JADE HOCHSCHULE

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CAREER FINAL PROJECT

Economic profitability of photovoltaic panels in a passive house

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1. Important data.

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Semester: Summer semester

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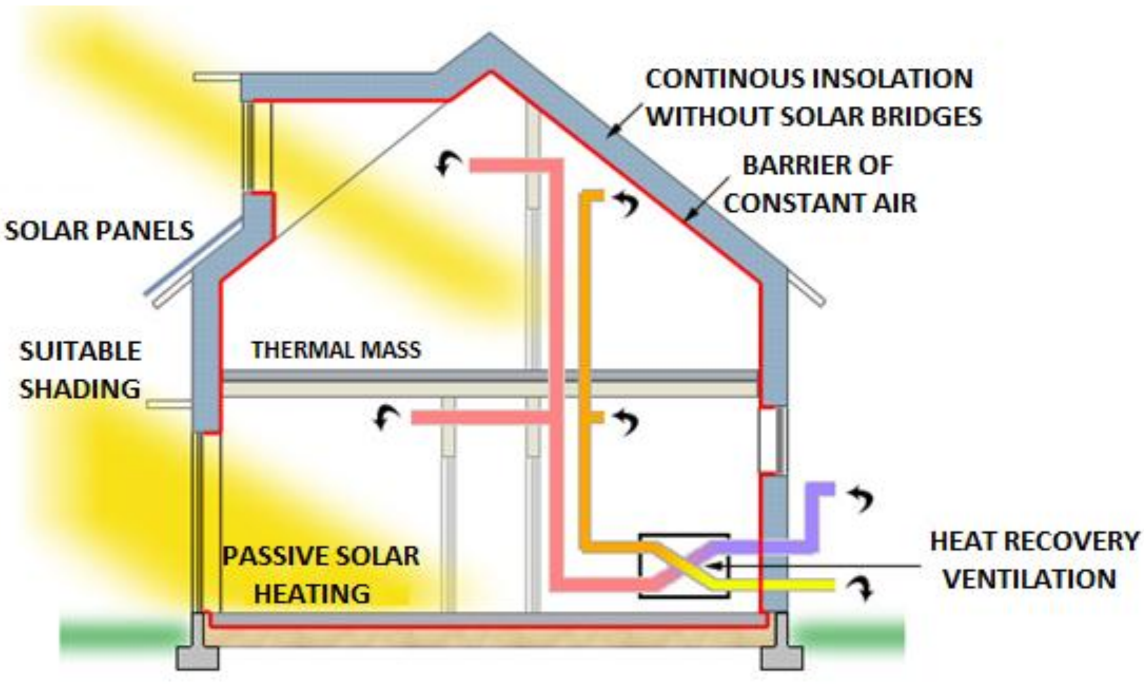
Date: August, 31st 2012

2. Introduction.

The following project is based on the construction of a passive house in the Jade Hochshule University of Oldenburg. The objective of the project is if it works out profitable to supply the house that we are going to construct only with the energy of the photovoltaic panels, without having to buy power from the net. To introduce the topic we will explain what it is a passive house.

A **passive house** is a house designed and executed to have the least possible energy expenditure. Most of the energy of the house is spent on creating a pleasant atmosphere. And the inside, providing a warming temperature in winter and a cooling one in summer.

The first step to obtain this low energetic consumption aim is the design. By adopting passive measures it is possible to save up to 90 % in the invoice of energy used to condition the house. It is obtained using: good thermal isolations, avoiding thermal bridges, ventilating under controlled conditions and using interchangers in the net of ventilation, with a few carpentries and glasses calculated for the minimal possible losses, adopting appropriate shading mechanisms and the design of site-specific sun exposure.



Picture 1

In this picture are explained the variations of ventilation offered to maintain the temperature inside the house warm in summer and cool in summer.

These houses designed in Germany, are hermetically closed (although they have windows which can be opened to leave in case of fire) and they renew the air through a system that manages to keep the heat inside the house. Therefore, the passive house may lack boiler, even in Germany, It preserves the heat received from the sun and from the human beings which inhabit it. Provided that it has been developed for cold climates, many people doubt his application in the Mediterranean climate.

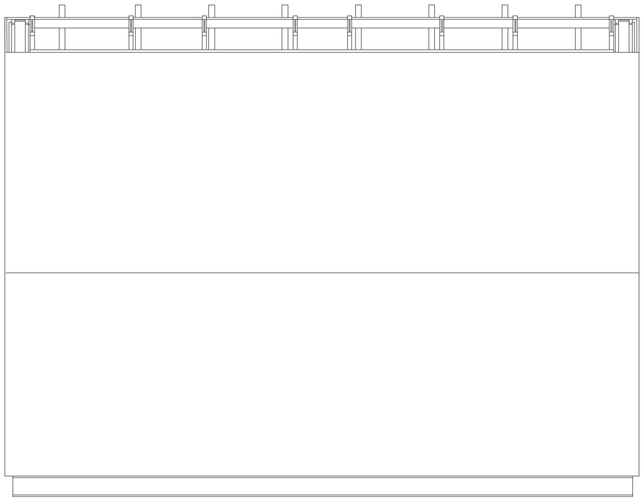
Several studies revealed that the standard passive house has been developed in Germany and Sweden, which are northern and which have a different climate from Spain. But, as Wolfgang Schneider's has demonstrated in his study "Passive Houses in South West Europe ": in Seville (one of the warmest cities of Spain) the demand of heating during the winter's months is higher than the demand of refrigeration during the summer. This study justifies that it is necessary to be protected by thermal isolation not only from the cold, but also from the heat, especially the constructive elements most exposed to the Sun during the summer. Therefore we could say that it is viable to build a passive house in terms of energy savings.

3. Description of the house.

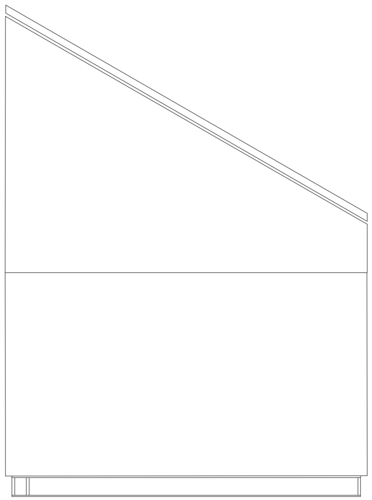
Once clarified what is a passive house, we are going to do the study of the house that we try to construct in the Jade Hochshule. This house will be used as a model so that those interested could observe the functioning of it and as a meeting or conference hall. For this reason the proportions of the house are not excessively larger. In the following planes dimensions of the house will be detailed.

3.1 Planes

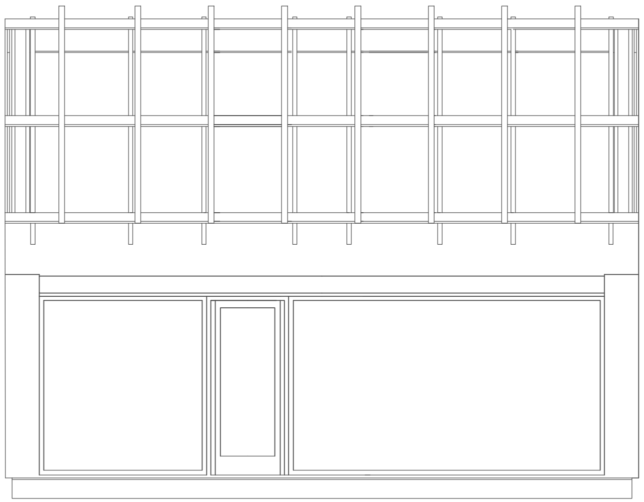
PLANES E: 1/100



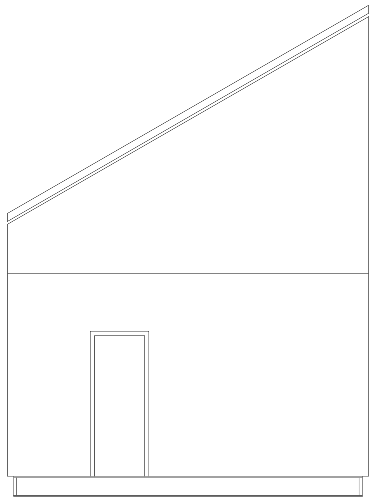
NORTH



WEST

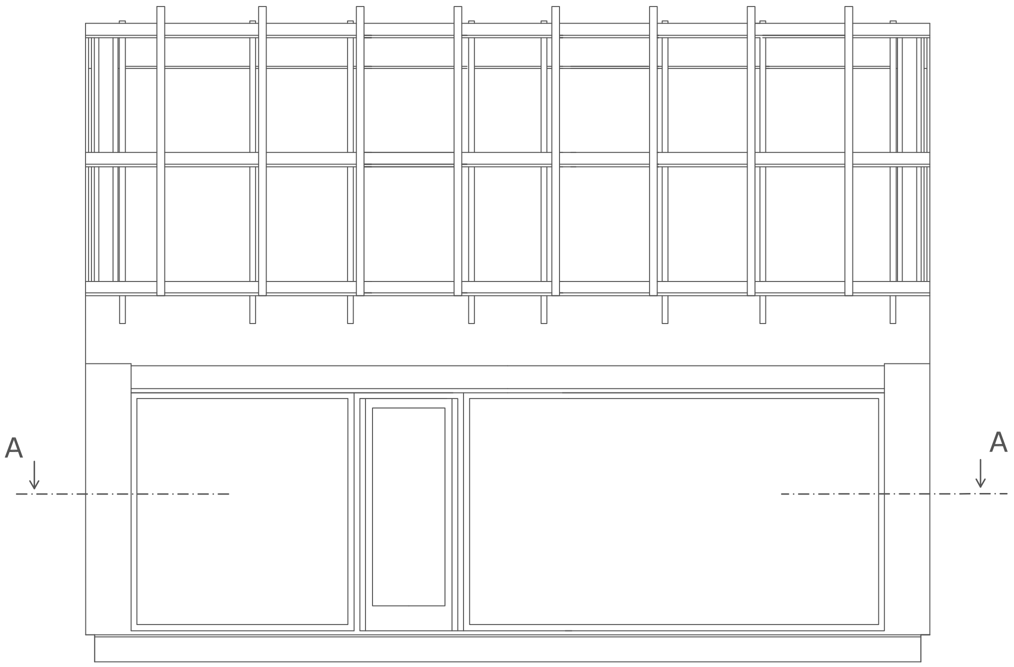


FRONT VIEW

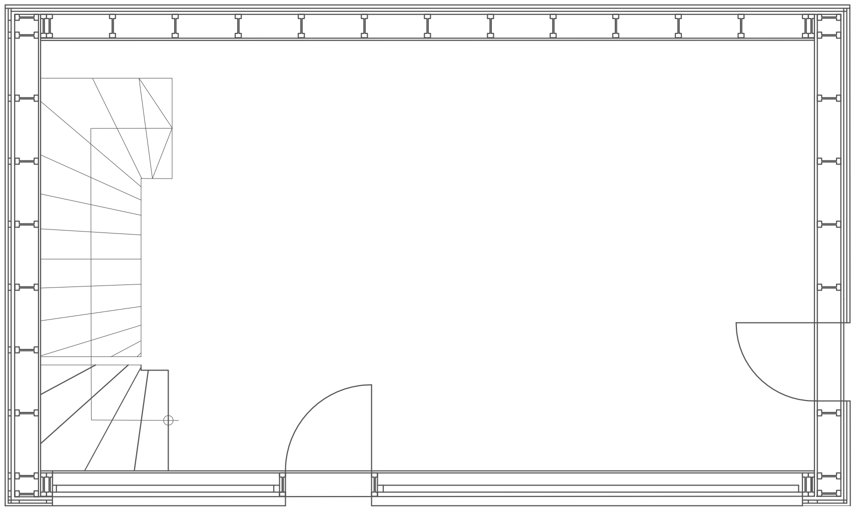


EAST

PLANES E: 1/75

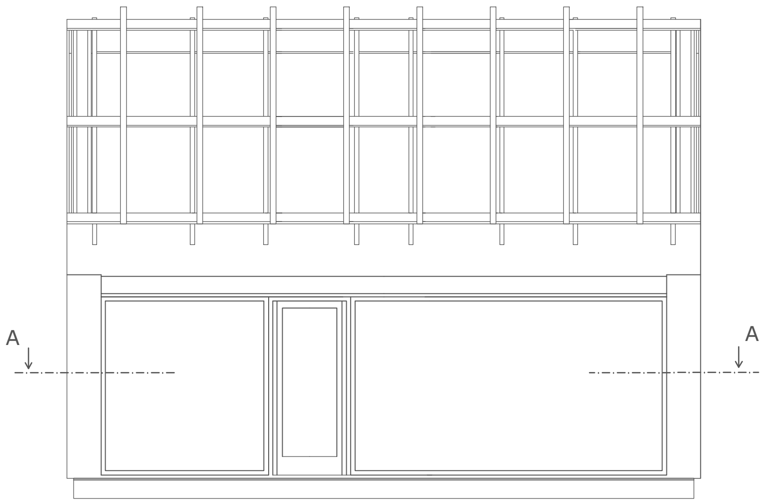


FRONT VIEW

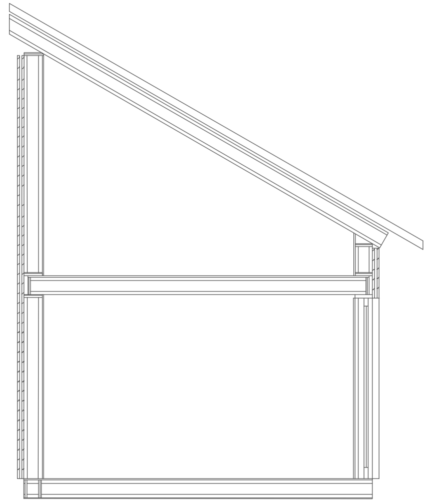


TOP VIEW A-A

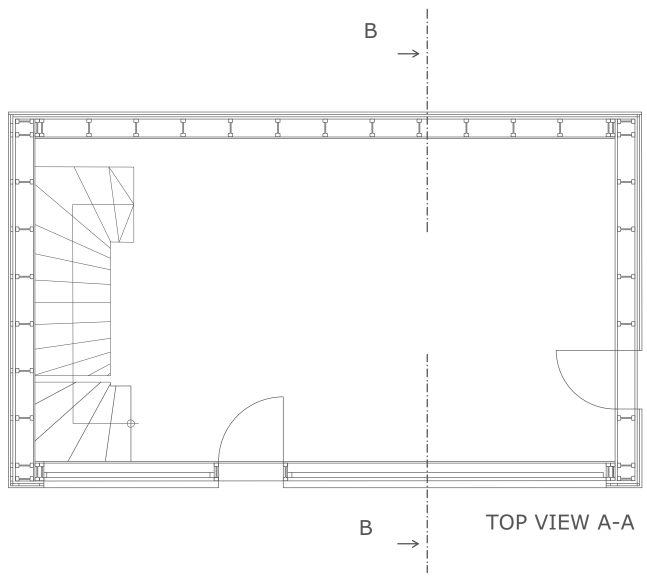
PLANES E: 1/100



FRONT VIEW



SECTION B-B



TOP VIEW A-A

3.2 Photos.

In these images the model is realized to scale 1:5 of the house that is going to be constructed.

Picture 2

The passive house would have two floors, since we have clarified in the planes. The front would be a glass through which the sun shall give light to all rooms *(picture 2).*

Picture 3

The model has been photovoltaic panels like is going to put it around the house´s roof *(picture 3).*

In these pictures (4-5) shows the house from different points of view. The model gives the project a visualization of how the house will look when it will be completed.

Picture 4

Picture 5

4. Objective of the project.

The aims of the project are the following ones:

- The study of the profitability of putting photovoltaic panels. The energy we get from them can be sold to the net and it is profitable for own energetic consumption.
- Know the energetic demand used by the house in summer and in winter, and do researches to know if it is possible abstain from using the energy from the net, and only supply us with the solar power placed on the house's roof.
- Amortization of photovoltaic panels, calculating the cost of them and the loan that we have to request.
- As mentioned above, passive houses are designed for cold climates but could be viable in Mediterranean climate, so we will do the comparison placing the house in Spain to observe the climatic differences.
- The study of the profitability of putting photovoltaic panels in the same passive house situated in Spain.

5. Differences in elevation and temperature between Germany and Spain.

To perform all these steps, first we are going to make a study of the solar elevation difference between the two countries. This information is very important, in order to the solar panel fulfils its function; it needs to have the correct inclination for be more exposed to the Sun.

Furthermore the following graphs show clearly the solar elevation differences between the two countries in both winter and summer. In this section the temperature differences besides the elevation will be also detailed.

In Spain, due to its sunny climate, the panels extract major performance for the high temperature and uniformity.

But this cannot occur in Germany. As discussed in later sections, we will do a research about the possibility to use the solar power instead of requiring electricity from the net and stock up ourselves.

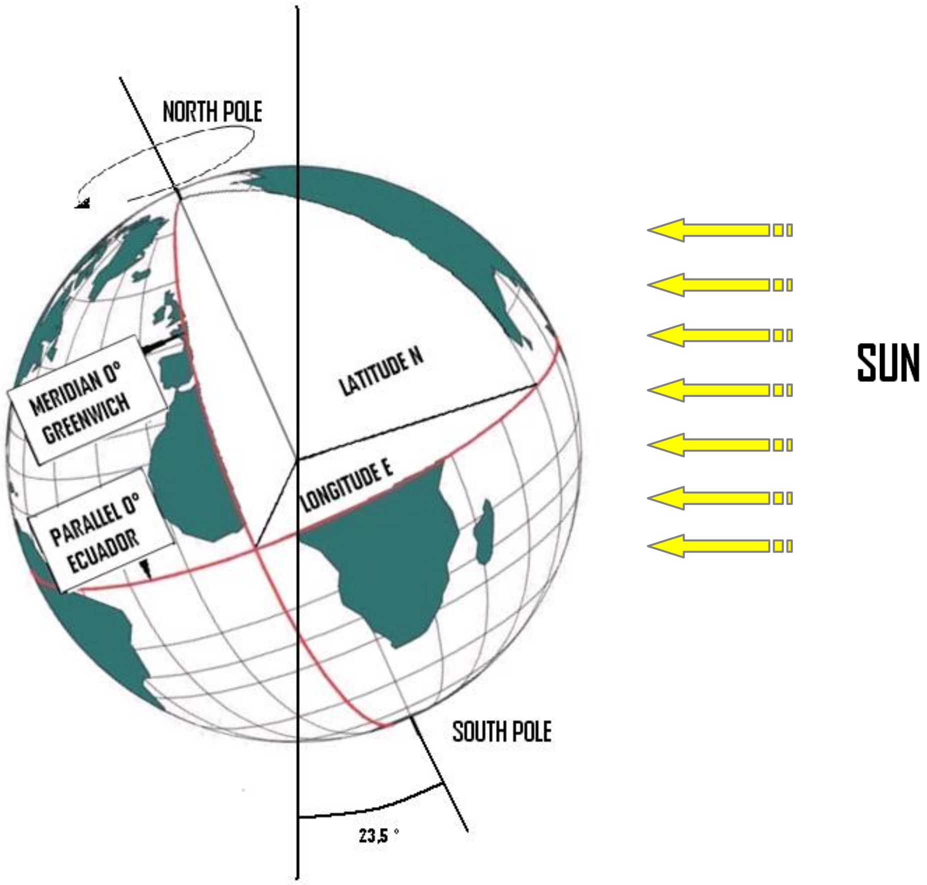
Previously we will briefly explain the position of the earth from the sun through a photo representing the parameters needed to understand the later graphs. So in photo 3 it is observed: the length, the latitude, the meridian of Greenwich, the equator, the direction that turns the land, the angle of inclination of the earth and where the sun is placed.

The following data indicates the geographical coordinates of Spain and Germany, and more in detail the coordinates of Oldenburg and Valencia.

Oldenburg's position is: Latitude **53° 10' 0 N** Longitude **8° 12' 0 E**

Valencia's position is: Latitude **39° 28' 56.53 N** Longitude **-0° 20' 36.8 O**

Considering the position of both cities, it is observed the day length, and the difference of temperature in each city. In order to clarify the information of the figure, Germany is placed to latitude of 53 ° and the sun reaches it beyond to Spain placed to lower latitude.



Picture 6

The temperature in Spain is higher and the day shorter. The detailed study will help us to notice the differences with higher accuracy. Hereunder graphs based on the climate and the solar elevation will be explained (This information is relevant for the installation of the panels).

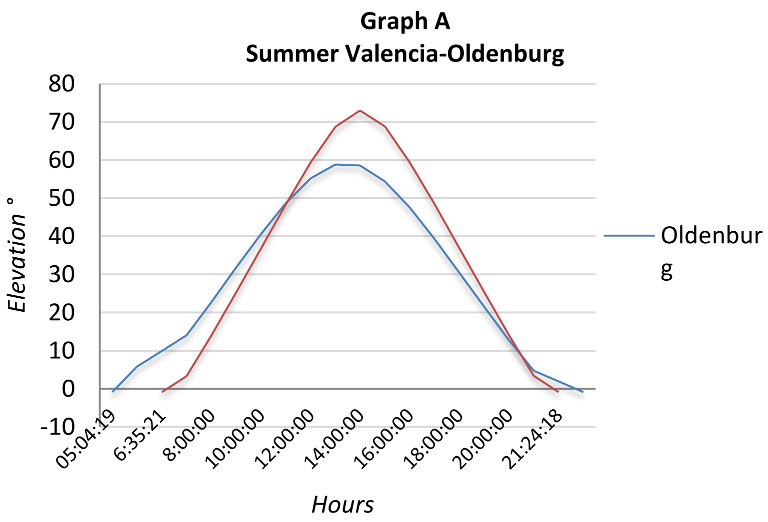
5.1 Graphs of the solar elevation in both countries per days.

The information in the table below shows the solar elevation at the same day in Oldenburg and in Valencia. The graph on the right shows clearly the elevation difference between the two cities.

In *Graph A* it is observed that although the sun's elevation is higher in Spain the day is longer in Oldenburg. We will have much more light power in Valencia but on the other hand fewer hours of sunlight.

Summer		
Hours	**Oldenburg**	**Valencia**
5:04:19	-0,83	
6:00:00	5,88	
6:35:21	9,98	-0,83
7:00:00	14,07	3,34
8:00:00	22,82	14,05
9:00:00	31,81	25,3
10:00:00	40,62	36,83
11:00:00	48,71	48,34
12:00:00	55,21	59,38
13:00:00	58,87	68,73
14:00:00	58,56	73,01
15:00:00	54,39	68,79
16:00:00	47,57	59,45
17:00:00	39,33	48,43
18:00:00	30,47	36,92
19:00:00	21,51	25,4
20:00:00	12,83	14,15
21:00:00	4,76	3,45
21:25:18	1,96	-0,83
21:47:30	-0,83	

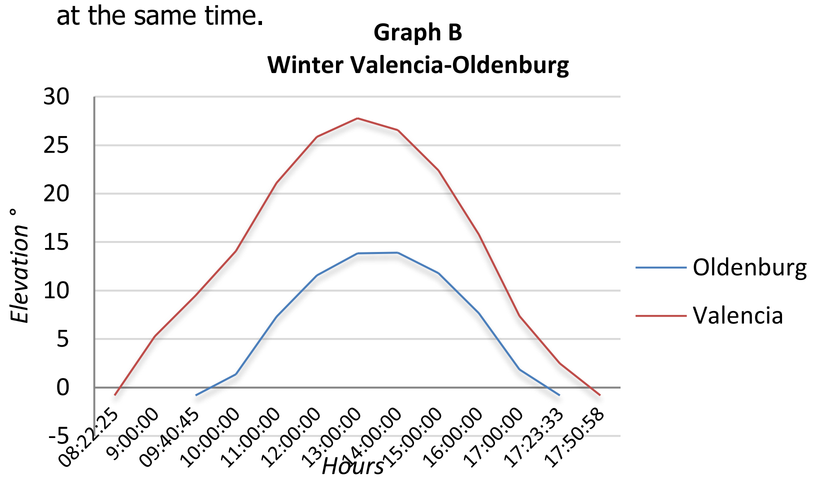
Table 1



In *graph B* it is observed that a winter days in Oldenburg are shorter than in Valencia, furthermore the inclination of the earth influences the position of the sun, so the sunbeams are much more inclined. In Valencia, during winter there are more hours of light so therefore more power from sunlight at the same time.

Winter		
Hours	**Oldenburg**	**Valencia**
8:22:25		-0,833
9:00:00		5,29
9:40:45	-0,833	9,46
10:00:00	1,35	14,05
11:00:00	7,28	21,1
12:00:00	11,54	25,85
13:00:00	13,81	27,75
14:00:00	13,89	26,54
15:00:00	11,77	22,38
16:00:00	7,64	15,79
17:00:00	1,83	7,36
17:23:33	-0,833	2,46
17:50:58		-0,833

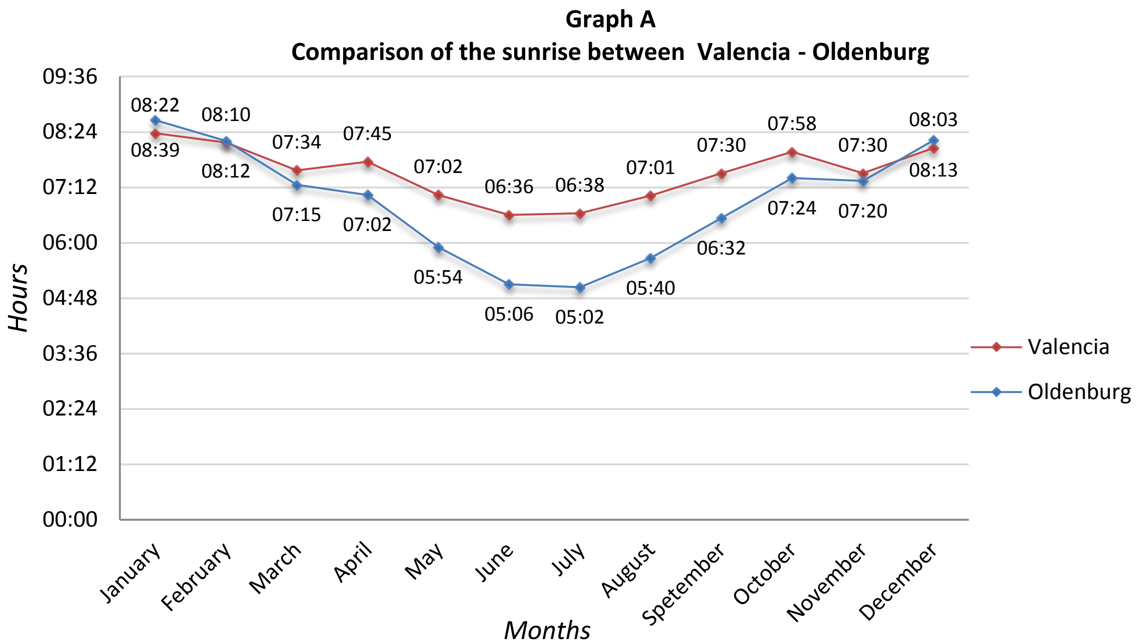
Table 2



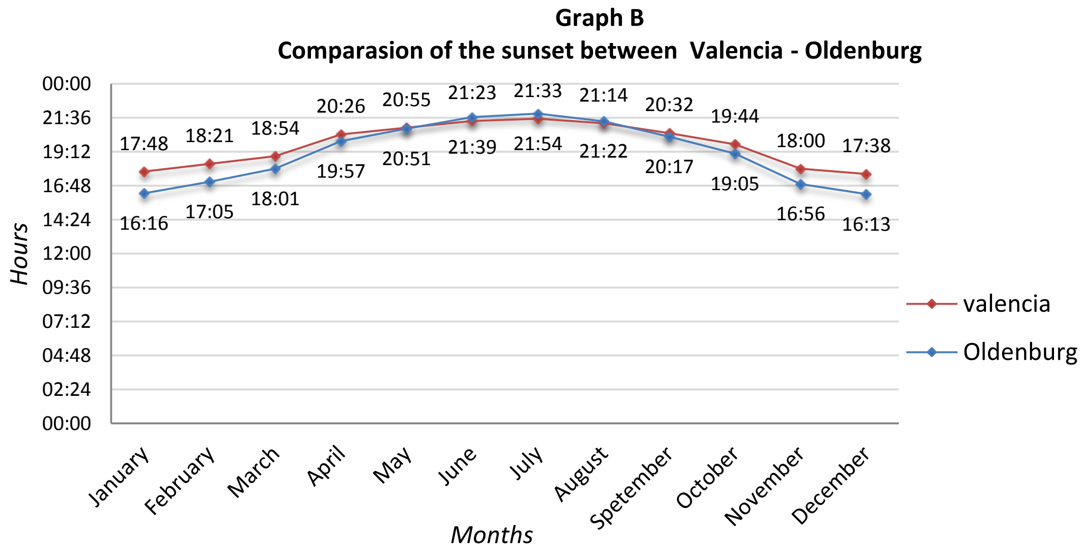
5.2 Graphs of the solar elevation per month.

5.2.1. Graphs of hourly differences of dawns per month.

The *graph A* represents the dawning hour the 1st of every month in both cities. The more significant thing that we can observe is that in June and July the hourly difference between dawns is of 1,30h. Therefore the hours of Oldenburg's solar light will be major due to the day length.

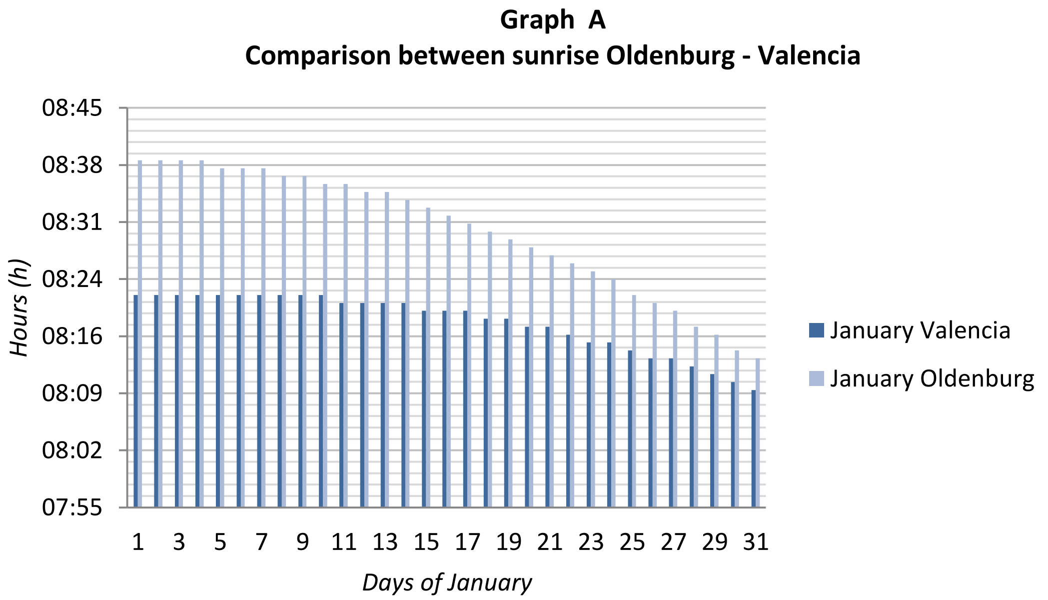


The *graph B* represents the hour of sunset the 1st of every month in both cities. Here the most significant aspect is that in December and January the hourly difference between sunsets is about 1,30h approximately, which means that in these months the day in Oldenburg is shorter and has fewer hours of solar light.

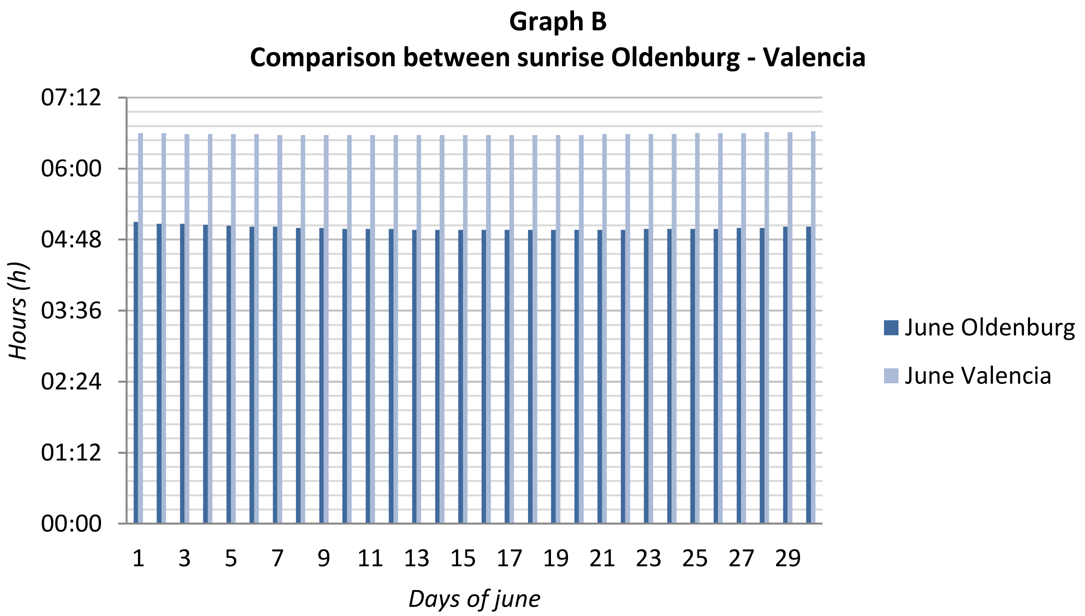


5.2.2 Graphs of hourly differences of dawns per days.

The *graph A* is focused on the dawn and its hourly differences during the month of January. It is possible to observe that at the beginning of the month the hourly difference is bigger than at the end. It is important emphasise that in Oldenburg the hourly difference between the begging and the end of the month is almost about 20 minutes. However in Spain its difference is scarcely a few minutes.



The *graph B* represents the dawn and the hourly differences during the month of June.
The hourly difference between both cities is constant, approximately 1,30h of difference.



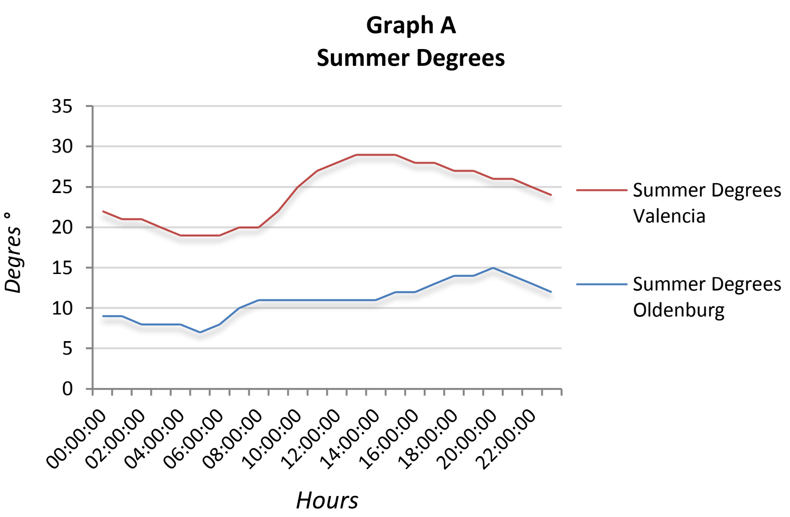
5.3 Graphs of the difference of temperatures between both cities.

5.3.1 Study of the difference of climates of both cities per days.

The *graph A* represents the temperature degrees found in both cities in a particular day (June 4, 2012). It is relevant that the difference of temperature between the two cities is higher than 10 degrees. The information is very relative since it is not possible study the difference of the temperature per days due to the considerable changes from one day to another.

Summer Degrees		
Hours	Valencia	Oldenburg
0:00:00	22	9
1:00:00	21	9
2:00:00	21	8
3:00:00	20	8
4:00:00	19	8
5:00:00	19	7
6:00:00	19	8
7:00:00	20	10
8:00:00	20	11
9:00:00	22	11
10:00:00	25	11
11:00:00	27	11
12:00:00	28	11
13:00:00	29	11
14:00:00	29	11
15:00:00	29	12
16:00:00	28	12
17:00:00	28	13
18:00:00	27	14
19:00:00	27	14
20:00:00	26	15
21:00:00	26	14
22:00:00	25	13
23:00:00	24	12

Table 3

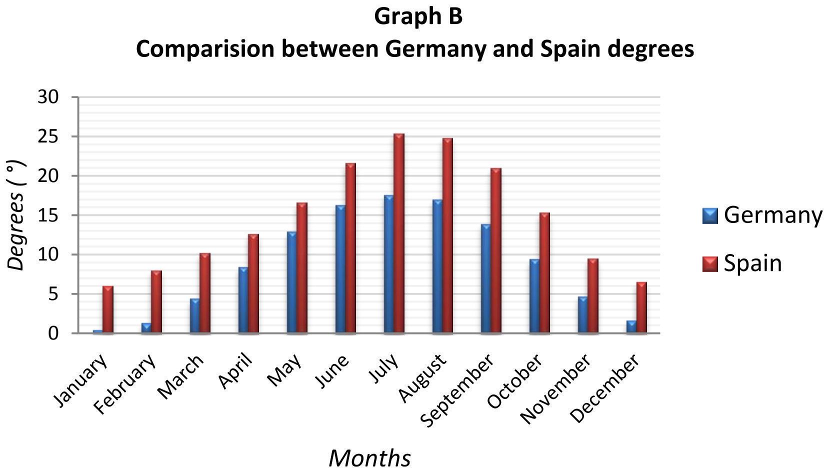


5.3.2 Study of the difference of climates of both countries per month.

In the *graph B* it is observed the difference of almost 10 degrees of temperature every month. The temperatures represented in the table are indicative due to the variation of the temperatures from one day to another. In Spain the consumption of electricity to warm the house is lower than Germany and it is used from November to February. On the other hand the coolest temperatures in Germany make essential the use of energy during two more months than Spain, also in October and March.

Months	Countries	
	Germany	Spain
January	0,4	6
February	1,3	8
March	4,4	10,2
April	8,4	12,6
May	12,9	16,6
June	16,3	21,6
July	17,6	25,4
August	17	24,8
September	13,9	21
October	9,4	15,3
November	4,7	9,5
December	1,6	6,5

Table 4

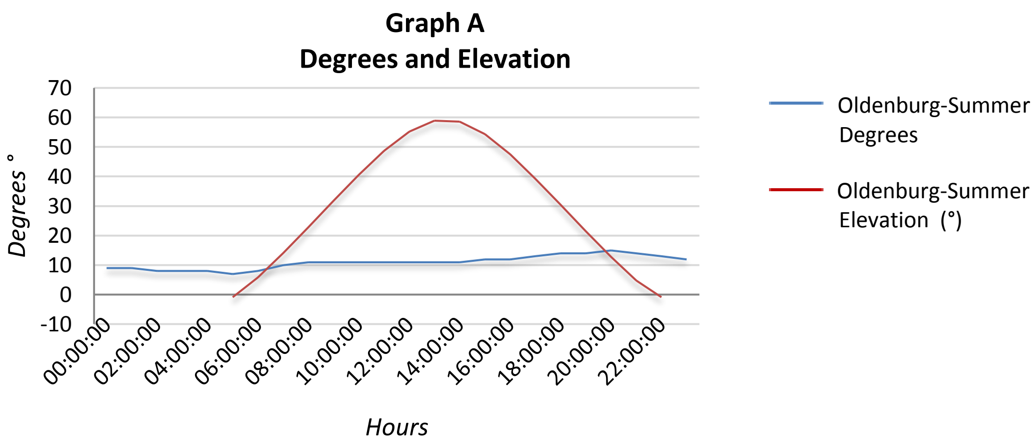


The passive houses must keep the temperature constant. It must be kept between 20 and 21 degrees.

5.4 Study of the comparison of the elevation and temperature of both countries.

5.4.1 Comparative graph of elevation of the sun and temperature of Oldenburg.

In the *graph A* we can observe that in highest peak of solar elevation, which is when the photovoltaic panel absorbs the sunlight, in Oldenburg the temperature reaches 11 degrees. Therefore with an elevation of 60 ° approximately the temperature is 11 degrees. As temperature is constant the range of the sun with major solar elevation is between 11 and 13 degrees of temperature.

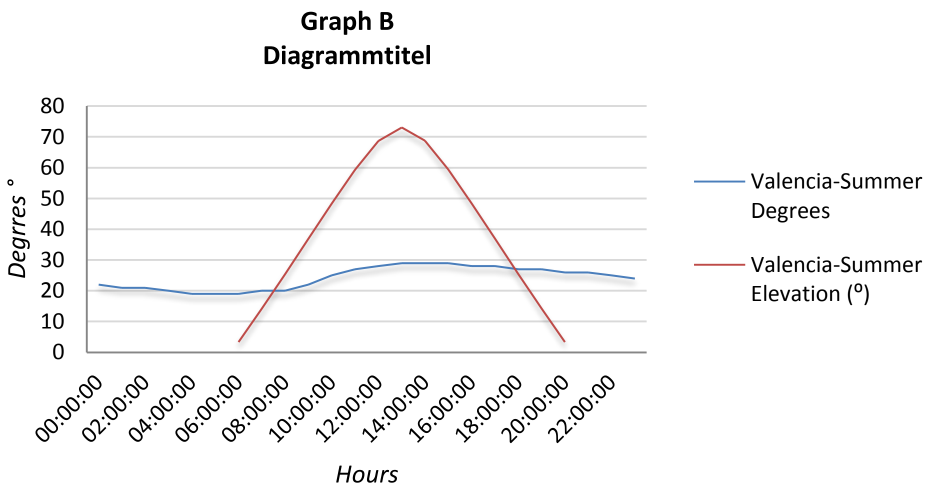


It needs to be taken into account that the data gathered in this graph is based on a particular day. Depending on the day temperatures can be higher or lower.

5.4.2 Comparative graph of elevation of the sun and temperature of Valencia.

The graph A shows that in the moment of more elevation of the Sun, which is when the photovoltaic panel absorbs more sunlight, the temperature in Valencia reaches from 25 to 29 degrees from 11 a.m. until 19 p.m.

It means that with an elevation of 73 degrees, the temperature is 29 degrees. In Valencia, although the day is shorter, the elevation of the sun is higher, so it has from 25 to 30 degrees more than Oldenburg.



As it has been said previously, the information of the graph is relative because the temperature degrees can change from one day to another. Also it needs to be taken into consideration that the temperature between north and south Spain are different, mainly because temperatures are colder in the northern regions.

6. Amortization of photovoltaic panels.

This section will be focused on the amortization which means the profitability of the solar panels installation and on the possibility to sell to the net the resulting power or use it for our own consumption.

The relevant information that has to be known is provided by the contracting company ("LICHTKRAFT NORD solar Energy"). The information is based on: the performance of the panels, the wattage produced and its cost.

The information provided by the company is the following:

- Cost of the photovoltaic panels: 12.000 Euros (estimated price)
- Performance of the panels: 800 KWh/year
- Nominal power installed: 5,760 kW

This information helps us to calculate the quantity of energy that the solar panels produce per year. Moreover, if we multiply the performance of the panels by the nominal power installed the result is 4.608,00 kwatts per year.

If in Germany the costs of the energy is *0,1994 Euros/kWh*, the result per year expecting that all the energy from the panels are sold, reaches *918,84 Euros* per year.

Assuming that we have *6000 euros* for paying the panels, and another 6000 euros from a bank 15 years loan, the cost would be *484,60 Euros* per year during 15 years.

Therefore during the first 15 years (duration of the loan) from the installation of the panels we would obtain *434,24 Euros* per year considering that all the energy obtained from the panels has being sold by to the net. After the first 15 years we would obtain *918,84 Euros* per year. What it demonstrates that if the panels work properly during 6 years after the end of the loan payment, we would recoup the money invested on the panels.

It is important to have money in advance to install the panels in the house or it would be impossible to make the payment.

Everything explained previously can be observed more detailed in the following table:

The information for the elaboration of the table is the following:

- Production of the panels: 800 kWh/year
- Installed power: 5,760 kW
- Price of the energy: 0,1994 €/ kWh
- Cost of the panel: 12.000 Euros
- Down payment: 6000 Euros
- Loan: 6000 Euros
- Interest rate: 0,025
- Duration loan: 15 years
- Annuity: 484,60 Euros

With the information above the table would be:

Year	Electricity(kW)	Turnover €	Financing €	Cash Flow €
0				-6.000,00
1	4.608,00	918,84	484,60	434,24
2	4.608,00	918,84	484,60	434,24
3	4.608,00	918,84	484,60	434,24
4	4.608,00	918,84	484,60	434,24
5	4.608,00	918,84	484,60	434,24
6	4.608,00	918,84	484,60	434,24
7	4.608,00	918,84	484,60	434,24
8	4.608,00	918,84	484,60	434,24
9	4.608,00	918,84	484,60	434,24
10	4.608,00	918,84	484,60	434,24
11	4.608,00	918,84	484,60	434,24
12	4.608,00	918,84	484,60	434,24
13	4.608,00	918,84	484,60	434,24
14	4.608,00	918,84	484,60	434,24
15	4.608,00	918,84	484,60	434,24
16	4.608,00	918,84	0,00	918,84
17	4.608,00	918,84	0,00	918,84
18	4.608,00	918,84	0,00	918,84
19	4.608,00	918,84	0,00	918,84
20	4.608,00	918,84	0,00	918,84

Table 5

The result of the table demonstrates as it has been shown before that the installation of the panels is impossible without money in advance.

Using the previous information but changing the quantity of money of the loan the result would be the following:

- Production of the panels: 800 kWh/year
- Installed power: 5,760 kW
- Price of the energy: 0,1994 €/ kWh
- Cost of the panel: 12.000 Euros
- Down payment: 0 Euros
- Loan: 12000 Euros
- Interest rate: 0,025
- Duration loan: 15 years
- Annuity: 969,20 Euros

The table with the data above:

Year	Electricity (kW)	Turnover €	Costs of the panel €	Cash Flow €
0				0,00
1	4.608,00	918,84	969,20	-50,36
2	4.608,00	918,84	969,20	-50,36
3	4.608,00	918,84	969,20	-50,36
4	4.608,00	918,84	969,20	-50,36
5	4.608,00	918,84	969,20	-50,36
6	4.608,00	918,84	969,20	-50,36
7	4.608,00	918,84	969,20	-50,36
8	4.608,00	918,84	969,20	-50,36
9	4.608,00	918,84	969,20	-50,36
10	4.608,00	918,84	969,20	-50,36
11	4.608,00	918,84	969,20	-50,36
12	4.608,00	918,84	969,20	-50,36
13	4.608,00	918,84	969,20	-50,36
14	4.608,00	918,84	969,20	-50,36
15	4.608,00	918,84	969,20	-50,36
16	4.608,00	918,84	0,00	918,84
17	4.608,00	918,84	0,00	918,84
18	4.608,00	918,84	0,00	918,84
19	4.608,00	918,84	0,00	918,84
20	4.608,00	918,84	0,00	918,84

Table 6

It shows that during the 15 years of the loan, paying with the money that we obtain from selling the electricity to the net, it is not enough for the payment of the PV. This is the main reason why all the numbers are negative.

Though with the money earned in a year from selling the electricity to the network, it is possible to pay our every month consumption, the bank would not provide the loan because it does not trust the personal financial situation. If this happens the solution is to find another long-term loan or a loan with the interest lower.

7. Energy efficiency of the photovoltaic panels.

In this section we will calculate the purchase of energy to the net in the winter's months. During the summer the excess of energy will allow us to sell the power to the net obtaining profitably.

7.1 Solar factor of the photovoltaic panels per month.

The solar factor is the quantity of energy obtained by the panels exposed at sunny hours during different months. Depending on the month the panels will be exposed more or less sunny hours.

These are the percentages of the panel expositions by months:

- January → 2,20 %
- February → 4,10 %
- March → 7,50 %
- April → 11,70 %
- May → 14,80 %
- June → 13,80 %
- July → 14,30 %
- August → 12,80 %
- September → 8,90 %
- October → 5,90 %
- November → 2,80 %
- December → 1,20 %

7.2 Energy panels provide month per month.

With the information of the solar factor per months and calculating the electricity that the panels provide us per year it is possible to calculate the energy provided month per month.

- Total solar panel electricity produced per year: 4.608,00 kW
- Solar factor per months:

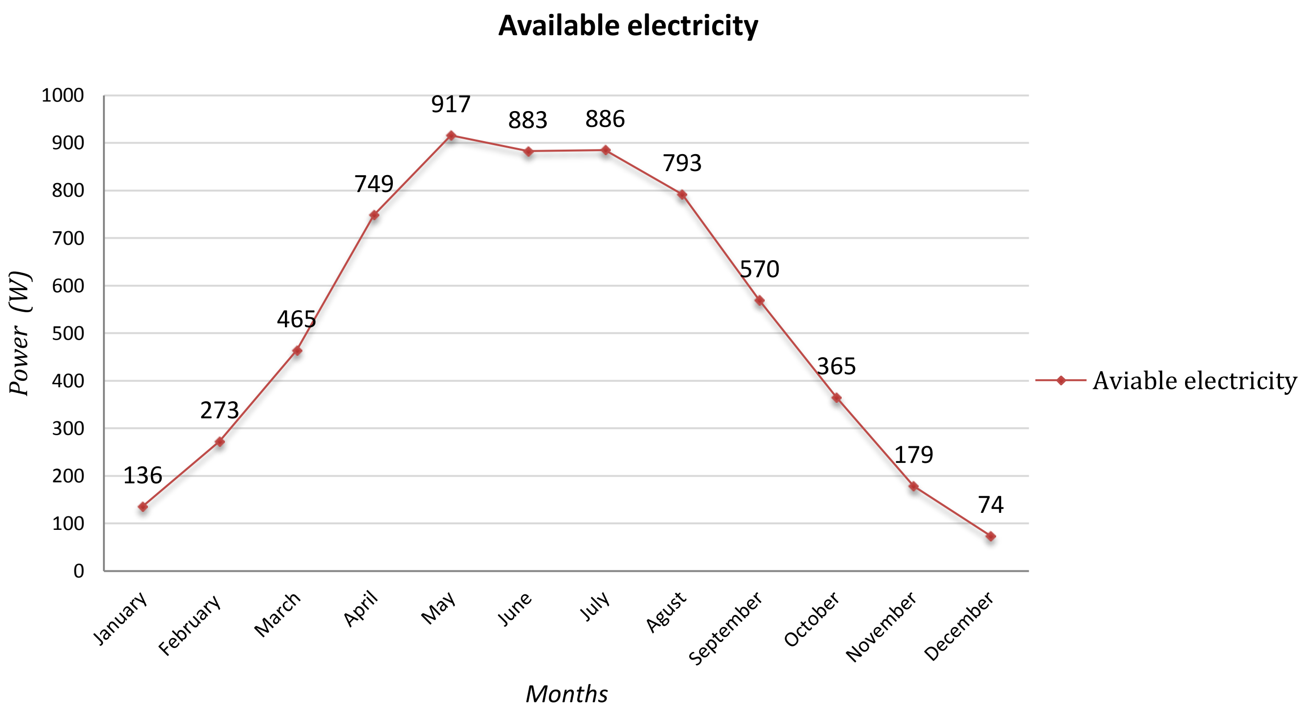
  - January → 2,20 % x 4.608,00 = 101,38 kWh
  - February → 4,10 % x 4.608,00 = 188,93 kWh
  - March → 7,50 % x 4.608,00 = 345,60 kWh
  - April → 11,70 % x 4.608,00 = 539,14 kWh
  - May → 14,80 % x 4.608,00 = 681,98 kWh
  - June → 13,80 % x 4.608,00 = 635,90 kWh
  - July → 14,30 % x 4.608,00 = 658,94 kWh
  - August → 12,80 % x 4.608,00 = 589,82 kWh
  - September → 8,90 % x 4.608,00 = 410,11 kWh
  - October → 5,90 % x 4.608,00 = 271,87 kWh
  - November → 2,80 % x 4.608,00 = 129,02 kWh
  - December → 1,20 % x 4.608,00 = 55,30 kWh

7.3 Power that the panels provide month per month.

Once calculated the energy that the panels provide and having into account the hours of sun per month we can calculate the electricity per month. These results will allow us to prepare a graph with the curve of energy provided by the panels. The results would be the following:

- January ⟶ 101,38 / 744h = 0,136 kW 136 W
- February ⟶ 188,93 / 696h = 0,273 kW 271 W
- March ⟶ 345,60 / 744h = 0,465 kW 465 W
- April ⟶ 539,14 / 720h = 0,749 kW 749 W
- May ⟶ 681,98 / 744h = 0,917 kW 917 W
- June ⟶ 635,90 / 720h = 0,883 kW 883 W
- July ⟶ 658,94 / 744h = 0,886 kW 886 W
- August ⟶ 589,82 / 744h = 0,793 kW 793 W
- September ⟶ 410,11 / 720h = 0,570 kW 570 W
- October ⟶ 271,87 / 744h = 0,365 kW 365 W
- November ⟶ 129,02 / 720h = 0,179 kW 179 W
- December ⟶ 55,30 / 744h = 0,074 kW 74 W

Once we have calculated the W per month the graph of the energy provided by the panels would e the following:



It is observed that May is the month when more electricity is provided: *917 W*. This month excess of energy can be sold to the net. Nevertheless December is the month when less electricity is provided: *74 W* so the purchase of electricity will be needed.

7.4 Election of the heat pump.

The passive house planned to be built will be equipped with a heat pump. The mechanical heat pumps exploit the physical properties of a volatile evaporation and condensation of a fluid known as refrigerant.

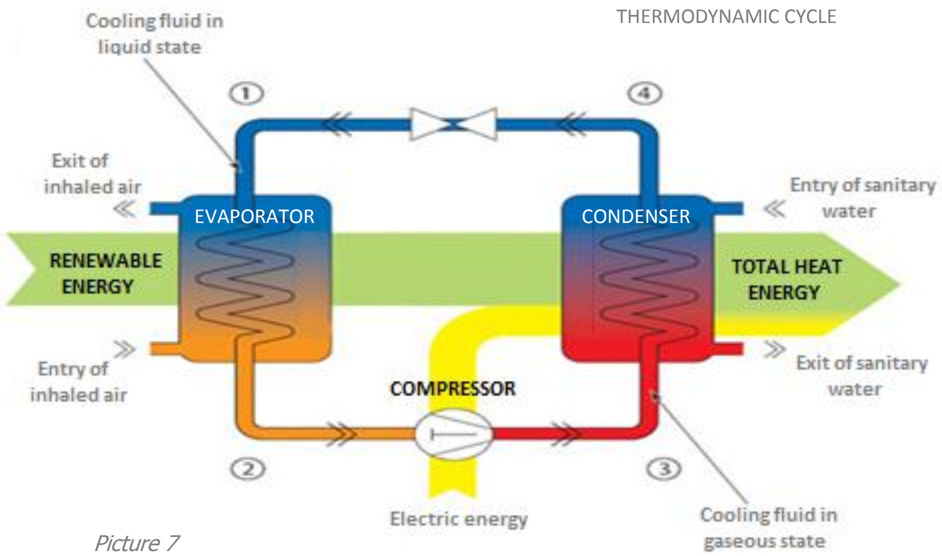
The function of a heat pump is the following:

1. The cold fluid is at low temperature and low pressure. The air absorbed from the atmosphere passes through the evaporator, where the refrigerant absorbs the ambient air temperature and changes the state.

2. When the refrigerant passes through the compressor it stills in low pressure, when the pressure increases so does the temperature.

3. The increment of temperature releases vapour in a high condition of energy. This vapour circulates along the condenser where it is yielding all the energy of the accumulated water, and returns to liquid state.

4. Once the fluid is liquid, it passes through the expansion valve to the fluid back in their initial conditions (low pressure and low temperature).



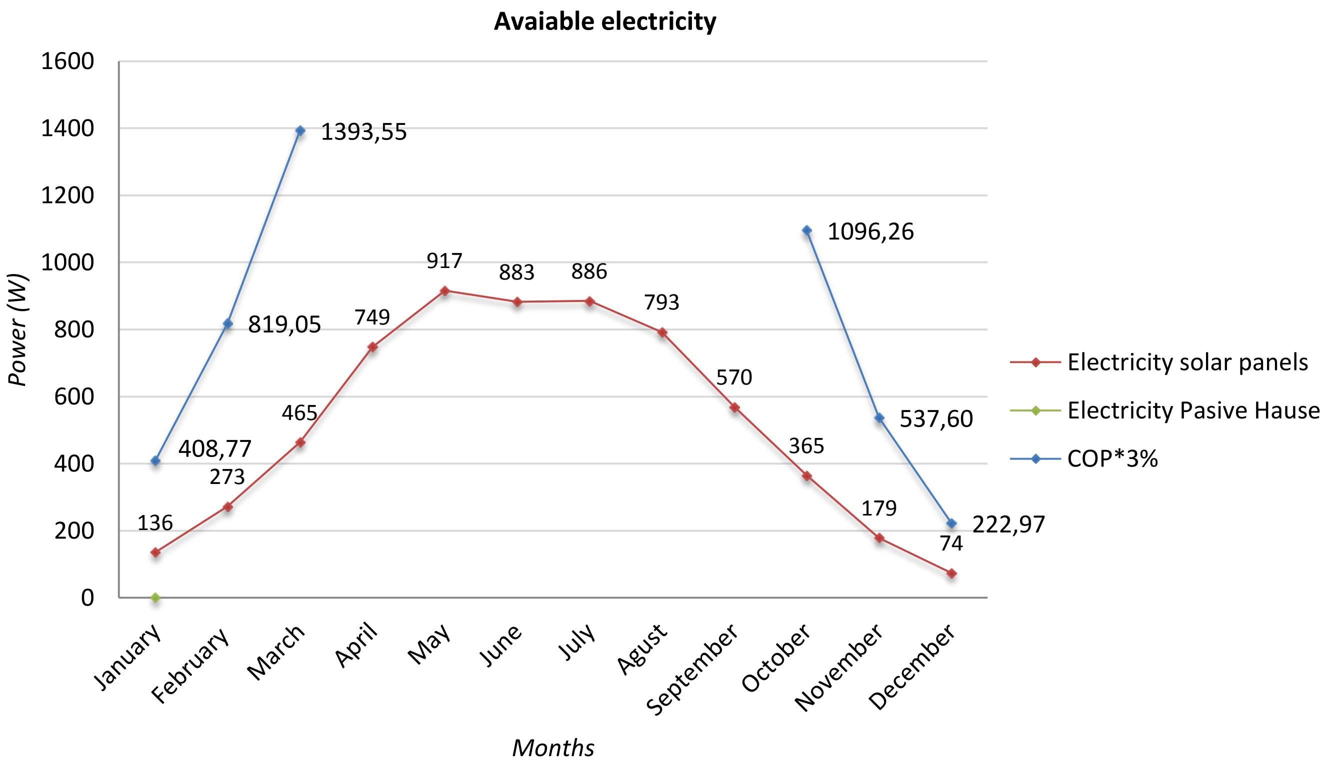
Picture 7

To determine the efficiency of the heat pump must resort to COP (Coefficient of Performance). This shows the association between the supplied power and the power consumed. The COP 3 implies a performance of 300%, which is, for 1 kWh of electric energy provided, 3kWh energy remains heat at the storage tank.

The COP varies according to the type of heat pump used and according to the conditions of functioning. The variable which influences the most is the temperature, though it has to be considered the cold water inlet temperature and the temperature of preparation and relative humidity.

Once we know the electricity that our panels provide it is possible to calculate the energy provided by the pump bulbs, assuming that the coefficient of the pump wide three times the energy that the panels provide. So we would obtain the following information:

- January ⟶ 136 W x 3 = 408,77 W
- February ⟶ 273 W x 3 = 819,05 W
- March ⟶ 465 W x 3 = 1393,55 W
- April ⟶ 749 W x 3 = 2246,40 W
- May ⟶ 917 W x 3 = 2749,94 W
- June ⟶ 883 W x 3 = 2649,60 W
- July ⟶ 886 W x 3 = 2657,03 W
- August ⟶ 793 W x 3 = 2378,32 W
- September ⟶ 570 W x 3 = 1708,80 W
- October ⟶ 365 W x 3 = 1096,26 W
- November ⟶ 179 W x 3 = 537,60 W
- December ⟶ 74 W x 3 = 222,97 W



The information of the summer's months is not represented since there is an excess of electricity which we are not going to use because the demand will be very low.

As it has been mentioned previously, a **passive house** is a house designed and executed to have the minimum expense of energy. Most of the energy used generates an agreeable environment inside the house, warm in winter and cold in summer. The passive houses are an achievement because all the energy used is renewal and does not harm the environment.

The use of a heat pump, other systems of warming the sanitary water, the air expelled is not the result of any type of combustion but fresh air from the outside. The heat pumps contribute even in small measure to reduce the global warming and also the CO2 emissions to the atmosphere. In fact, it is demonstrated that a bomb of 80 litres reduces 480 kg/year of CO2 related to the energy production.

In summary, the purpose of the heat pump is to take to another level the concept of warming of sanitary water. The heat pump is an important step towards the efficiency and the energetic saving and its source of energy is something as simple as the air. It is a flexible product, easier to install and cheaper than other equipment's which use renewable energies from the sun or from the temperature of the earth. The heat pump can cover the real needs of the house and being at the same time accessible to the user.

7.5 Energetic demand of the house.

Taking into consideration the electricity provided by the photovoltaic panels, to know its profitability it is important to know which energy requires our house.

7.5.1 Heat demand.

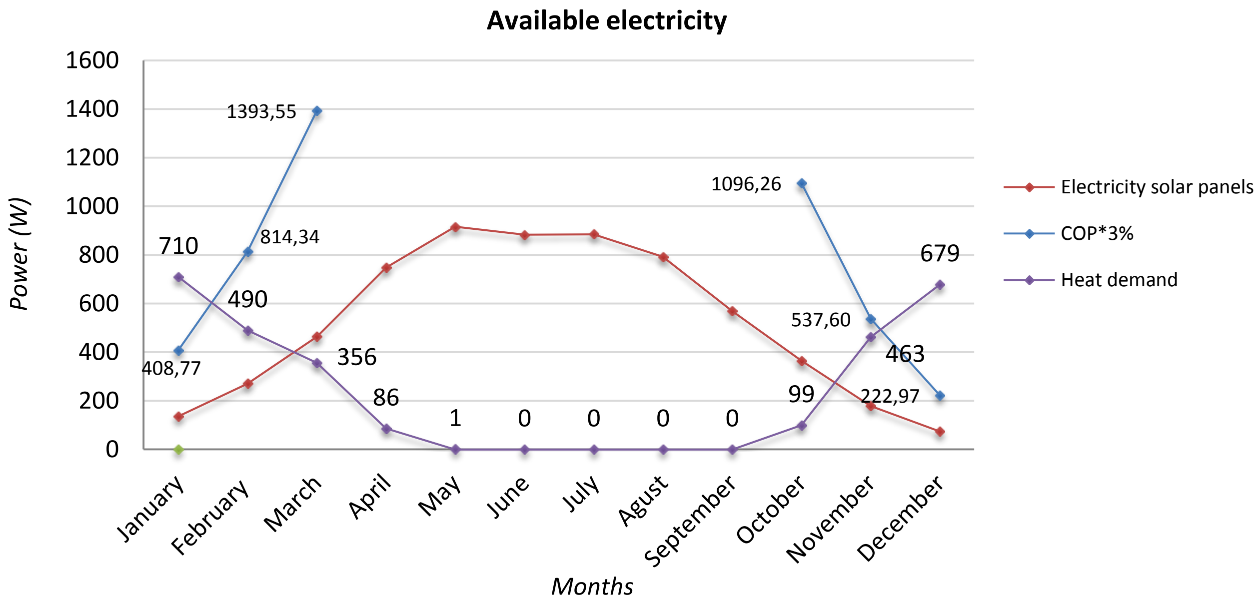
The data representing the heat demand of the house is the following:

	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Dez	Jahr	
Heizgr.Std. Außen	14,6	12,6	11,6	8,4	5,3	2,7	1,8	2,2	4,4	7,9	11,0	13,7	96	kKh
Heizgr.Std. Grund	8,3	8,3	9,1	7,8	6,3	3,3	1,7	0,8	1,8	2,9	4,5	6,6	62	kKh
Verluste Außen	677	584	539	388	245	124	83	104	204	366	512	636	4462	kWh
Verluste Grund	48	48	53	45	37	19	10	5	10	17	26	38	357	kWh
Summe spezif. Verluste	15,6	13,6	12,7	9,3	6,1	3,1	2,0	2,3	4,6	8,2	11,6	14,5	103,5	kWh/m²
Solare Gewinne Nord	2	3	6	8	11	12	12	9	6	4	2	1	76	kWh
Solare Gewinne Ost	0	0	0	0	0	0	0	0	0	0	0	0	0	kWh
Solare Gewinne Süd	99	200	224	282	289	258	272	292	272	214	109	71	2581	kWh
Solare Gewinne West	0	0	0	0	0	0	0	0	0	0	0	0	0	kWh
Solare Gewinne Horiz.	0	0	0	0	0	0	0	0	0	0	0	0	0	kWh
Solare Gewinne opak	0	0	0	0	0	0	0	0	0	0	0	0	0	kWh
Innere Wärmequellen	97	88	97	94	97	94	97	97	94	97	94	97	1142	kWh
Summe spezif. Angebot solar + intern	4,2	6,3	7,0	8,2	8,5	7,8	8,2	8,6	8,0	6,8	4,4	3,6	81,6	kWh/m²
Nutzungsgrad	100%	100%	100%	97%	71%	39%	24%	27%	58%	98%	100%	100%	71%	
Heizwärmebedarf	**528**	**341**	**265**	**62**	**1**	**0**	**0**	**0**	**0**	**74**	**333**	**505**	**2109**	**kWh**
spezif. Heizwärmebedarf	11,3	7,3	5,7	1,3	0,0	0,0	0,0	0,0	0,0	1,6	7,2	10,8	45,3	kWh/m²

Table 7

The table shows the information needed to calculate the heat demand of the house. The information is obtained by KWh. To represent the information in a graph we will converse the kWh to W. The graph shows that in December and January the electrical demand is higher than the energy provided by the photovoltaic panels. These two months we have to purchase the power from the net. The remaining months we will generate electricity and sell it to the network earning money.

The graph represents the electricity from the panels and the house demand of electricity.



7.5.2 Demand of energy needed for lighting, computers, etc.

Apart from the heat demand, it is important needed energy for the lighting and for other electrical appliances. Knowing the electricity that required each device and the hours that are plugged at day, we can calculate how much energy is needed for its properly functioning. Though we obtain all the energy per month, it is important to know which is the energy required for our own consumption.

First of all, the energy needed for the lighting has to be calculated according to the season, because less energy is needed in summer than in winter. The table shows the wattage of light needed at each room and the hours which light will be plugged depending on how many people are in the house and the duration of the day.

		Winter	Summer	Winter	Summer
LIGTHING	Power W	Hours of daily use (h/day)	Hours of daily use (h/day)	Energy (Wh/day)	Energy (Wh/day)
Room of meetings (1st floor)	260	4	2	1040	520
Bathroom	20	1	1	20	20
Stairs	40	1	1	40	40
Second floor	60	4	2	240	120
TOTAL	380			1340	700

Table 8

The light we need in the first floor changes depending the season if it is in summer or in winter, because as seen in section 4, in Germany the day in winter is shorter than in summer. So the light of the room will be plugged more hours in winter than in summer (approximately 2 hours).

To the electricity needed for lightening we have to add the energy needed for the electrical devices used in the house. The house will be divided into: a bathroom, a little kitchen and a meeting room at the first floor. The meeting room will be equipped with computers and several devices.

The electrical devices used will be the followings:

- Computer
- Printer
- Ventilation
- Sound equipment
- DvD equipment
- Wireless router
- Cordless telephone
- TV
- Fridge
- Microwave
- Expreso machine
- Toaster oven
- Cooking ranger

Knowing more or less the hours that will be plugged in each device, we extract its power demand month by month. It is representing on the following table:

EQUIP	Power W	Hours of daily use (h/day)	Electric Compsuption (Wh/day)
Computer	100	8	800
Printer	45	0,021	0,975
Ventilation	30	24	720
Sound equipment	30	4	120
DVd player	17	4	68
Wireless router	7	8	56
Cordless telephone	3	24	72
TV	250	0,083	20,83
Fridge	200	1,5	300
Microwave	600	0,5	300
Expresso machine	360	0,16	60,00
Toaster oven	1200	0,16	200,00
Cooking range	1000	0,25	250
TOTAL			**2967,81**

Table 9

Each device will have an energy demand according to the time they are plugged. The appliance of the kitchen will not be plugged too long, because the house will be mainly used for meetings. The appliance will not be in use with the same frequency that if it was placed in a normal house.

Once calculated the energy that we need to supply our electronic equipments as well as the light needed in all the house, The conclusion is that in winter the W needed would be *4,31 kWh* and in summer *3,67 KWh*.

7.6 Calculation of the economic profitability of the PV.

The energy produced by the panels will be used to power the electrical devices different days of the month. Depending on the month we would be able to sell the exceed of energy.

If in January the energy produced is *3,27 KWh/d* and we need *4,31 KWh/d* in order to the functioning of the electrical devices, we will need to purchase energy from the network. If the price of the energy from the network is *0,194 Euros/kWh* this month the electricity will cost *36,01 Euros* .The following table shows month by month the amount of energy we have to purchase from the net and the exceeds of energy that we can sell to the network:

Months	Energy solar panels kWh/d	Energy EQUIP kWh/d	Energy SP - Ene. EQUIP. kWh/d
January	3,27	4,31	-1,04
February	6,51	4,31	2,20
March	11,15	4,31	6,84
April	17,97	3,67	14,30
May	22,00	3,67	18,33
June	21,20	3,67	17,53
July	21,26	3,67	17,59
August	19,03	3,67	15,36
September	13,67	3,67	10,00
October	8,77	3,67	5,10
November	4,30	4,31	-0,01
December	1,78	4,31	-2,53

Table 10

The column of the right refers to the energy provided by the panels and it means less energy needed for the electrical devices which will not be in use. Depending on the month it shall be reduced *4,31 kWh* (summer) or *3,67 KWh* (winter).

The months of January, November and December we will have to buy electricity from the net. The other of months we will be able to sell the exceeded energy to the network and charge for it.

In addition to the energy we just obtained, we need to consider the heat demand of the house. Thus we obtain the following table:

Months	Energy solar panels kWh/d	Energy SP - Ene. EQUIP. kWh/d	Energy demand for heating kWh/d	Energy PV - Engy. D. heating kwh/d
January	3,27	-1,04	5,7	**-6,7**
February	6,51	2,21	4,1	**-1,9**
March	11,15	6,84	2,8	**4,0**
April	17,97	14,30	0,7	**13,6**
May	22,00	18,33	0,0	**18,3**
June	21,20	17,53	0,0	**17,5**
July	21,26	17,59	0,0	**17,6**
August	19,03	15,36	0,0	**15,4**
September	13,67	10,00	0,0	**10,0**
October	8,77	4,46	0,8	**3,7**
November	4,30	-0,01	3,7	**-3,7**
December	1,78	-2,52	5,4	**-8,0**

Table 11

Therefore in the months we have to purchase or to sell the following quantity of energy:

- January ⟶ We have to buy 6,7 kWh/d 208,2 kWh/month
- February ⟶ We have to buy 1,9 kWh/d 51,9 kWh/month
- March ⟶ We can sell 4,0 kWh/d 123,7 kWh/month
- April ⟶ We can sell 13,6 kWh/d 408,4 kWh/month
- May ⟶ We can sell 18,3 kWh/d 567,8 kWh/month
- June ⟶ We can sell 17,5 kWh/d 525,9 kWh/month
- July ⟶ We can sell 17,6 kWh/d 545,2 kWh/month
- August ⟶ We can sell 15,4kWh/d 476,1 kWh/month
- September ⟶ We can sell 10,00 kWh/d 300,1 kWh/month
- October ⟶ We can sell 3,7 kWh/d 113,7 kWh/month
- November ⟶ We have to buy 3,7 kWh/d 111,2 kWh/month
- December ⟶ We have to buy 8,0 kWh/d 246,6 kWh/month

So considering that the purchase of energy costs *0,22 €/kWh* and by selling it you earn *0,1994 €/kWh*, we will be able to know how much we have to pay to buy the energy or how much we will earn if we sell the extra energy.

Considering the previous table and prices of electricity we obtain the following Table:

Months	Total energy kwh/month	Total euros
January	-208,2	-45,80
February	-51,9	-11,41
March	123,7	24,00
April	408,4	79,24
May	567,8	110,16
June	525,9	102,02
July	545,2	105,78
August	476,1	92,37
September	300,1	58,22
October	113,7	22,05
November	-111,2	-24,47
December	-246,6	-54,25
TOTAL		**457,9**

Table 12

We would earn *457,9 Euros* per year despite the fact that in beech months we have to buy energy from the network. Since there is much more left then than during summer months, installing the photovoltaic panels is profitable for us.

8. Energy efficiency of the photovoltaic panels in Spain.

In this paragraph we will calculate the profitability of the house if we built it in Spain. The technical aspects will be the same but we have supposed that in Spain the absorption of the panels is 30 % higher than in Oldenburg. Also assume that we will use 30 % less of light both in winter and in summer, since there is more solar radiation. So, we will calculate the purchase of energy to the net in the winter's months. During the summer the excess of energy will allow us to sell the power to the net obtaining profitably. The economic calculation is realized without bearing in mind the cooling demand in summer months.

Taking into account that we have mentioned before, we will obtain the following table with the energy that we would have to buy or sell according to the month in which we are:

Months	Energy solar panels kWh/d	Energy SP - Ene. EQUIP. kWh	Energy demand for heating kWh/d	Energy PV - Engy. D. heating kwh/d
January	4,25	0,35	5,7	**-5,3**
February	8,47	4,56	4,1	**0,5**
March	14,49	10,59	2,8	**7,7**
April	23,36	19,90	0,7	**19,2**
May	28,60	25,14	0	**25,1**
June	27,56	24,10	0	**24,1**
July	27,63	24,18	0	**24,2**
Agust	24,73	21,28	0	**21,3**
September	17,77	13,87	0	**13,9**
October	11,40	7,50	0,8	**6,7**
November	5,59	1,69	3,7	**-2,0**
December	2,32	-1,59	5,4	**-7,0**

Table 13

Apart from the fact that the solar panels absorb 30% more of energy, we must consider if we build the house in Spain, the consumption of light will be less because we will have more light intensity. So we would get these results from subtracting the 30% of the energy used in Oldenburg.

	Winter	**Summer**
TOTAL energy -30%	938 Wh	490 Wh
Lighting (kWh)	0,938	0,49
Equip (kWh)	2,97	2,97
TOTAL (kWh)	**3,91**	**3,46**

So considering that the purchase of energy costs *0,17 €/kWh* and by selling it you earn *0,34 €/kWh*, we will be able to know how much we have to pay to buy the energy or how much we will earn if we sell the extra energy.

The prices of the energy are extracted from the penultimate decree about photovoltaic solar energy. Nevertheless, taking in account the situation of the Spanish economy, the Spanish ministry have extracted a last decree in which they stop having subsidies to install photovoltaic solar panels and now by every kWh generated it will be paid to price of the market, it is not a stipulated price, is a price depending on the offer of generation and the demand of energy.

Considering the previous table and prices of electricity we obtain the following Table:

Months	Total energy kwh/month	Total euros
January	-165,3	-28,95
February	14,1	4,80
March	239,9	81,55
April	576,5	196,00
May	779,1	264,88
June	722,9	245,80
July	749,4	254,81
Agust	659,6	224,26
September	416,0	141,43
October	207,7	70,61
November	-60,4	-10,59
December	-217,5	-38,10
TOTAL		**1406,50**

Table 14

We would earn *1406,50 Euros* per year despite the fact that in beech months we have to buy energy from the network. Since there is much more left then than during summer months, installing the photovoltaic panels is profitable for us.

In difference with the construction of the house in Oldenburg we see clearly that we extract more profitability in Spain, since getting more amount of solar energy and the price of the energy that we sell to the net is higher, we get almost three times more money per year.

9. Conclusion

In conclusion, we can say that according to the completed study that it is profitable to put photovoltaic panels in the house. Besides that the panels generate energy that can be used for our own consumption and the excess can be sold and more profit can be extracted.

Spain has not sufficiently developed the topic of renewable energies. We have observed that putting the house in Spain would be very profitable because the solar panels obtain more amounts of sunlight thus creating a larger quantity of energy. Nevertheless, the Spanish population isn't sufficiently curious to invest in renewable energies because it is not promoted adequately. Germany, being the global leader in green energy, centers a lot of their attention on sustainable energy and has focused on subsidizing this energy to promote it.

We have seen, in the paragraph of amortization, to be able to finance the installation of the panels in the Passive House but we would need money in order for it to function profitably. In a similar situation in Spain it would be quite difficult. In the north of Europe it would not be a problem because the standard of living is higher here than that of Spain. This problem would not happen only in the case of Spain since to be able to construct a Passive House it is necessary that enough money is allotted in advance to be able to finance it and make it profitable. I hope that when the economic state normalizes to construct a Passive House anywhere will not cost additional expenses thus being more respectful to the environment while extracting profits from excess energy.

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- Attached is a DVD with all the data I have used, including, excel, drawings and extra information.