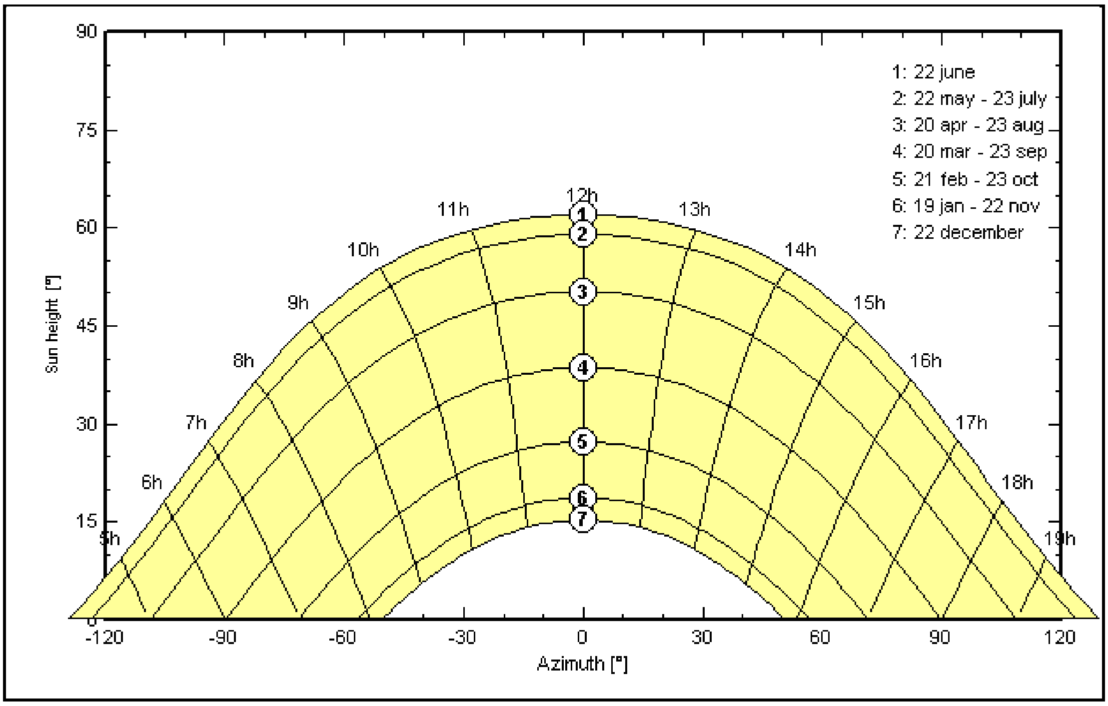


Figure B2:Solar Path at Wrexham

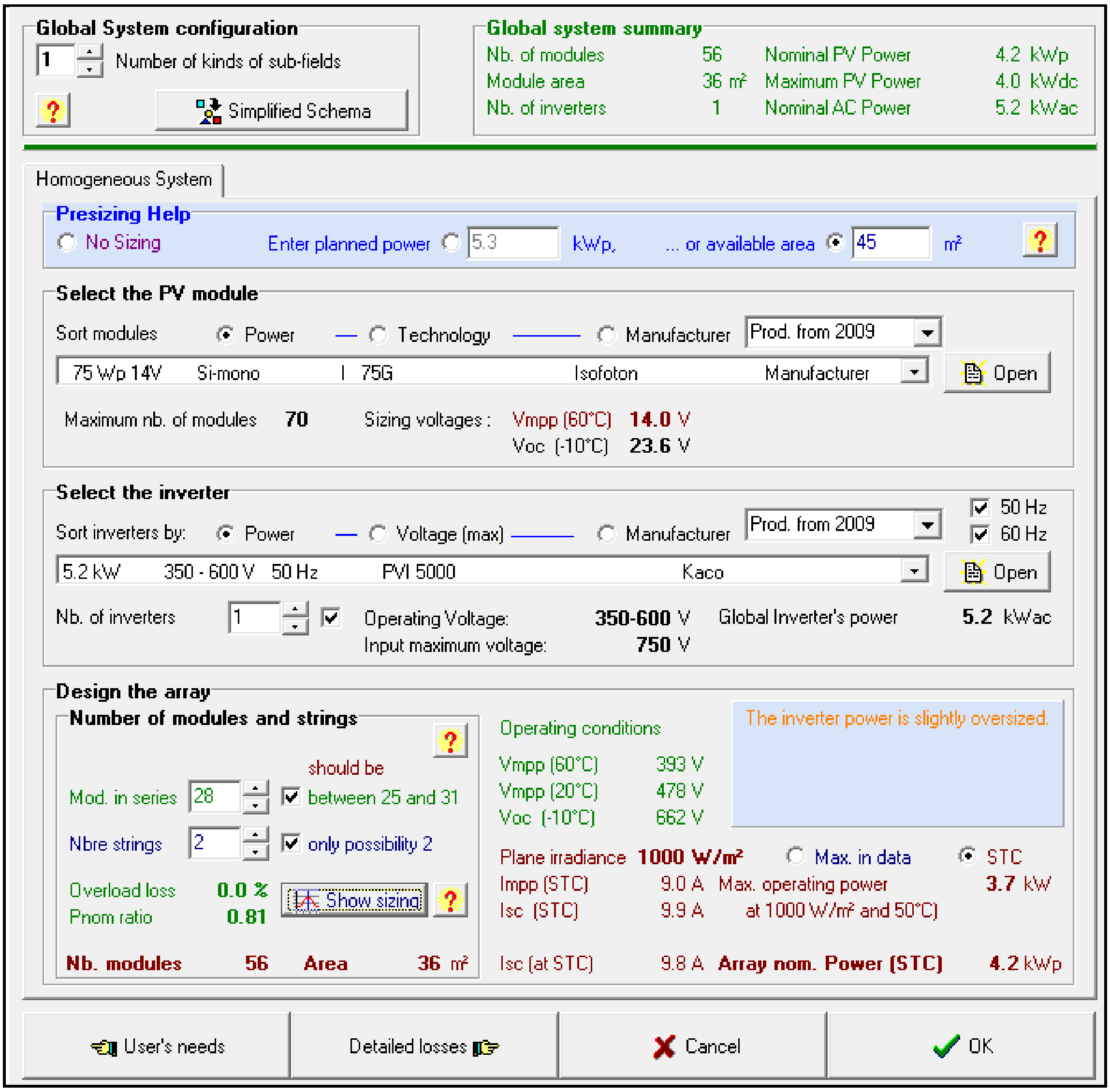


Figure B3:Descriptioin of the elements choosen

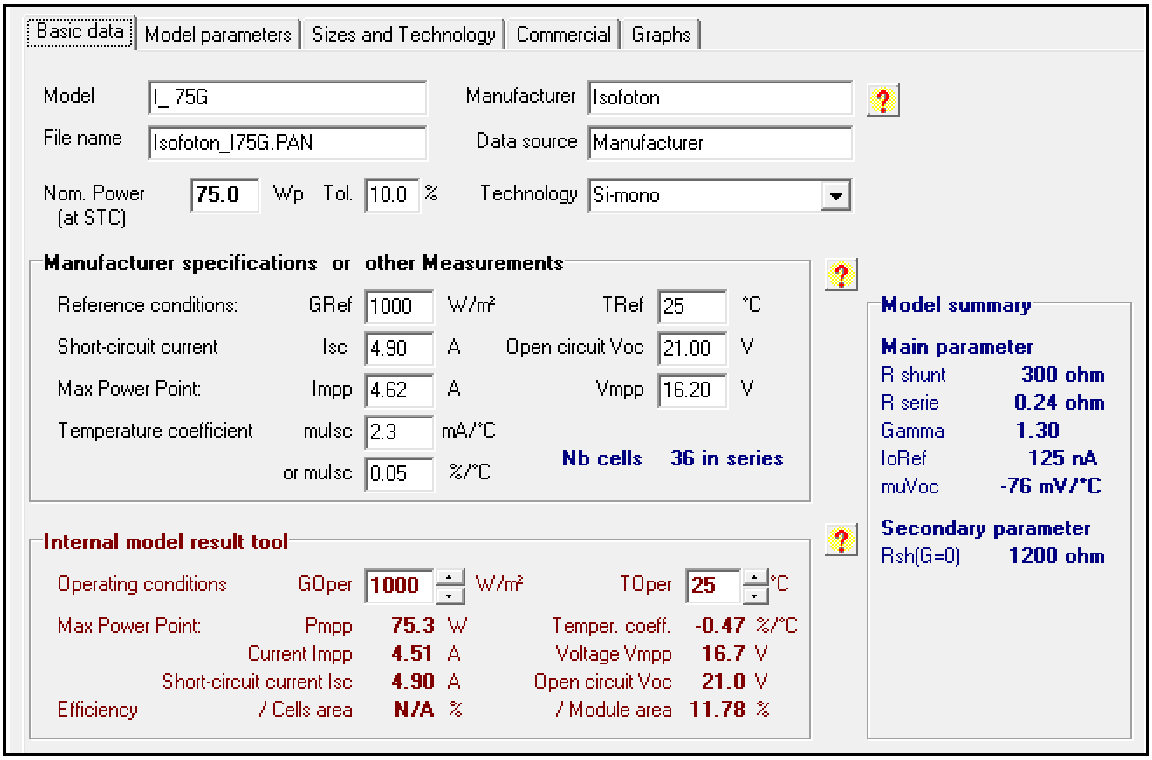


Figure B4:Characteristic ot the photovoltaic module

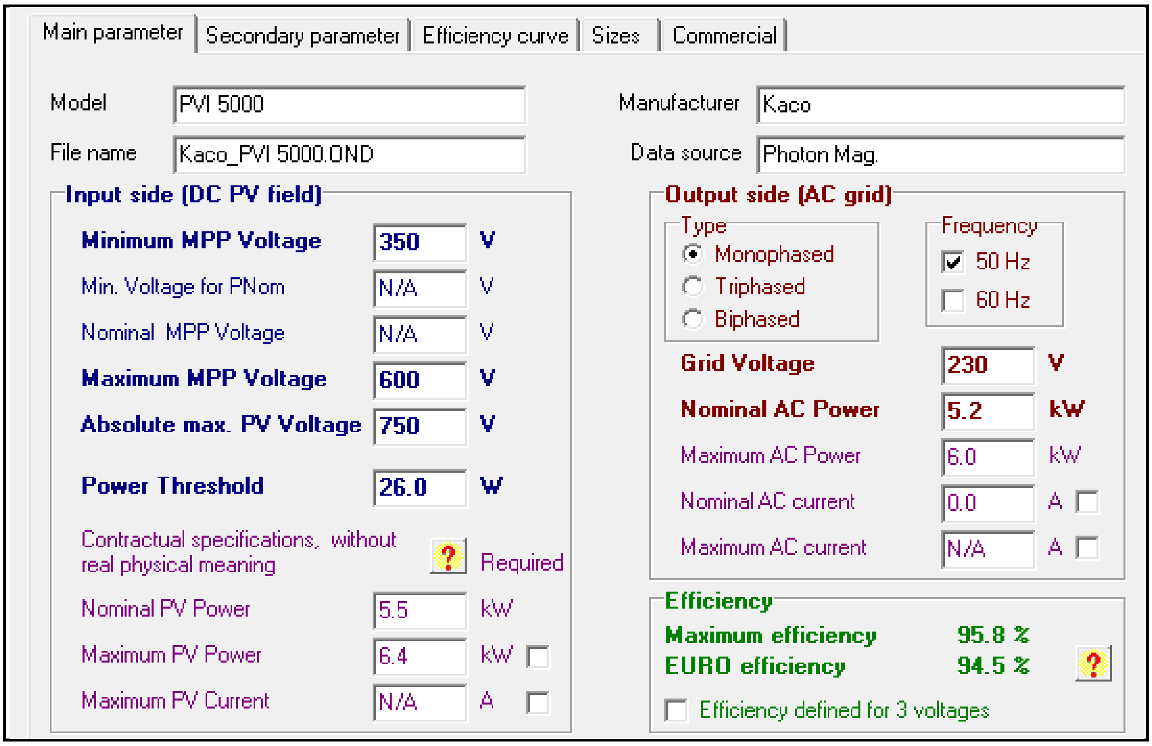


Figure B5:Characteristic of the inverter

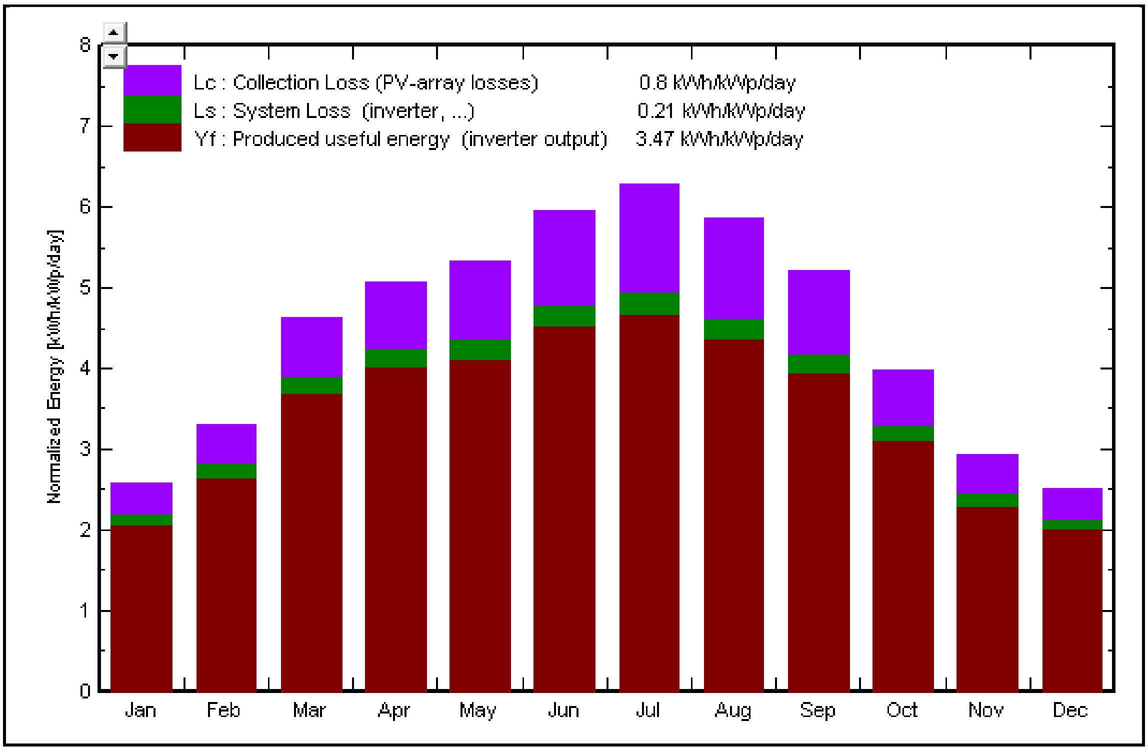


Figure B 6: Normalized productions in Pamplona (per Installed KWp)

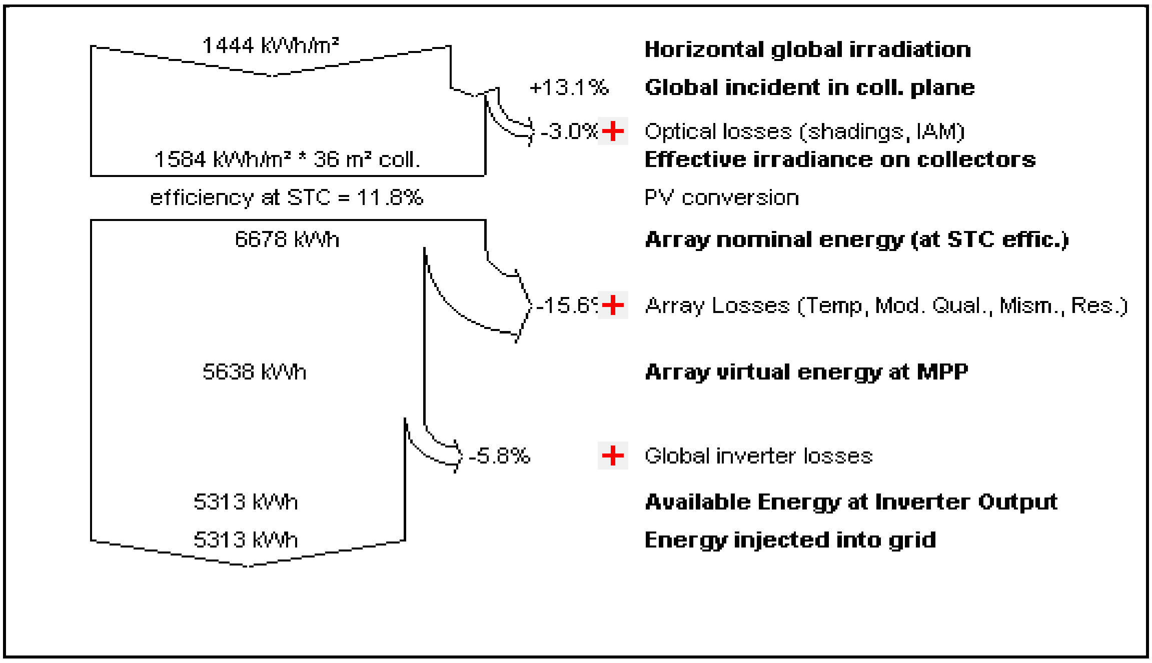


Figure B7:Loss diagram per year in Pamplona

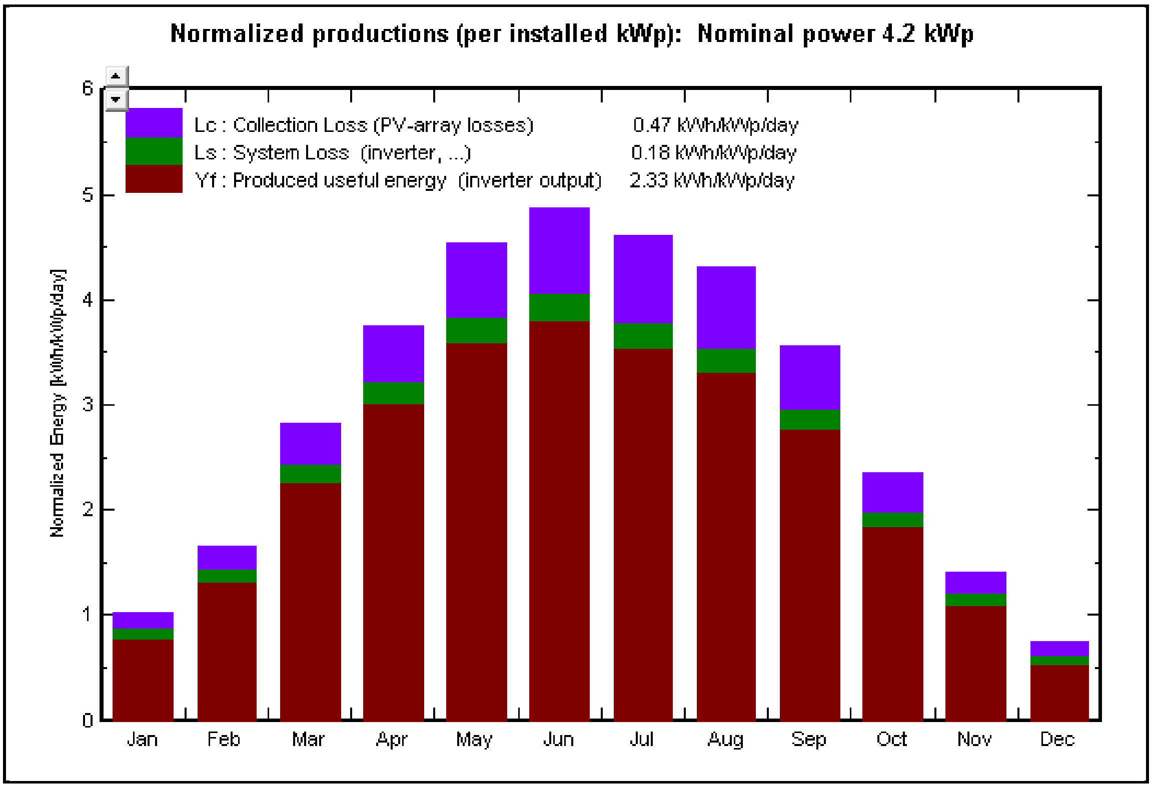


Figure B8: Normalized productions in Wrexham (per Installed KWp)

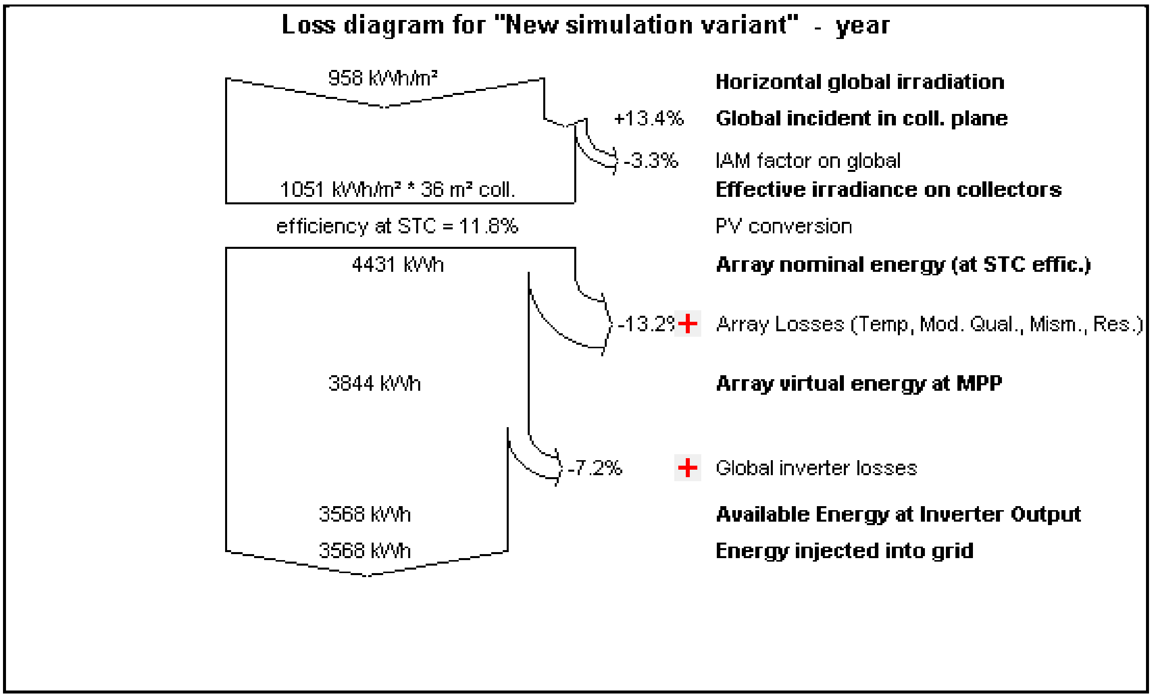
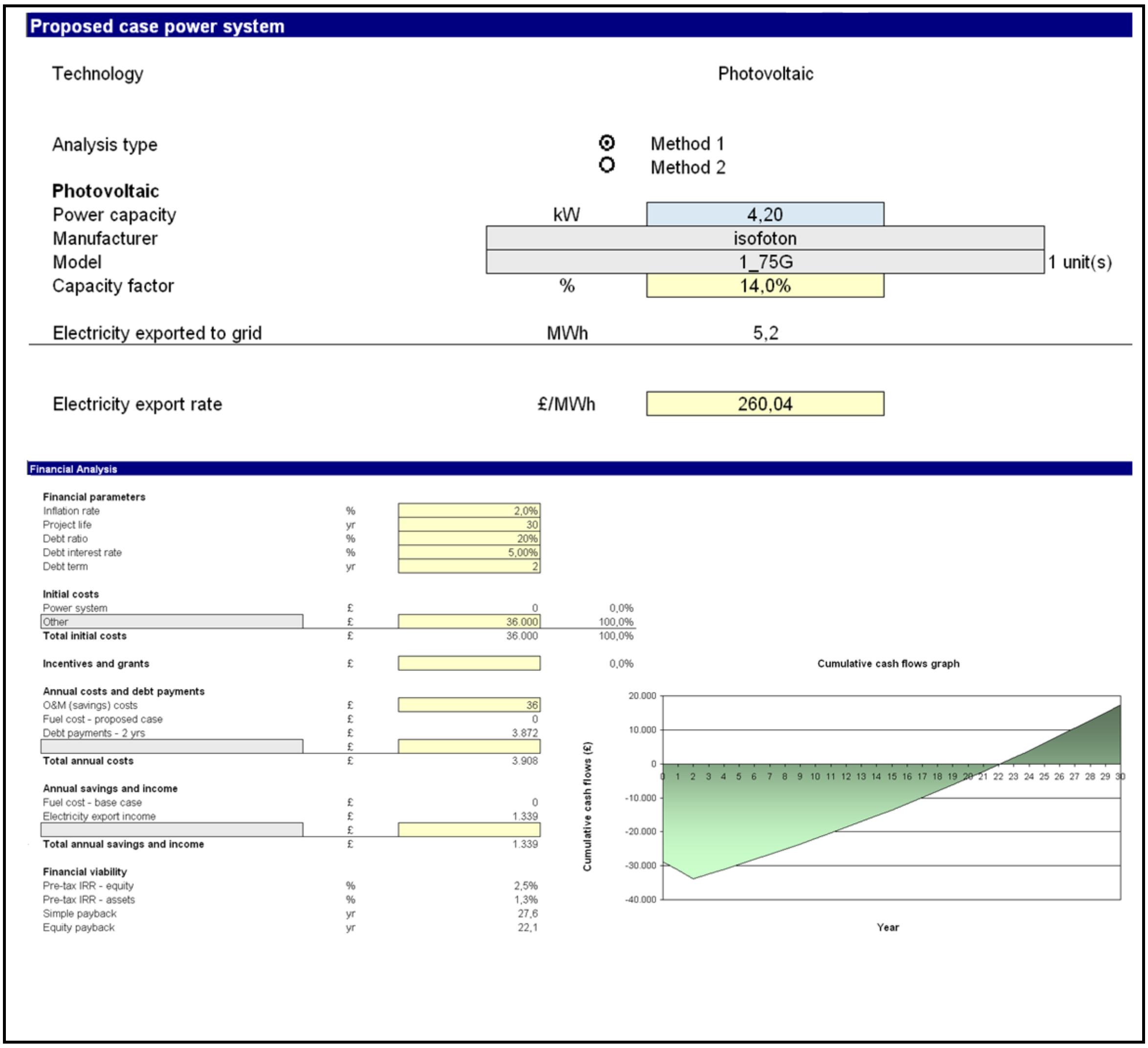


Figure B9 :Loss diagram per year in Wrexham



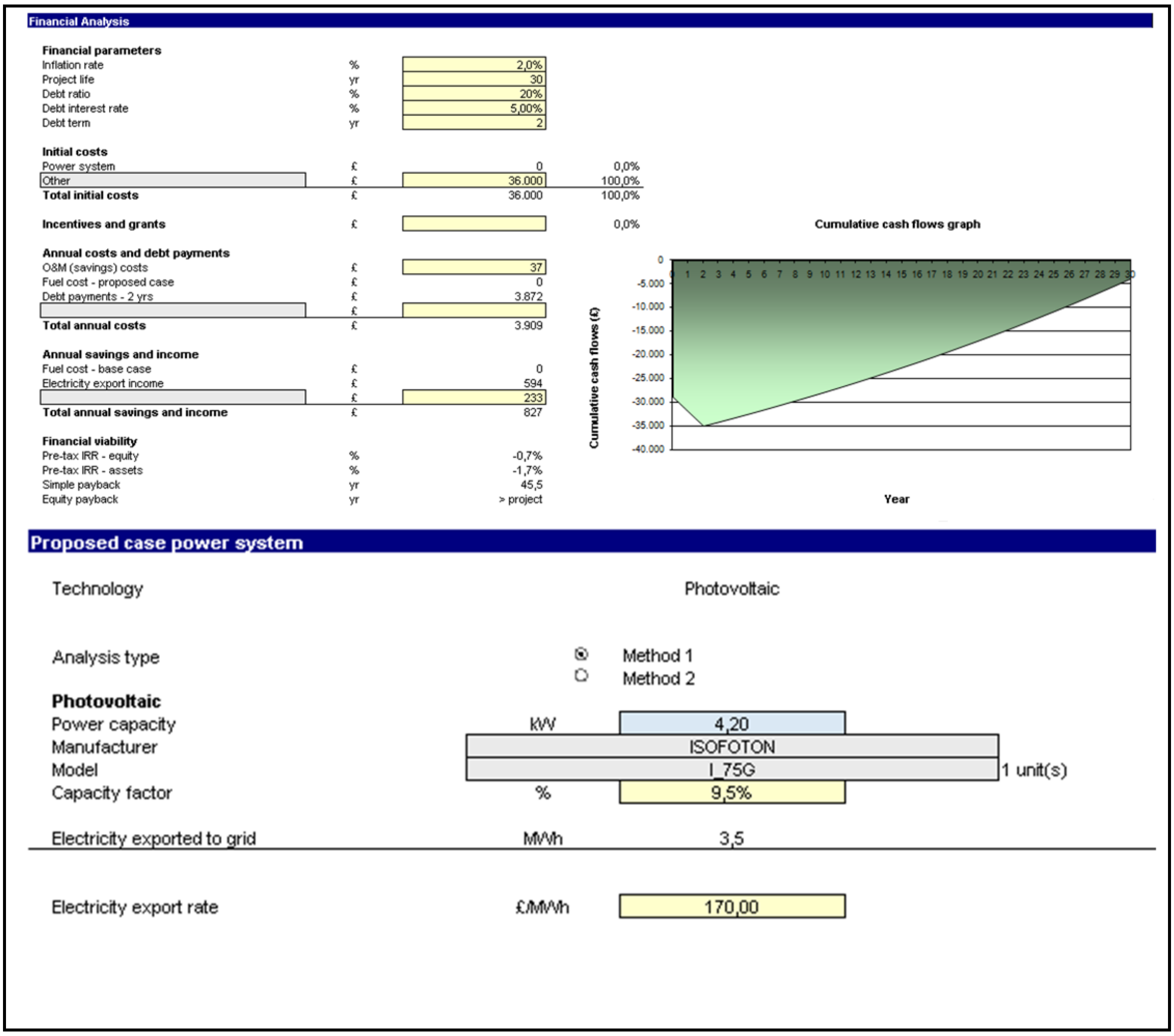
Proposed case power system

Technology		Photovoltaic
Analysis type		⦿ Method 1 ○ Method 2
Photovoltaic		
Power capacity	kW	4,20
Manufacturer		isofoton
Model		1_75G (1 unit(s))
Capacity factor	%	14,0%
Electricity exported to grid	MWh	5,2
Electricity export rate	£/MWh	260,04

Financial Analysis

Financial parameters			
Inflation rate	%	2,0%	
Project life	yr	30	
Debt ratio	%	20%	
Debt interest rate	%	5,00%	
Debt term	yr	2	
Initial costs			
Power system	£	0	0,0%
Other	£	36.000	100,0%
Total initial costs	£	36.000	100,0%
Incentives and grants	£		0,0%
Annual costs and debt payments			
O&M (savings) costs	£	36	
Fuel cost - proposed case	£	0	
Debt payments - 2 yrs	£	3.872	
	£		
Total annual costs	£	3.908	
Annual savings and income			
Fuel cost - base case	£	0	
Electricity export income	£	1.339	
	£		
Total annual savings and income	£	1.339	
Financial viability			
Pre-tax IRR - equity	%	2,5%	
Pre-tax IRR - assets	%	1,3%	
Simple payback	yr	27,6	
Equity payback	yr	22,1	

Figure B10: Pay Back Period of Pamplona



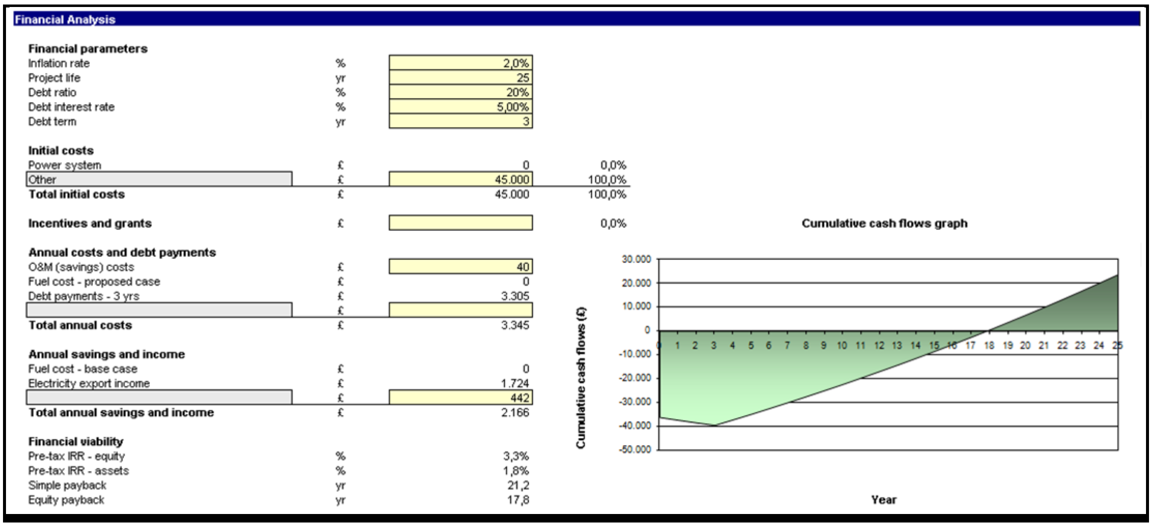
Financial Analysis

Financial parameters			
Inflation rate	%	2,0%	
Project life	yr	30	
Debt ratio	%	20%	
Debt interest rate	%	5,00%	
Debt term	yr	2	
Initial costs			
Power system	£	0	0,0%
Other	£	36.000	100,0%
Total initial costs	£	36.000	100,0%
Incentives and grants	£		0,0%
Annual costs and debt payments			
O&M (savings) costs	£	37	
Fuel cost - proposed case	£	0	
Debt payments - 2 yrs	£	3.872	
	£		
Total annual costs	£	3.909	
Annual savings and income			
Fuel cost - base case	£	0	
Electricity export income	£	594	
	£	233	
Total annual savings and income	£	827	
Financial viability			
Pre-tax IRR - equity	%	-0,7%	
Pre-tax IRR - assets	%	-1,7%	
Simple payback	yr	45,5	
Equity payback	yr	> project	

Proposed case power system

Technology		Photovoltaic	
Analysis type		◉ Method 1 / ○ Method 2	
Photovoltaic			
Power capacity	kW	4,20	
Manufacturer		ISOFOTON	
Model		I_75G	1 unit(s)
Capacity factor	%	9,5%	
Electricity exported to grid	MWh	3,5	
Electricity export rate	£/MWh	170,00	

Figure B 11: Pay back Period of Wrexham for the Pv Installation



Financial Analysis

Financial parameters			
Inflation rate	%	2,0%	
Project life	yr	25	
Debt ratio	%	20%	
Debt interest rate	%	5,00%	
Debt term	yr	3	
Initial costs			
Power system	£	0	0,0%
Other	£	45.000	100,0%
Total initial costs	£	45.000	100,0%
Incentives and grants	£		0,0%
Annual costs and debt payments			
O&M (savings) costs	£	40	
Fuel cost - proposed case	£	0	
Debt payments - 3 yrs	£	3.305	
	£		
Total annual costs	£	3.345	
Annual savings and income			
Fuel cost - base case	£	0	
Electricity export income	£	1.724	
	£	442	
Total annual savings and income	£	2.166	
Financial viability			
Pre-tax IRR - equity	%	3,3%	
Pre-tax IRR - assets	%	1,8%	
Simple payback	yr	21,2	
Equity payback	yr	17,8	

Figure B 12 : Pay back period for the Hybrid System in Wrexham

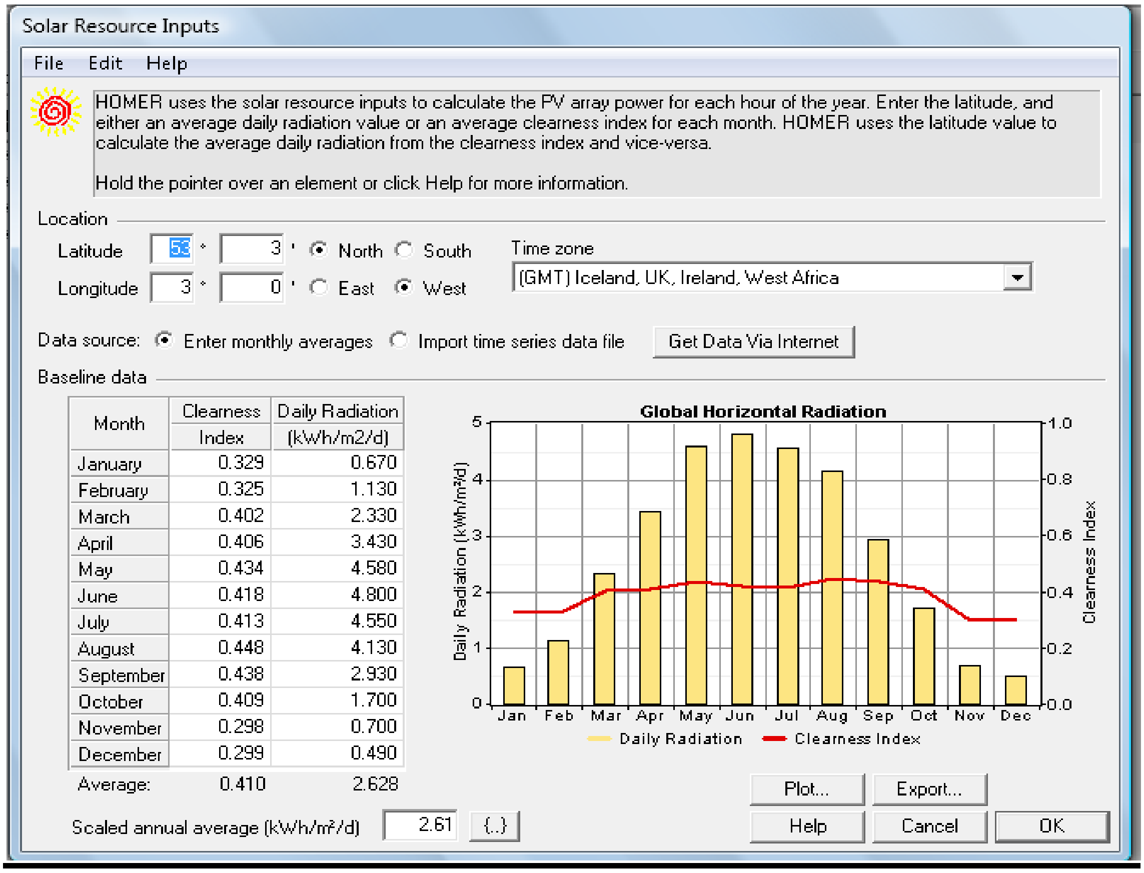


Figure B 13: Window of the Solar Energy of the software Homer

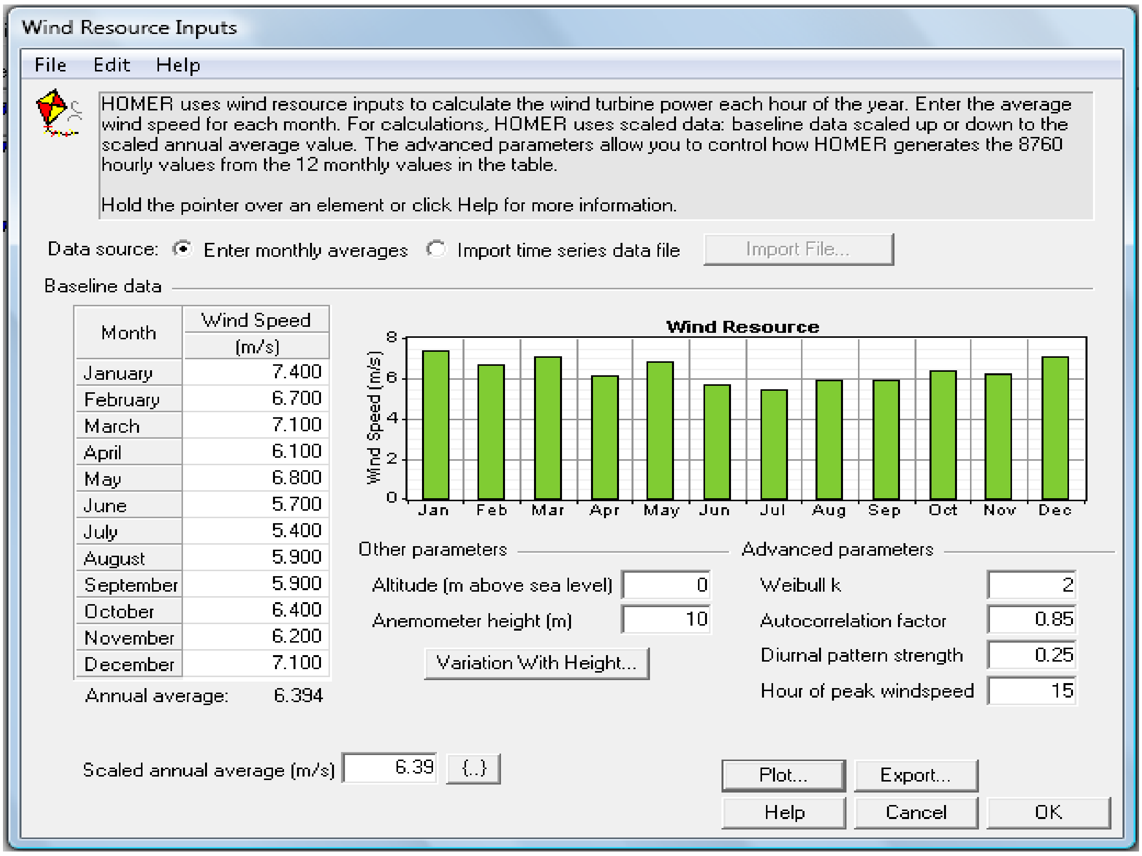


Figure B 14: Window of the wind energy for Wrexham in the software Homer

APPENDIX C:CATALOGUES

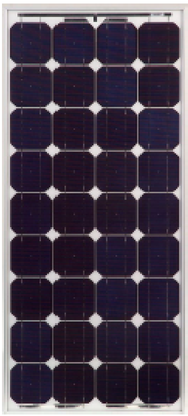
SumSol

Módulo fotovoltaico **Isofotón I-75 S/12**

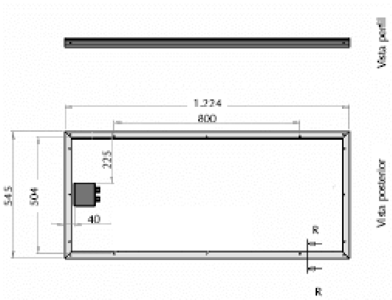
CARACTERÍSTICAS FÍSICAS	
Dimensiones	1.224 x 545 x 39,5 mm
Peso	9 kg
Número de células en serie	36
Número de células en paralelo	1
Tamaño de las células	125 x 125 mm (5")
TONC (800 W/m², 20ºC, AM 1,5, 1 m/s)	47ºC

CARACTERÍSTICAS ELÉCTRICAS	
Tensión nominal (Vn)	12 Vcc
Potencia máxima (Vmax)	75 Wp (±10%)
Corriente de cortocircuito (Isc)	4,67 A
Tensión de circuito abierto (Voc)	21,6 V
Corriente de máxima potencia (Imax)	4,34 A
Tensión de máxima potencia (Vmax)	17,3 V
Voltaje máximo del sistema	760 V

Nota: datos obtenidos en Condiciones Estándar de Medida (CEM): Tª = 25ºC – AM = 1,5 – E = 1.000 W/m²



CARACTERÍSTICAS CONSTRUCTIVAS	
Células	Si monocristalino, texturadas y con capa antirreflexiva.
Contactos	Redundantes, múltiples en cada célula.
Laminado	EVA (etilen-vinil acetato)
Cara frontal	Vidrio templado alta transmisividad
Cara posterior	Protegida con tedlar de varias capas
Marco	Aluminio anonizado
Cajas de conexión	1 x IP-65 con diodo de by-pass
Toma de tierra	Sí
Certificados	CE, IEC-61215, Clase II
Garantía de potencia	10 y 25 años (90 y 80%)



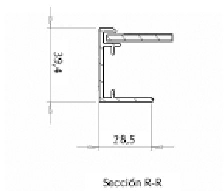


Figure C1 : Photovoltaic Module Isofoton I_75G

Less is More: No Transformer, Lots of Power.

The Powador 2500xi – 5000xi transformerless string inverters.

Inverters without transformers offer a higher degree of efficiency. And KACO specialises in transformerless inverters.

This means: All of our single-phase units in the 00xi series operate with a full bridge without a step-up converter. According to the principle of pulse width modulation, four IGBT power switches emulate the sinusoidal voltage curve of the public power grid. This is also known as an H4 bridge and self-commutated units. However, the input voltage must be greater than the peak line voltage for it to be used. All KACO transformerless inverters are purposely equipped with a wide MPP range of 350 V to 600 V. The no-load voltage is 800 V, which simplifies the work of installers as the installation is laid out. This is also true of the integrated DC disconnector. Screw terminals make connecting to the grid easy. That makes it possible for you to connect installations with several inverters to the grid without additional measures.

All Powador inverters with an output up to and including 8 kW operate with purely passive, silent convection cooling. The heat that is lost is, to a great degree, dissipated via the heat sink on the rear of the unit. The rest of the heat is radiated from the surface of the aluminium housing. No fans, no problems, long life.

Highlights

- Integrated DC disconnector
- Integrated AC/DC-sensitive residual current protection
- Integrated potential-free fault signal
- S0 interface for control of large displays
- Highest degree of efficiency due to purely transformerless technology
- Pure convection cooling
- Easy installation due to mounting plate and housing doors
- MPP controller

Figure C2: Inverter Kaco 5000xi

Powador 5000xi

Electrical data	5000xi
Input variables	
PV max. generator output	6800 W
MPP range	350 V ... 600 V
No-load voltage	800 V
Max. input current	18.0 A
Number of strings	3
Number of MPP controllers	1
Inverse polarity protection	short-circuit diode
Output variables	
Rated output	5500 W
Max. output	6000 W
Supply voltage	acc. to local requirements
Safety cut-out	acc. to local requirements
Rated current	23.9 A
Max. current	26.0 A
Rated frequency	50 Hz / 60 Hz
cos phi	≈ 1
Number of grid phases	1
Distortion factor for rated output	< 3 %
General electrical data	
Max. efficiency	96.3 %
European efficiency	95.3 %
Standby consumption	11 W
Night consumption	0 W
Min. grid feed	approx. 35 W
Switching plan	self-inverted, transformerless
Network monitoring	acc. to local requirements
Mechanical data	
Display	LCD 2 x 16 characters
Control units	2 buttons for display control
Interfaces	RS232 / RS485, S0
Fault signalling relay	potential-free NOC max. 30 V / 1 A
Connections	PCB terminals within the device (max. cross section: 10 mm²) Cable supply via cable connections (DC-connection M16, AC-connection M32)
Ambient temperature	-20 °C ... +60 °C *
Temperature monitoring	> 75 °C temperature-dependent impedance matching > 85 °C cut-out
Cooling	free convection / no fan
Protection class	IP54
Noise emission	< 35 dB (A) (noiseless)
DC-switch	integrated
Casing	Aluminium
H x W x D	600 x 340 x 220 mm
Weight	30 kg

The text and figures reflect the current technical state at the time of printing. Subject to technical changes. Errors and omissions excepted

* Derating at higher temperatures

KACO new energy.

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Figure C3: Inverter Kaco 5000xi

AET

ESTRUCTURA SUNTOP II

El SunTop II se ha desarrollado como sistema universal de montaje sobre tejados inclinados. Este sistema, además de ser especialmente fácil de instalar gracias al uso de los perfiles de aluminio patentados por Conergy, tiene una excelente relación calidad-precio.

1. Módulo
2. Perfil del sistema
3. Portamódulos
4. Escuadra de sujeción para tejado
5. Portamódulos terminal
6. Elemento de unión

Características

- Aplicación flexible. Con SunTop II se pueden instalar sin problemas paneles fotovoltaicos con marco sobre tejados inclinados en construcciones nuevas y antiguas con cualquier tipo de cubierta.
- Montaje rápido. Todos los componentes han sido prefabricados conforme al tipo de módulo elegido y según la configuración del campo de paneles. Su fácil instalación permite un tiempo de motaje breve y un uso mínimo de herramientas. Incluye una ayuda de montaje para la fila inferior de módulos, que facilita su alineación y garantiza un remate recto del campo.
- Gran seguridad. Con SunTop II puede solicitar un presupuesto ajustado a su instalación, satisfaciendo así el requisito para solicitar una licencia de obras. La construcción cumple con ello la norma DIN 1055.
- Gran compatibilidad de módulos. Es posible utilizar prácticamente todos los tipos de módulos con bastidor de diferentes fabricantes.
- Gran capacidad de adaptación. Gracias a la alta flexibilidad de ajuste de los perfiles Conergy, se pueden conseguir campos planos fotovoltaicos sobre cubiertas con superficies irregulares.
- Precios atractivos. Gracias a una fabricación optimizada, se pueden realizar adaptaciones individuales con plazos de entrega muy cortos y precios atractivos.
- Máximo periodo de vida útil. Todos los componentes utilizados se fabrican de aluminio y de acero especial. Su elevada resistencia a la corrosión garantiza una vida útil máxima, ofreciendo asimismo la posibilidad de una reutilización completa.
- Estabilidad garantizada. Conergy Systems ofrece una garantía de 10 años sobre la estabilidad de los materiales utilizados.

Descripción esquemática

a. Módulo fotovoltaico con bastidor
b. Sujetamódulos
c. Riel básico Conergy Systems
d. Gancho de tejado
e. Cabrio
f. Soporte terminal

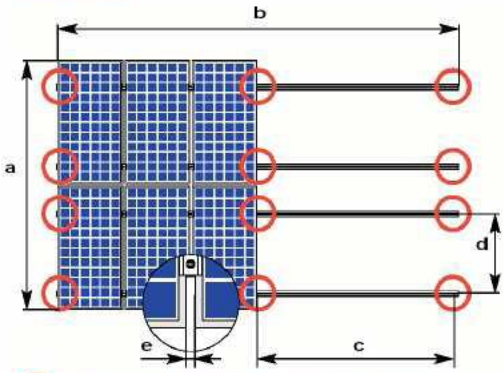
Figure C4: Structure Suntop II

Herramienta/Material

. Llave de boca (tam. 10)
. Llave de boca (tam. 13)
. Carraca (tam. 10)
. Carraca (tam. 13)
. Llave de hexágono interior 6 mm
. Taladradora de acumulador y broca espiral
. Tronzadora a muela para piedra
. Cuerda

a = número de módulos verticales x altura del módulo
b = número de módulos horizontales x (anchura del módulo + e)
c = distancia de las escuadras de sujeción para tejado horizontales = 1,5 m - 2 m
d = distancia de las escuadras de sujeción para tejado verticales = aprox. _a_de altura del módulo en función de la posición de las tejas
e = distancia entre los módulos: 17 mm

Planificación



DATOS TÉCNICOS SUNTOP II (STC II)

Ubicación	Sobre tejado inclinado
Tipo de cubierta	Prácticamente todos los tipos (teja flamenca, plana, pizarra, ripias embetunadas y tejado ondulado)
Inclinación del tejado	Hasta 60° *
Altura máxima del edificio	Hasta 20 m
Carga de nieve	1,4 kN/m2
Paneles fotovoltaicos	Con marco
Alineación	Vertical, (horizontal dependiendo del fabricante)
Extensión del campo de paneles	Libre
Posición del campo de paneles	Libre **
Compensación de desnivel de cubierta	< 40 mm
Distancia entre ganchos	Un máximo de 2000 mm, dependiendo de su ubicación, de la altura del edificio y del panel usado
Norma	Según la norma DIN 1055
Perfiles de apoyo	Acero inoxidable (V2A)
Color	Natural

* Compatible con tejados de teja árabe y teja de hormigón. Cubiertas de eternit ondulado o similar para grandes superficies con una inclinación superior a 15 °C.
** Una instalación en los bordes y en las esquinas de la cubierta aumenta las cargas debidas al viento.

Figure C5 : Structure Suntop II

Nº de hélices	2
Diametro Ø	3.7 m
Material	Fibra de vidrio y carbono
Sistema eléctrico	Generador trifásico de imánes permanentes
Imanes	Neodimio
Voltaje	24, 48
Regulador	Digital
Velocidad de viento para arranque	3,5 m/s
Velocidad de viento para potencia nominal	12 m/s
Velocidad de viento para freno automático	14 m/s
Potencia máxima	3000 W
Frecuencia	50/60 Hz
Índice de protección	IP 65
Altitud máxima de utilización	2000 m
Peso	125

Figure C6:Dates of the Small wind Turbine Inclin 3000 Neo

Figure C7: Inverter Kaco 8000xi

Modelos disponibles

Denominación del modelo	Powador 8000xi
Número de artículo	70213000

Entrada - Data eléctricos

Potencia posible del generador FV	9 kW_p
Rango de tensiones MPP	350 - $600V_{cc}$
Tensión máxima permitida en vacío	$800V_{cc}$

Salida - Datos eléctricos

Potencia CA nominal	$8000W_{ca}$
Potencia CA máxima	$8000W_{ca}$
Tensión de la red Desconexión de seguridad	190...253 V después de 10 min superior a 253 V (según VDE 0126-1-1 y EN 50160) en el plazo de 0,2 s superior a 264 V (VDE 0126-1-1)
Control de la red	Control trifásico redundante según VDE 0126-1-1:2006-02, conforme VDEW
Frecuencia	47,5 ... 50,2 Hz
Control de frecuencia integrado	Sí, según VDE 0126-1-1:2006-02
Protección integrada contra corrientes de defecto sensible a corriente universal	Sí, según VDE 0126-1-1:2006-02

Inversos - Datos eléctricos

Eficiencia máxima	96,2%
Eficiencia europea	95,4%
Concepción del circuito	Rectificador monofásico de onda completa en tecnología IGBT
Frecuencia de reloj	18 kHz

Inversor - Datos mecánicos y técnicos

Indicadores ópticos	LED 1 Generador fotovoltaico activo (verde) LED 2 Alimentación de la red activa (verde) LED 3 Fallo (rojo) Display LC (2 x 16 caracteres)
Elementos de manejo	2 botones para manejo del display
Interfaces	RS232 / RS485 (seleccionables mediante botones) Interfaz S0
Aviso de fallos	Contacto libre de potencial
Conexiones	Conexión CA mediante bornes Conexión CC mediante conectores
Temperatura ambiental	-20°C ... +40°C
Refrigeración	Convección
Protección	IP54 según EN 60529:1991 + A1:2000
Dimensiones (ancho x largo x alto)	340 x 200 x 810 mm
Peso	38 kg

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e-Mail: info@kaco-geraetetechnik.de
www.kaco-geraetetechnik.de

La siguiente generación de inversores sin transformador:

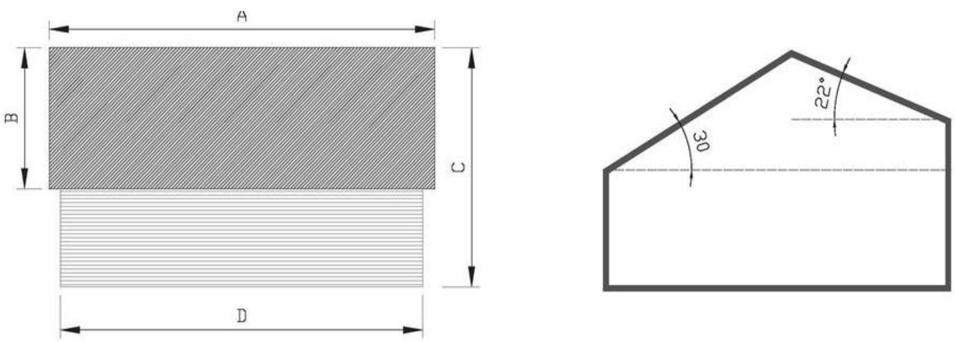
La fuerza concentrada, compacto, potente y altamente innovador. El nuevo Powador 8000xi con fusibles de protección de ramales integrados y una potencia máxima de 8000 W_{CA} puede emplearse en instalaciones fotovoltaicas con una potencia de generador de hasta 9000 W_p. El punto especial: el interruptor de CC se halla ya integrado. También este nuevo aparato ha sido mejorado por nuestros expertos de KACO. Como todos los aparatos sin transformador de KACO, también éste contiene un control trifásico redundante, incluyendo una protección contra corrientes de defecto sensible a corriente universal. La incorporación del control trifásico en la norma VDE 0126-1-1:2006-02 es una clara confirmación de la filosofía de KACO: "máxima fiabilidad y estabilidad de funcionamiento para beneficio del cliente". El control de la red está adaptado a las exigencias de la norma y, con ello, los aparatos KACO pueden conectarse a la red sin necesidad de otras medidas incluso en instalaciones con varios inversores. Gracias a la posibilidad de selección del modo de interfaz es usted flexible también en la elección de accesorios y en el registro y evaluación de datos. Usted puede ajustar in situ qué protocolo de interfaz (RS232 o bien RS485) debe utilizarse. Además se ha incluido un contacto de aviso de fallos libre de potencial. El diseño de la carcasa sirve para exponer también estas nuevas características del producto de cara al exterior. Por supuesto, la estabilidad de funcionamiento y la fiabilidad del aparato se mantienen. Mediante el sistema de protección IP54 el aparato es adecuado también por supuesto para unas condiciones ambientales desfavorables. En cuanto a garantía y servicio tampoco hay soluciones intermedias para KACO. La garantía de 7 años (prolongable opcionalmente a 11 años) sienta nuevas bases.

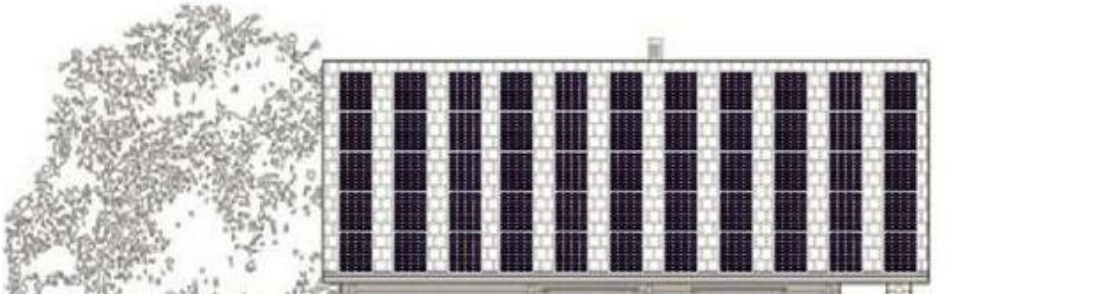
Su comerciante

31000298-01-070811

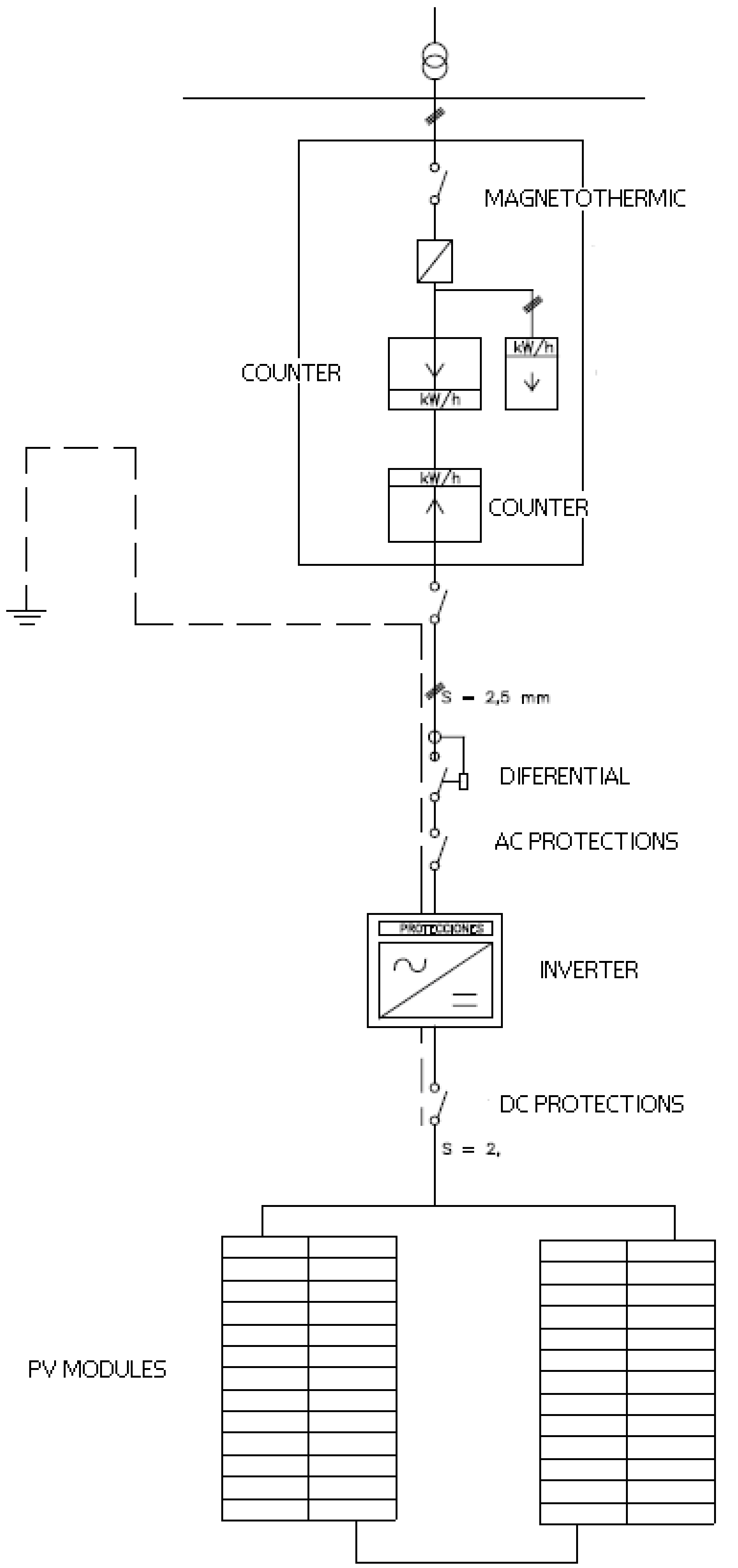
Figure C8: Inverter Kaco 8000xi

A = 9
B = 3,3
C = 6
D = 8

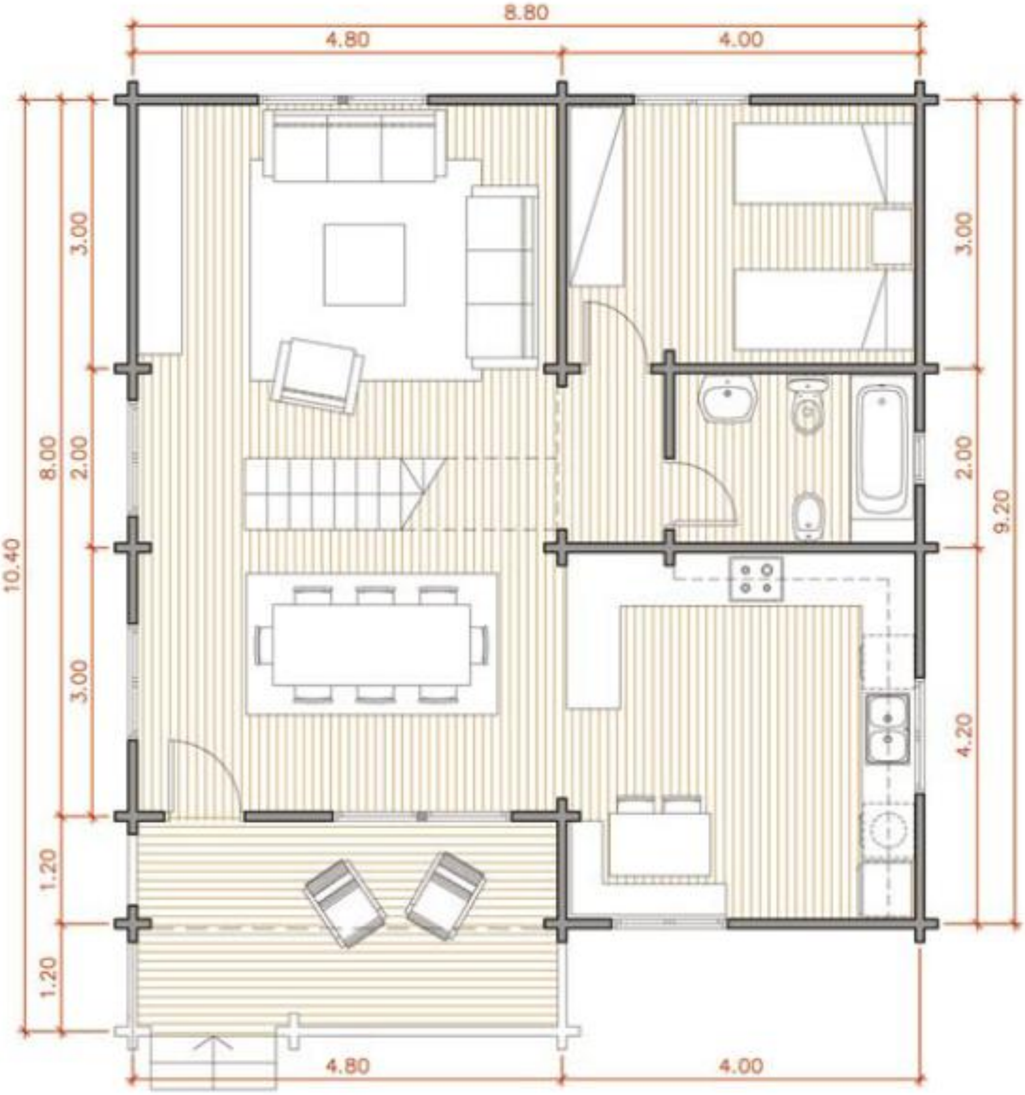


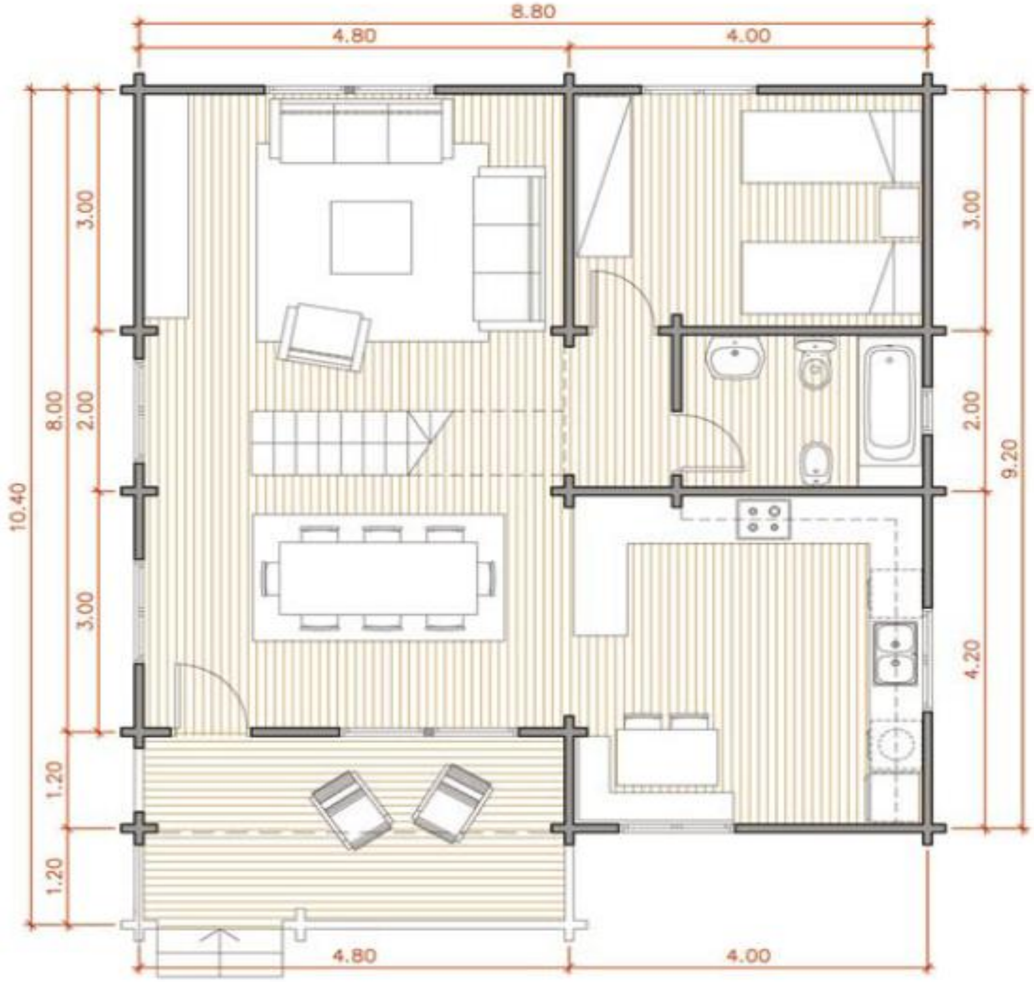


FACHAD LATERAL


MAGNETOTHERMIC
COUNTER
kW/h
kW/h
kW/h
COUNTER
S = 2,5 mm
DIFERENTIAL
AC PROTECTIONS
PROTECCIONES
INVERTER
DC PROTECTIONS
S = 2,
PV MODULES

FACHAD LATERAL


8.80
4.80
4.00
3.00
2.00
3.00
8.00
10.40
1.20
1.20
3.00
2.00
9.20
4.20
4.80
4.00


8.80
4.80
4.00
3.00
8.00
2.00
10.40
3.00
1.20
1.20
3.00
2.00
9.20
4.20
4.80
4.00