ESCUELA TÉCNICA SUPERIOR DE INGENIEROS INDUSTRIALES Y DE TELECOMUNICACIÓN

Titulación :

INGENIERO TÉCNICO INDUSTRIAL ELÉCTRICO

Título del proyecto:

RENEWABLE COUNTRY HOTEL

Álvaro Couso Gómez
Alfredo Ursúa Rubio
Pamplona, 27 de Julio de 2011

INDEX

CHAPTER 1

1.1 Aim

The aim of this project is to study the possibility of getting a house, isolated to the network, as sustainable as possible. It means to achieve the maximum energy savings without neglecting the economic aspect. This should take into account many factors such as using the resources of the place in the best efficient way and be innovative whether it is possible or not.

As the house is supposed to be placed in a quite mountainous area, resources that should be developed are wind, solar and geothermal power. In order to get energy from those two resources, solar panels, solar collectors and geothermal pipes should be used. So at the end of this project the house should have the following installations:

- Geothermal pump installation in order to keep the house warm: Different alternatives will be analysed so as to get the best option to heat the house. Once the possible solutions are explained, one of those will be choose to be installed in the hotel.
- Solar Panels installation so as to connect to the net: In the design of solar photovoltaic installation selling electricity instead of using it for the house own consumption will be more profitable. This is because of the high purchase price of the kWh generated by the photovoltaic solar energy.
- Solar thermal installation to provide hot water: This energy will be used in order to produce hot water. Different possible alternatives to this system will be studied and the reasons of the chosen alternative.
- Electrical installation: The electrical installation will be performed with its wiring planes and single line diagram. The size of wires will be calculated throughout different criteria.

Other objective to be achieved is to get a significant reduction in CO_2 emissions to the atmosphere, as it is an important issue throughout these years.

1.2 Locations and Description

The house is situated on the road between Olite and San Martin de Unx, belonging to the region of Navarre in Spain. Its location is depicted in *figure 1*.

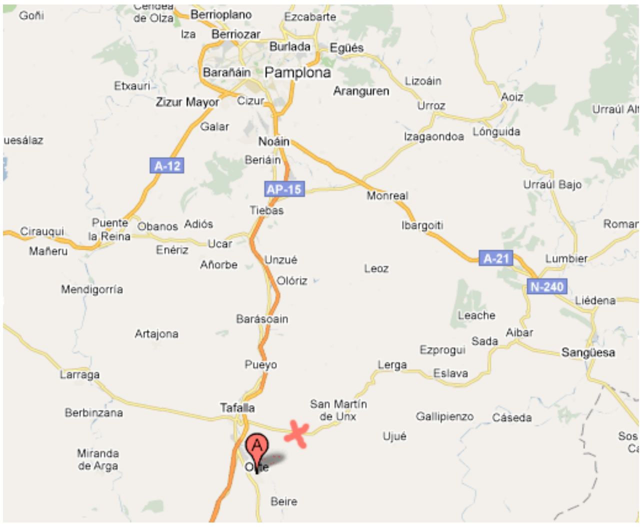

Figure 1.2.1: Country hotel location.

It is a two storeys high house. The first floor has a space of 322.5 m^2 and the second floor has 166.29 m^2. Therefore the house has a total space of 488.72 m^2.

The arrangement of the country hotel is depicted in Appendix 1 so as to clearly know the distribution of each room. Besides, walls dimensions are also shown. All of this is needed to come with the calculation of the thermal loads.

The surface of each room of the house is explained below:

First Floor

Throughout the first floor it is able to find several rooms whose function is to provide country hotel guests the opportunity to have fun and meet new people. There is also a kitchen and a living room.

Room	**Surface (m2)**
Reception	18.0
TV room	54.0
Living room	72.0
Game room	102.0
Kitchen	27.0
Toilets	9.0
Stairs	9.0
Corridor	21.9
Machines room	7.5

Table 1.2.1 Rooms surface in first floor.

Second Floor

The second floor is the place where the rooms are. As it is shown in the table below there are five ensuite rooms.

Room	**Surface (m2)**
Room (1,2,3,4)	16.0
Room 5	19.04
Bathroom (1,2,3,4,5)	8.0
Stairs	8.0
Corridor	31.5
Service room	3.75

Table 1.2.2 Rooms surface in second floor.

1.3 Orientation

In order to get the suitable orientation for the house, the climate of the region where the house is located is needed. Thus, the table below shows the average temperatures in the area in each month.

Month	Average Temperature (ºC)
January	4.2
February	6.6
March	10.0
April	11.2
May	17.9
June	21.6
July	23.6
August	23.9
September	19.4
October	15.9
November	10.4
December	5.9

Table 1.3.1 Average temperatures in Navarra.

As it can be seen, this region is cooler than warmer so the best orientation will be chosen so as to get the higher sun hours during the winter. That's why the most suitable orientation is south.

Room	Orientation
Reception	NE
TV room	SE
Living room	S
Game room	NW - SW
Kitchen	N
Toilets	N
Stairs	N
Corridor	
Room 1 + Bathroom	SE
Room 2 + Bathroom	S
Room 3 + Bathroom	SW
Room 4 + Bathroom	NW
Room 5 + Bathroom	N
Service room	NE

Table 1.3.2 Orientation of each room.

CHAPTER 2

2.1 Climate control alternatives

2.1.1 Underfloor heating system

It is the most efficient and economic way to warm up the house. It is also clean, noiseless, confortable and healthy. That is so that World Health Organization recommends it.

The tubes are mounted in hot in order to prevent surface stresses formation that might cause future fissures and leaks. These tubes are capable to work with hot and cold water and ensure absolute reliability within thirty years.

Underfloor heating system consists of an evenly spread network of pipelines buried. Water flows through it with a moderate temperature of about 35º to 40º C. *Figure 2.1.1.1* shows a sample of how it is built.

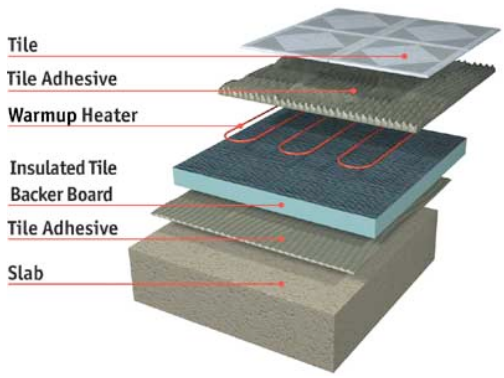

Figure 2.1.1.1 Underfloor heating system sample

The heat across the floor is distributed so that shares an ideal temperature so as to keep your feet warm and head cold. This temperature distribution helps the user to save energy. Using other kind of systems to warm the air tends to be near the ceiling while the greatest needs are close to the floor. So heating the surface is enough to warm up the room without having to heat the air close to the ceiling.

2.1.2 Heating Pump

Generate heat using this system is the way that consume less energy and which extracts energy from the environment, commonly using the air. The heat generated can be used to heat the water in order to use it as hot water or heating system water.

The operating principle is the same as using a refrigeration appliance. By taking energy from the indoor air at a low temperature and lending it to the outdoor air, that has a higher temperature, the room gets a cool environment. If the operation is reversed a heating pump is got. For this reason most of these devices are reversible so as to cool in summer and heat in winter.

It presents very high efficiencies when the difference between the temperature inside and outside is moderate (about 10º C).

The energy consumed by the heat pump is electric so it may come from the network or be generated in a clean and sustainable installation such as solar panels one.

This system should produce motions of warm air layers, causing more movements of dust and creating a less hygienic and healthy environment.

There are three different operation possibilities to use a heating pump. The three possibilities are shown below:

- Air – Water
- Air – Air
- Geothermal pump

2.1.2.1 Air – Water

This kind of heat pump extracts heat from outside air and transfers it to the water that is flowing through the heating system. This allows the user to adapt this system when there is a heating system installed.

The hot water generated is able to heat the house with either radiators or underfloor heating system but only the underfloor heating system is the only one that can cool the house.

2.1.2.2 Air – Air

An air – air heat pump extracts energy using the outside air and lend it to the inside rooms with a pleasant temperature.

Although the efficiency of this type of heat pump is slightly lower than the explained above it has the advantage of being a reversible installation so any additional device is not required.

2.1.2.3 Geothermal pump

The use of a low enthalpy geothermal energy relies on the principle that the ground has a more constant temperature that the outdoor air. The greater the depth is the less changes fluctuations are observed because geological materials remain at a fairly constant temperature throughout the year.

In the Spanish case, at five meters deep, the soil temperature is about 15 ºC and between fifteen and twenty meters deep, thermal stability is about 17ºC all the year.

A geothermal system uses a heat pump and holes in the ground so as to take advantage of that warm temperature. The heat pumps explain above use a huge amount of energy in order to achieve what the user wants. That's why these heat pumps are really efficient due to the fact the difference between the temperature outside and in the ground are lower than the others so the energy consumption decreases. So the heat exchange with the ground can provide the same excellent environment rather than using a conventional heat pump and also with less energy.

The Coefficient of Performance (C.O.P) show how efficient is a heat pump. The C.O.P of a geothermal pump is of about 4 to 6 while an air – air pump C.O.P is between 2 and 3. This means that for a unit of energy used in this system you get 4 or more heat or cold energy units.

In order to use the ground temperature is necessary to make a series of holes.

Depending on the land, geological conditions and on the size of the place that is going to be heated the holes dimensions might vary between 10 or 15 cm. wide. Inside each hole is placed a pipe in where the heat exchange takes place. Each pipe consists of a tube, usually made of polyethylene filled with fluid. Generally the flowing fluid is water or a saline solution with antifreeze in order to prevent the fluid get solidifies.

The fluid circulates continuously through the closed loop. It drops to be heated or cooled and goes up again. At this point the fluid gives up its heat or cold to the refrigerant and then to the heating system either air or water. Then the fluid goes back down through the circuit and starts again. The system has a high yield because the exchange is made at a depth between 30 and 100 meters.

There are different configurations in order to make the exchange in the ground:

- Horizontal exchanger.
- Vertical exchanger.
- Open-loop configuration.

2.1.3 Biomass

Biomass is a renewable fuel that comes from a vegetable source, which includes the use of forest residues or agricultural waste. There are also crops whose production is send to the generation of this kind of fuel.

The "pellets" are waste from forestry and wood industries, which are crushed and turning them into shavings. Once they are dried they are pressed into small cylinders. This type of product is an advanced biomass application. It is a clean, easy to use product and it is able to work autonomously for hours. They are also environmentally friendly because of being a waste instead of having to cut off trees. "Pellets" boilers have yields much higher than wood, have a good efficiency, generate less smoke, can heat water and radiators can be connected to this installation.

The energy produce is high compared with its low price, therefore with these boilers the user is able to get a good environment saving up at least a 40 % comparing them with a gas-oil boiler. A "pellets" boiler is depicted in *figure 2.1.3.1*.

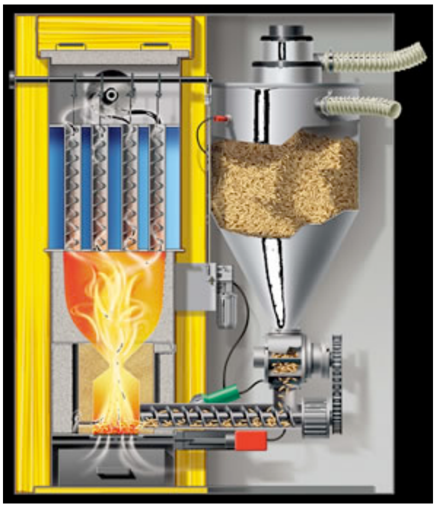

Figure 2.1.3.1 A "pellets" boiler sample

2.1.4 Central heating radiators

The radiators heating system is installed mainly in Spain. It is especially suitable for areas with low minimum temperatures.

Thus, this option offers the possibility or installing a heat generator. This type of heating system is characterized by their high yield and low NO_x emissions.

2.1.5 Air conditioning system

Inverter technology improves traditional air conditioning systems. Other air conditioning systems are continuously repeating start-stop cycles in order to adjust the temperature but this technology can maintain a constant temperature and consume only the necessary energy to achieve it. In order to do this, the cooling capacity decreases or increases depending on the temperature required at any time without having to connect or disconnect the compressor.

The result is a better atmosphere and a lower cost (saving up 25 %). Due to the fact that temperature variations are avoided, the consumption is optimized increasing the life of the device.

In addition, these devices get a lower noise level and better air distribution, improving the environmental conditions.

2.2 Climate control alternative election

Once the different alternatives have been exposed, the most interesting and suitable for the house must be chosen.

The objective is to find a system which have significant energy savings but also clean, quiet and healthy at the same time. In this case, where energy efficiency and sustainability are priority criteria, the underfloor heating system has been chosen. Another system like radiators has been rejected because its water temperature is between 80º C and 90º C.

One of the advantages of the system is that with the same installation it is able to distribute either heat or cold. By taking into account temperature profiles the most similar to the ideal heating is the underfloor heating system. *Figure 2.2.1* shows the temperature profiles of the different studied systems.

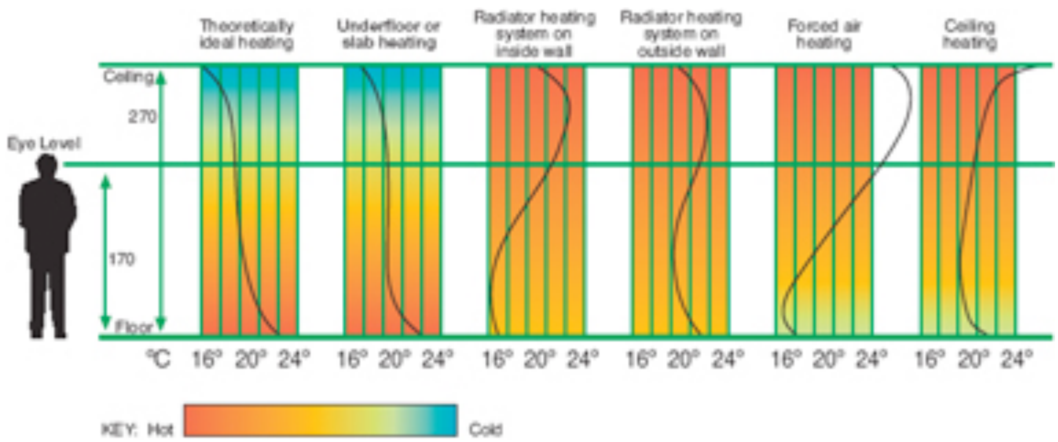

Figure 2.2.1 Temperatures profiles

As the underfloor heating system does not require high water temperatures flowing through its pipes, the geothermal heat pump has been chosen as well in order to feed the system with its highly yield contribution.

In this way a resource that is not really well know in Spain but efficient is used. Other alternatives such as biomass has not been chosen due to the fact that it pollutes more and it causes a disgusting smoke. Besides an auxiliary system would have been needed for summer. Furthermore, the outside temperature does not affect the working process of the geothermal pump.

The geothermal pump configuration used will be the vertical exchanger one owing to the fact that the horizontal exchanger needs a large area and that is not possible in this situation.

2.3 Thermal Loads

2.3.1 Heating System (Winter)

The heating system is capable of producing heat through its own combustion, share it to the fluid, transported and released into the environment when and where it is necessary. There should be a balance between lack and excess heat.

In order to avoid having a heating installation costs and energy consumption very high is essential to calculate thermal loads. So as to do this process, it is necessary to calculate one by one each factor that have an influence in each room.

This study is really important due to the fact that the omission of some of these factors will affect all the installation and because of that, costs and energy consumption will increase.

Thermal load calculation is one of the most important factors. The thermal load is calculated as the heat losses happened throughout the hotel. Heat losses are mainly produced because of transmission losses. The transmission coefficients needed to obtain the thermal loads are on the manual: *"Manual de Aislamiento Termico"*. The transmission coefficients chosen are the following ones:

Outdoor Walls: *C type wall with insulator 60*
k= 0.36 kcal/m^2hºC = 0.418 W/ m^2ºC

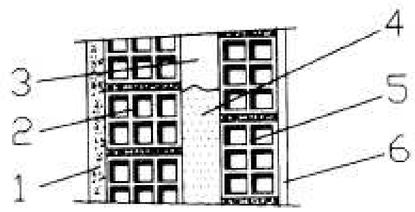

Figure 2.3.1.1 Type C squedule

Indoor Walls: By references: k= 1.2 W/ m^2ºC

Ceiling: *Forged with a concrete vault H, H=16, e=20*
k= 0.73 kcal/m^{2}hºC = 0.85 W/ m^{2}ºC

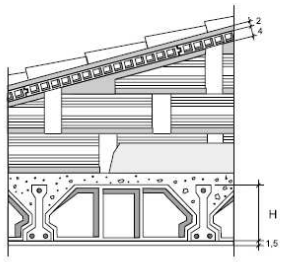

Figure 2.3.1.1 Forged with a concrete vault squedule

Windows: *Double "Climalit" and wood*
k= 2.7 kcal/m^{2}hºC

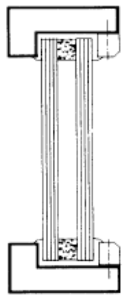

Figure 2.3.1.1 Double window squedule

Indoor doors: By references: k= 7 W/ m^{2}ºC

Outdoor doors: By references: k = 4.5 W/ m^{2}ºC

In order to find the outdoor temperature variation, Table 5 of *"Manual de Aislamiento Termico"* is used. The variation in this case is – 5 ºC. However, there is a table in the same manual that shows the different temperatures for each room. The temperatures for each room are the following ones:

Room	Temperature (ºC)
Toilets	17.0
Reception	17.0
Stairs	17.0
Corridor	17.0
Bathroom	20.0
Living room	19.0
Kitchen	16.0
Room	15.0
Common Room	20.0
Service Room	18.0

Table 2.3.1.1 Indoor temperatures

In order to calculate thermal loads, the house is being divided in its own rooms; the walls are broken down into different parts because there are windows and doors and the transmission coefficient varies. The following table shows the heat losses produced in each room so as to know the load to deal with in winter:

Room	Qtotal (W)
Reception	795.73
TV room	1864.42
Living-room	1904.97
Game room	2608.9
Kitchen	155.04
Toilets	248.81
Corridor & Stairs	(-)66.2
Room 1	269.07
Room 2	144.39
Room 3	125.19
Room 4	125.19
Room 5	296.07
Bathroom 1	471.34
Bathroom 2	471.34
Bathroom 3	502.22
Bathroom 4	502.22
Bathroom 5	500.14
Corridor	1064.93
Service Room	249.27
Total	**12233.05**

Table 2.3.1.2 Heat losses.

As it can be seen, the total load that must be neutralized is approximate 12233.05 W.

2.3.2 Air Conditioning system (Summer)

It is essential to make the thermal loads calculation as a result of heating needs. To do this, it is necessary to determine the factors, one by one, that have influence on the installation so as to design what it is really needed. As a consequence of that, installation costs and consumptions will decrease.

There are several terms that will keep constant during the process. These are the main terms:

1) Localization: Navarra
2) Outdoor maximum temperature: 33ºC
3) Outdoor relative humidity: 58%
4) Daily temperature variation (VTD): 10ºC
5) Indoor temperature: 25ºC
6) Surface density of wall: 500 kg/m^2

The calculation of the heat load will vary depending on the time of the day. Thus, a time and a month must be chosen which in this case is a summer month. The time and month must be the one with the maximum load so as to design an installation that can operate under all environmental conditions in summer.

The temperature outside the hotel and the temperature outdoor in that time are different. The time that has been taken is 14 pm so there will be a correction factor:

TE = TEPV + C1 + C2

TEPV means the outdoor temperature in summer and C1 and C2 are coefficients of correction. In this case, C1= 0 (July) and C2= -0.5 (14 pm). Therefore, the temperature outside will be:

TE = 33 + 0 + (-0,5) = 32,5 → TE = 32,5.

The heat load is the heat per unit that comes into a room where there is a lower temperature than outside and the humidity is normally lower than outside as well.

2.3.2.1 Summer thermal loads components

This heat is divided into two forms. One is called the sensible heat and happens when there is a temperature difference. The other one is called latent heat and is a result of the difference between the humidity in the outside and inside. A comfortable humidity is between 50% and 60% and the humidity outside the hotel is 58% so the latent load is not going to be taken into account.

Here there is a summary of the most important sensible loads in summer and the following tables show the results of different calculations.

- Sensible heat throughout outdoor walls QSME.

- Sensible heat throughout outdoor horizontal walls QSCE.

- Sensible heat throughout outdoor windows QSCV.

- Sensible heat due to radiation throughout outdoor windows QSRV.

- Sensible heat because of the lights QSIL.

- Sensible heat due to visitors QSOC.

2.3.2.1.1 Sensible heat throughout outdoor walls QSME

Room	QSME (W)
Reception (1)	54.9
Reception (2)	23.32
Toilets (2)	10.41
Stairs (2)	12.41
Kitchen (2)	33.23
Game room (4)	43.42
Game room (5)	90.87
Game room (6)	39.26
Living room (4)	42.64
TV room (1)	106.43
TV room (4)	31.98
Service room (1)	14.7
Service room (2)	15.51
Room 1 (1)	47.3
Room 1 (5)	23.27
Room 2 (4)	23.27
Room 3 (4)	23.27
Room 4 (2)	19.83
Room 5 (2)	24.54
Stairs (1)	39.24
Stairs (2)	12.41
Bathroom 1 (4)	12.22
Bathroom 2 (4)	12.22
Bathroom 3 (3)	31.03
Bathroom 3 (4)	12.22
Bathroom 4 (2)	10.41
Bathroom 4 (3)	31.03
Bathroom 5 (2)	10.41
Total	**851.74**

Table 2.3.2.1 QSME

2.3.2.1.2 Sensible heat throughout outdoor horizontal walls QSCE

	QSCE (W)
Ceiling	5647.17
Total	**5647.17**

Table 2.3.2.2 QSCE

2.3.2.1.3 Sensible heat throughout outdoor windows QSCV

Room	QSCV (W)
Reception	42.39
TV room	105.97
Living room	141.3
Game room	388.58
Kitchen	42.39
Toilets	21.2
Room 1	52.99
Room 2	52.99
Room 3	52.99
Room 4	52.99
Room 5	52.99
Bathroom 1	21.2
Bathroom 2	21.2
Bathroom 3	21.2
Bathroom 4	21.2
Bathroom 5	21.2
Corridor	43.45
Service room	16.96
Total	**1173.14**

Table 2.3.2.3 QSCV

2.3.2.1.4 Sensible heat due to radiation throughout windows QSRV

Room	QSRV (W)
Reception	159.8
TV room	1253.25
Living room	1671.0
Game room	8712.21
Kitchen	159.8
Toilets	79.9
Room 1	626.63
Room 2	626.63
Room 3	626.63
Room 4	199.76
Room 5	199.76
Bathroom 1	250.65
Bathroom 2	250.65
Bathroom 3	250.65
Bathroom 4	79.9
Bathroom 5	79.9
Corridor	547.86
Service room	63.92
Total	**15838.9**

Table 2.3.2.4 QSRV

2.3.2.1.5 Sensible heat because of the lights QSIL

Room	QSIL (W)
Reception	28.0
TV room	268.0
Living-room	160.0
Game room	217.5
Kitchen	145.0
Toilets	50.0
Stairs	50.0
Corridor	42.0
Rooms	350.0
Bathrooms	140.0
Corridor	70.0
Service room	14.0
Machines room	28.0
Total	**1562.5**

Table 2.3.2.5 QSIL

2.3.2.1.6 Sensible heat due to visitors QSOC

	QSOC (W)
	988.0
Total	**988.0**

Table 2.3.2.6 QSOC

2.3.2.2 Total summer thermal loads

Total heat load that the air conditioning system must deal with is shown in the following table:

	Sensible Q (W)
QSME	851.74
QSCE	5647.17
QSCV	1173.14
QSRV	15838.9
QSIL	1562.5
QSOC	988.0
Total	**26061.45**

Table 2.3.2.2.1 Total sensible heat Q

2.4 Geothermal pump drillings calculation

First, the type of ground in where drillings are going to be made must be known. In this case, the hotel is placed in a damp and clayey ground. Once the type of ground is know calculations can be developed using one of the tables provided by *Georenova* a company which provides geothermal elements.

Type of Ground	Test Drilling (W/m)
Dry ground Chippings, sand	20 - 30
Damp ground Silts, clay, sand	50 - 60
Water-saturated ground	70 - 90

Table 2.4.1 W/m depending on the ground

According to the table above and the type of ground in where the hotel is placed, the test drilling is between 50 and 60 W/m. In order to do the calculations 55 W/m is going to be used so with this data the number of drillings can be calculated.

So as to keep the house cool in summer 26061.45 W are needed; in the other hand it is needed a less quantity of power to keep the house warm in winter that's why the calculation is done with the summer thermal loads.

Drilling depth = Thermal load / Test drilling (W/m)

Drilling depth = 26061.45 W / 55 W/m = 473.85 m

A total depth of about 473.85 m is needed. In order to achieve this number of meters several drillings can be made. *Georenova* has on stock rolls of pipes of about 100 meters so it is necessary to bury 5 drilling of 100 meters each. The installation might have losses but as it is oversized that is not taken into account. Furthermore each drill must be separated 7 meters between them and they have to be close to the machines room in where the pump is going to be located.

Throughout the pipes a water and antifreeze mixture is circulating. Besides, once the test drilling is introduced into the ground, it has to be filled with a material called "bentonite" in order to lend the temperature flows between the pipe and the ground.

2.4.1 Heating pump election

Back in section 2.1.2 an explanation of the different types of heating pumps have been carried out, which are the following one:

- Air - water.
- Air – air.
- Geothermal pump.

Between these three systems the one that is going to be developed, is the geothermal pump because of several advantages:

1) From an environmental perspective, solar geothermal energy does not produce CO_2 emissions.
2) As health concerns, the absence of cooling towers avoid any bacteria contamination.
3) When geothermal pump exchanges the temperature it has a high yield due to

the fact that the outside temperature does not have an influence on the system so that makes a very efficient system.

4) As the installation temperature does not exceed 50 ºC, the house has a comfort temperature really high.
5) Maximize the installation life.
6) Increase reliability and comfort.
7) Easy to modify.
8) Without noise.
9) It is the most efficient solution from an economic perspective. The most significant costs are on the air conditioning system, heating system and the hot water system. When a solar geothermal is installed the following savings can be achieved in relation to other systems:

Geothermal Savings	
Comparing with gas-oil	75 – 80 % savings
Comparing with gas	60 – 70 % savings
Comparing with electricity	60 – 70 % savings
Comparing with heat pump	50 – 60 % savings

Table 2.4.1.1 Geothermal savings

Once the type of the heat pump is chosen technical characteristics have to be selected in order to suit with the needs. The pump is chosen in accordance to its characteristic curve.

In this case a sample of pump that is likely to be installed could be reversible water – water *Ciatesa IZE 160* heat pump. The following table shows the technical characteristics.

Citesa IZE 160		
Number of circuits Number of compressors Number of steps		1/1/1
Inside circuit	Flow (m^3/h)	5.9
	Load losses (m.c.a)	3.9
	Hydraulic connections E/S	1 1/2*
Outside circuit	Flow (m^3/h)	5.9
	Load losses (m.c.a)	3.5
	Hydraulic connections E/S	1 1/2*
Power consumed	Cool (kW)	9.5
	Heat (kW)	10.7
Maximum current	400 V/ III ph (A)	29
Dimensions	Large (mm)	888
	Wide (mm)	500
	Tall (mm)	1573
Weight (kg)		218

Table 2.4.1.2 Technical characteristics of a heat pump

CHAPTER 3

3.1 Solar Thermal Energy

In this section solar thermal installation so as to produce hot water will be detailed.

3.1.1 Technical Characteristics

Collector data is extracted from the catalogue of *Cointra,* a company that bases its production in the solar thermal energy. The collector model elected to this case is the *Icaro 2.0 VF*. The table below shows the characteristics of this model and the efficiency curve is depicted in *figure 3.1.1.1*.

Icaro 2.0 VF Model	
Total Surface (m^2)	1.97
Aperture surface (m^2)	1.89
Absorber surface (m^2)	1.87
Tall (m)	1.7
Wide (m)	1.16
Large (m)	0.08
Number of connections	4
Weight (kg)	35
Inside liquid (l)	1.4
Recommendable work caudal (l/h)	100 – 250
Maximum work pressure (bar)	10
Temperature (ºC)	177
Absorption grade	95 %
Emissivity	5 %
Maximum number of collector in shunt	8

Table 3.1.1.1 Technical characteristics

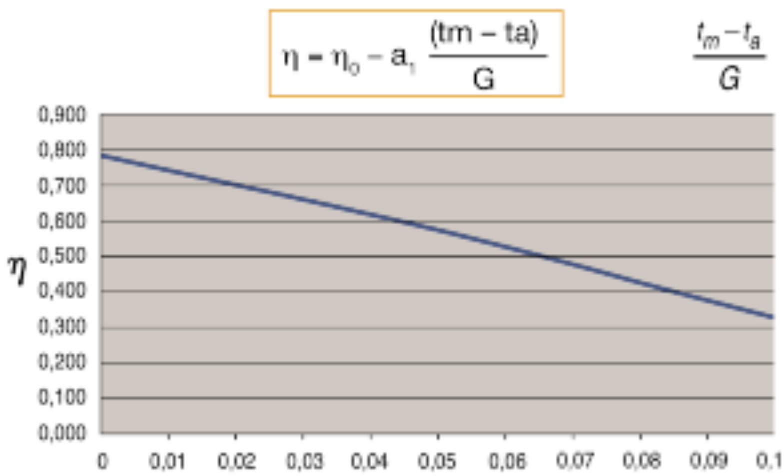

Figure 3.1.1.1 Efficiency curve

3.1.2 Daily water production calculation

In order to know how many litres of water the hotel needs, *"Codigo tecnico de edificacion"* should be consulted. There is a table that shows that a Hotel/Hostel** requires 40 litres per bed. So the total litres per day, according to the amount of beds that the hotel has are as explain in the following equation:

HW = 5 rooms x 2 people/room x 40 liters/day = 400 liters

As an accumulator is needed, a 400 litres accumulator should be chosen but as there is any of such capacity, a 500 litres accumulator is chosen in order to provide those litres.

3.1.3 Accumulator

The accumulator data is taken from the same catalogue as solar collectors. The model selected is *Milox-In 500 PB with manhole*. Technical characteristic are shown in the tables below. The first one is when working with boiler and the second one is when working with solar energy.

Milox-In 500 PB								
		Working with boiler						
Capacity (l)	**Exchange surface (m^2)**	**Exchange Power (kW)**	**Peak production (l/L*h)**	**Load primary losses (m.c.a)**	**Volume (l)**	**Weight (kg)**	**Insulation type**	**Insulation thickness (mm)**
500	2.11	77,3	2110	0.43	6.37	114	Crosslinked Polyethylene	35

Table 3.1.3.1 Technical characteristic when working with boiler

Milox-In 500 PB								
		Working with solar energy						
Capacity (l)	**Exchange surface (m^2)**	**Exchange Power (kW)**	**Peak production (l/L*h)**	**Load primary losses (m.c.a)**	**Volume (l)**	**Weight (kg)**	**Insulation type**	**Insulation thickness (mm)**
500	2.11	9.25	942	0.43	6.37	114	Crosslinked Polyethylene	35

Table 3.1.3.2 Technical characteristic when working with solar energy

3.1.4 Hydraulic Group

The hydraulic group is the circulation unit with the ability to regulate the flow based on the number of solar collector. The model chosen is *Cointra Grupo Solar 4* and the technical characteristics are explain in the following table:

Grupo Solar 4	
Flow regulator (l/min)	0.3 – 6
Pump speed number	3
Maximum number of collectors	4
Maximum work pressure (bar)	8
Maximum work temperature (ºC)	120
Manometer range (bar)	0 – 10
Security valve calibration (bar)	6
Connections (mm/inch)	DN 25/1’’
Dimensions (tall – wide) (mm)	437 – 252

Table 3.1.3.1 Hydraulic group technical characteristics

3.1.5 Mixing valve

Thermostatic mixing valve is designed for solar thermal installations with auxiliary boilers to support the system. It has some important advantages that are explained below and in table 3.1.4.1 technical characteristics are explained.

1) The thermostatic mixing valve uses 100 % of solar energy while gas consumption and boiler maintenance is considerably reduced.
2) Using the thermostatic mixing valve ensures that the boiler’s burner starts up only when the temperature supplied by solar collectors is less than what the user is requesting. When this happens the boiler’s burner provide the energy needed to raise the temperature to the value selected.
3) Whatever flow demand is required the temperature stability is assured thanks to the thermostatic mixing valve. There is a significant gas consumption saving comparing it with others. Furthermore the boiler operation time is minimized so there is a reduction in boiler maintenances.

Technical characteristics	
Regulation temperature range (ºC)	30 - 65
Precision (ºC)	± 2
Maximum static pressure (bar)	14
Maximum entrance temperature (ºC)	85

Table 3.1.4.1 Technical characteristics

3.1.6 Solar thermal collectors calculation

So as to know how the installations is going to be, an important factor should be taken into account firstly, the minimum solar contribution. This depends on the location of the hotel because depending on the area the minimum solar contribution varies. In this case and according to regulations, the minimum solar contribution is 50 %.

Figure 3.1.6.1 shows the different areas of solar contribution in Spain. It is divided in 5 areas and the country hotel is situated in area III

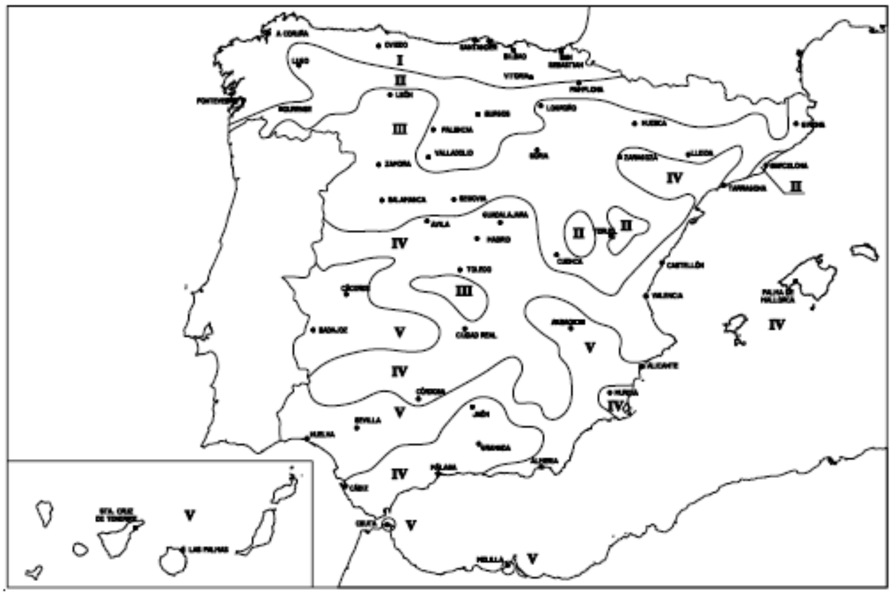

Figure 3.1.6.1 Spanish solar contribution areas

In order to complete the design of the collector installation, there is helpful software supplied by *Cointra*, in where some steps must be followed so as to get the final number of collectors and the energetic calculations. These are the steps followed:

<u>Step 1:</u> Search the location in where the installation is going to be performed and enter the minimum solar contribution obtained above.

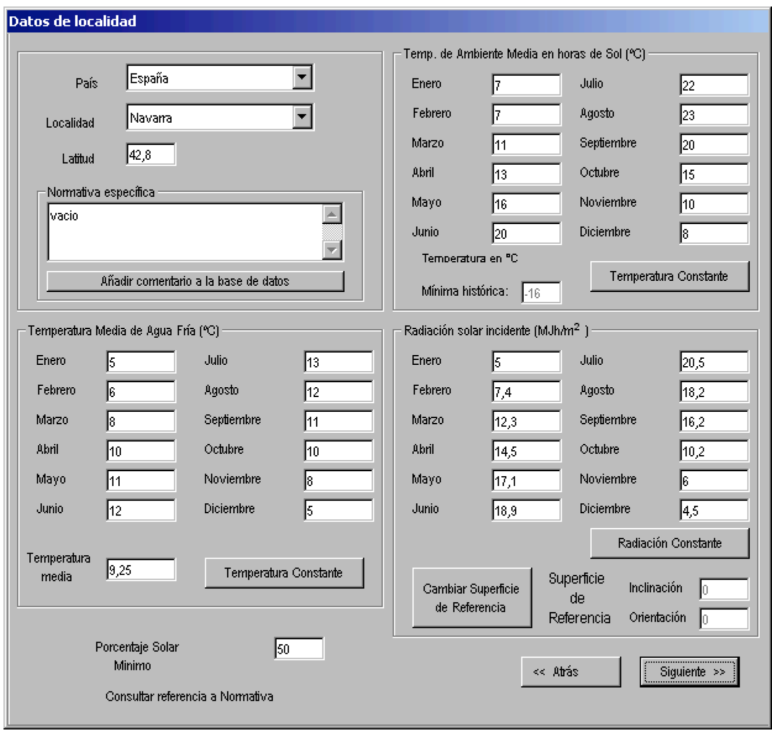

Figure 3.1.6.2 First step

Step 2: Introduce the daily water consumption. It is going to be supposed that the country hotel is full occupied.

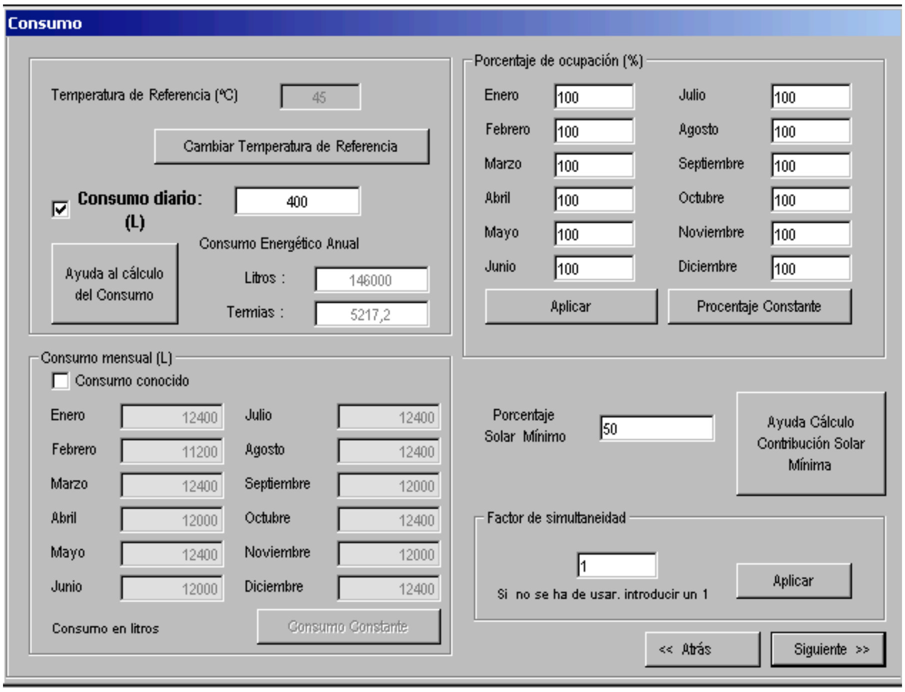

Figure 3.1.6.3 Second step

Step 3: Select the solar collector chosen above.

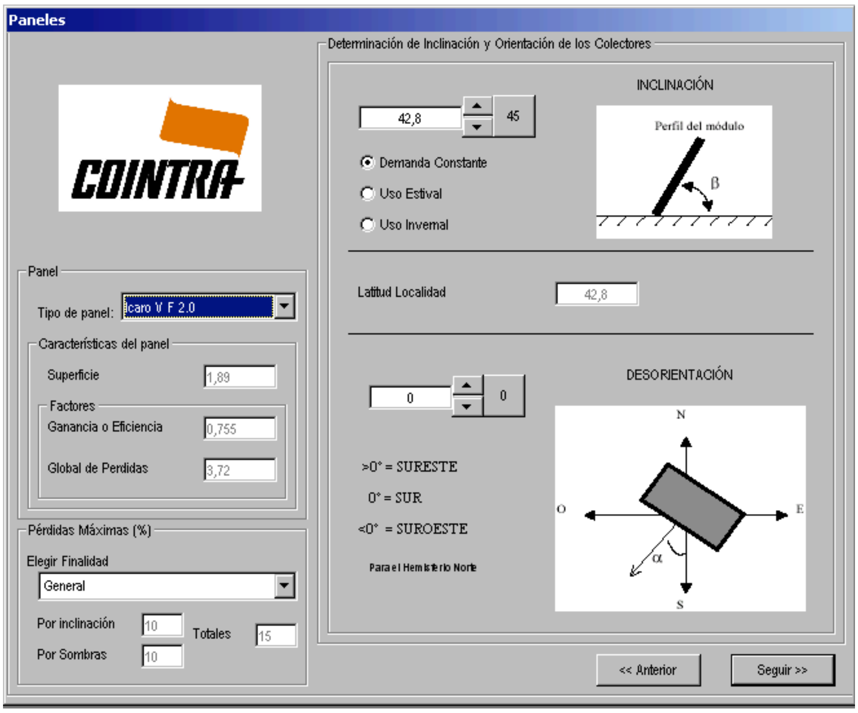

Figure 3.1.6.4 Third step

Step 4: Introduce the boiler capacity.

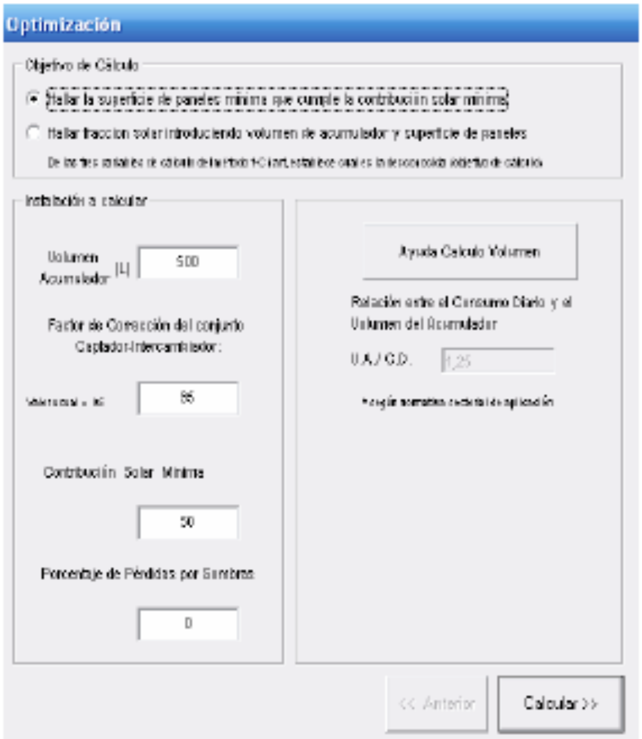

Figure 3.1.6.5 Fourth step

Step 5: Final calculation is done and it is shown in the table below.

Month	Average outdoor Temperature (ºC)	Average water Temperature (ºC)	Solar Radiation (MJ/m^2)	Month consumption (l)	Energy needs (kWh)	Energy production (kWh)	Solar Contribution
January	7	5	5	12400	576.67	164.35	0.285
February	7	6	7.4	11200	507.84	208.72	0.411
March	11	8	12.3	12400	533.42	341.39	0.640
April	13	10	14.5	12000	488.31	334.49	0.685
May	16	11	17.1	12400	490.17	364.69	0.744
June	20	12	18.9	12000	460.41	370.17	0.804
July	22	13	20.5	12400	461.34	416.59	0.903
August	23	12	18.2	12400	475.75	423.89	0.891
September	20	11	16.2	12000	474.36	425.50	0.897
October	15	10	10.2	12400	504.59	340.60	0.675
November	10	8	6	12000	516.21	213.71	0.414
December	8	5	4.5	12400	576.67	163.2	0.283
Annual	14.33	9.25	12.57	12166.67	505.48	313.94	0.64

Table 3.1.6.1 Energy calculations

Figure 3.1.6.6 Thermal solar proportion

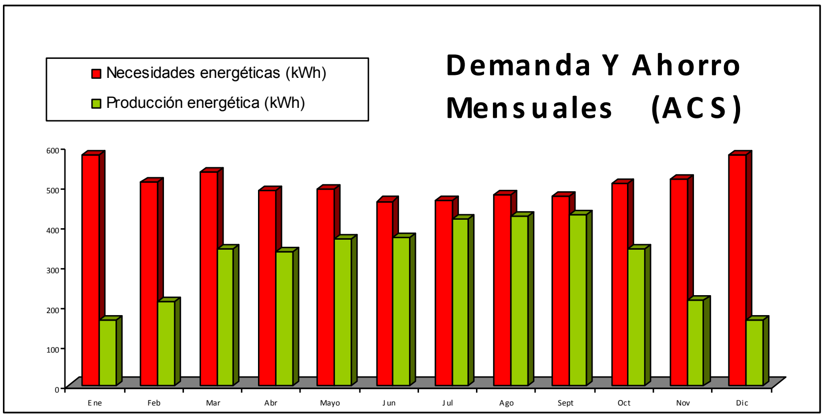

Figure 3.1.6.7 Monthly needs and savings

3.1.7 Support equipment

Solar thermal installation needs support equipment because in some specific moments it may have problems to supply all the hot water demand. That's the reason why a gas boiler is going to be installed to ensure good supplies of hot water. The boiler will be operating only when it is strictly necessary. It has been chosen because pollute less than a diesel boiler and it has higher yield.

The boiler has been selected from the *Cointra* catalogue. It is a *Superlative 35 E* model, which is one of the most powerful boilers of this company. It is a wall – mounted boiler to achieve energy savings and it has been chosen because of the following reasons:

- These models are especially recommended due to low NO_x emissions (best rating: Class 5 according to EN 297/A)
- The range of *Superlative* boilers provide a really high yield of about 109.3 % (30 % of its maximum power) so a significant energy saving results.
- It can work seamlessly with preheated water from solar thermal installations owing to its electronics control components.

The following table shows the technical characteristic of the *Superlative 35 E* model.

Superlative 35 E			
		Maximum Power	Minimum Power
General Data	Category	II 2H 3P	
	Type	C13, C23, C33, C43, C53, C63, C83, B23, B33	
	Combustion chamber	Watertight	
	Switching-on	Electronic	
	Flame control	Ionization	
Power/yield	Nominal energetic consumption (kW)	34.8	6.5
	Nominal thermic power (80º - 60º) (kW)	34.2	6.3
	Reduced thermic power (50º - 30º C) (kW)	36.7	6.9
	Nominal yield (80º - 60º) (%)	99.5	97.8
	Reduced yield (50º - 30º C) (%)	104.7	107.1
	Yield at 30 % of nominal power (%)	109.1	
	Energetic yield (Dir.92/42 CEE)	****	
Heating system data	Maximum pressure (bar)	3	
	Expansion vase capacity (l)	10	
	Expansion vase pressure (bar)	1	
	Temperature regulation (ºC)	20 – 90	
	Maximum tall of gauge pump (600 L/h) (m.c.a)	5.7	
	Minimum pressure (bar)	0.8	
	Antifreeze temperature (ºC)	5	
Hot water data	Maximum pressure (bar)	10	
	Temperature regulation (ºC)	40 - 55	
	Water flow ΔT 25 ºC (l/min)	19.6	
	Water flow ΔT 30 ºC (l/min)	16.3	
	Minimum pressure	0.25	
Gas feeding	Type	G.N/G.L.P	
	Maximum consumption G20 (m^3/h)	3.68	0.69
	Feeding pressure G20 (mbar)	20	
	Maximum consumption G31 (kg/h)	2.73	0.51
	Feeding pressure G31 (mbar)	37	
Electric supply	Voltage/Frequency (V/Hz)	230/50	
	Maximum power (W)	140	
	Electric protection grade (IP)	X5D	
Weight	Weight (kg)	42	

Table 3.1.6.1 Superlative technical characteristic

CHAPTER 4

4.1 Solar panels

Photovoltaic modules consist of a set of cells that produce electricity from the light that strikes them. Maximum power that they can deliver is called peak power.

When the assembly is exposed to sunlight, photons contained in the light share its energy to the semiconductor materials that can break the potential barrier of the P – N junction and exit through an external circuit, producing power. *Figure 4.1.1* shows how solar panels work.

The smallest semiconductor module with P –N junction and therefore capable of producing electricity is called photovoltaic cell. These solar cells are combined in certain ways to achieve the desired power and voltage. This set of cells on appropriate stand and adequate coatings in order to protect them is what forms a solar panel.

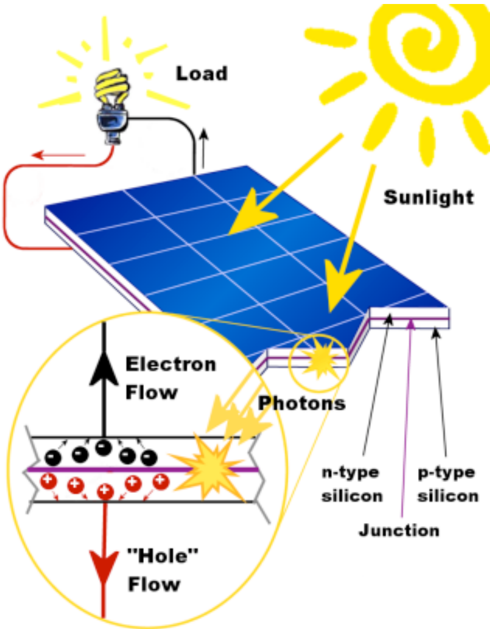

Figure 4.1.1 Solar panels way of producing electricity

Solar panels can be divided in three different types:

1) Monocrystalline: This type is made of sections of single silicon crystal (recognizable by their round or hexagonal shape). Their yields are higher than the rest.
2) Polycystalline: They are called so because they are built with small crystallized particles.
3) Amorphous: These type of cells are made with silicon not crystallized.

Its effectiveness is greater the larger are the crystals, but also its weight, thickness and cost. Monocrystalline cells yield is of about 20 % while amorphous may not reach 1 %, however it cost and weight is much lower.

4.1.1 Solar panel election

Taking into account what it has been said in sections above the panel chosen is a monocystalline because of its high yield. In order to carry out the installation a *Sanyo HIT 215 NHE Series* model is chosen. This solar cell is made from thin single silicon crystal surrounded by ultra-thin layers of amorphous silicon. This solar cell is environmentally friendly because it requires only 200 ºC for the links formation so this helps to save energy. The flat design is of about 200 μm think (conventional solar cell is of about 350 μm) so it helps to save silicon. The following table shows the technical characteristic of the solar panel.

Electric specifications		
Maximum power (W)		215 (+10 % - 5 %)
Voltage at maximum power (V)		42
Current at maximum power (A)		5.13
Open circuit voltage (V)		51.6
Dead short current (A)		5.61
Minimum power (W)		204.3
Maximum voltage (V)		1000
Temperature coefficient	**Pmax**	- 0.3 (%/ºC)
	Voc	- 0.129 (V/ºC)
	Isc	1.68 (mA/ºC)

Table 4.1.1.1 Technical characteristics

This *Sanyo HIT 215 NHE Series* solar panel has a cell efficiency of 19.3 % and module efficiency of 17.2 %

The solar panel dimensions are explained in the following table and depicted in *figure 4.1.1.1.*

General specifications	
Large (mm)	1570
Wide (mm)	798
Tall (mm)	35
Weight	15

Table 4.1.1.2 Solar panel dimensions

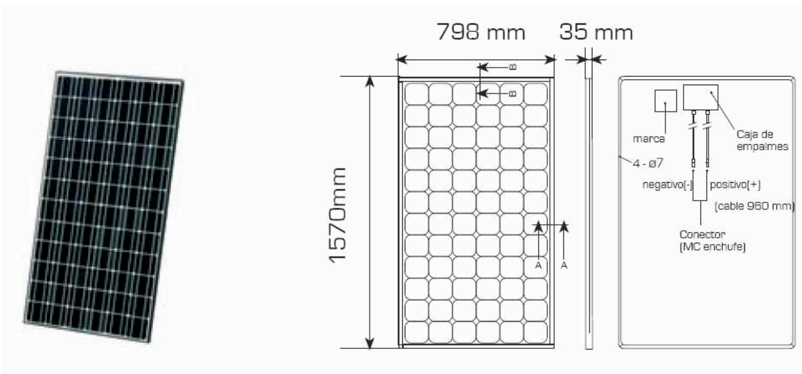

Figure 4.1.1.1 ***Sanyo HIT 215 NHE Series*** **Model dimensions**

4.2 Calculation of the solar panels installation

In order to size solar panels installation, the hotel needs must be taken into account and then calculate the necessary energy. Once that data is obtained and knowing the incident radiation (hps), the number of solar panels can be calculated.

Besides, if a higher depreciation of the installation want to be achieved, the installation will be connected to the network. Thus, the energy produced will be sold because its price is higher than the purchase price.

4.2.1 Electric loads

So as to determine the size of the installation the table below shows the electrical consumptions of electrical devices that can be found in a house.

Electric device	Power (W)
Dishwasher	2200
Washing machine	2200
Fridge	200
Freezer	135
TV	100
Low consumption bulbs	14 – 32
Fluorescent	58
Oven	3380
Extractor hood	215
Induction plate	7200
Boiler	140
Blender	300
Vacuum	500
Video	50
Microwaves	800
Toaster	800
Computer	100
Iron	1000

Table 4.2.1.1 Electric devices power

As it can be seen in the table above electric devices that use electric energy to heat need too much power to work. That's why these devices are not recommended to use with solar panels installations.

4.2.1.1 Energy needs

Energy needs in function of the hours of use of the electric devices is going to be determined. Some devices are switched on throughout the day. The following table shows the results.

Energy needs				
Electric Device	**Quantity**	**Power (W)**	**Time of use**	**Energy (Wh/day)**
Low consumption bulbs	60	14	3	2520
Low consumption bulbs	8	25	1	200
Low consumption bulbs	5	32	2	320
Fluorescent	5	58	4	1160
TV	6	80	2	960
Video	1	50	1	50
Vacuum	1	500	0.15	75
Computer	1	100	2	200
Toaster	1	800	0.1	80
Microwaves	1	800	0.15	120
Blender	1	300	0.15	45
Extractor hood	1	215	3	645
Dishwasher	1	2200	1	2200
Boiler	1	140	-	-
Washing machine	1	2200	0.5	1100
Fridge	1			200
Freezer	1			135
Total				10010

Table 4.2.1.1.1 Energy Wh/day

4.2.2 Incident radiation

It is necessary to look radiation tables to determine the incident radiation of the place. Those tables can be found in the "*Instituto Navarro de Metereologia".* Then the generation capacity needs a unit change in accordance to the following equation:

$$1\text{kWh} = 3600\text{kJ}$$

Solar radiation	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
kJ/m^2/day	13097	15116	17506	19145	19723	19805	19745	19316	17982	15613	13337	12274
kWh/ m^2/day	3.64	4.20	4.86	5.32	5.48	5.50	5.48	5.37	5.00	4.34	3.70	3.41

Table 4.2.2.1 Solar radiation

After changing the unit the incident radiation is being divided between the radiation power in order to get the sun peak hours.

$$hps = \frac{Incident\,radiation\left(kWh/m^2/day\right)}{Radiation\,power\left(kWh/m^2\right)}$$

Solar radiation	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Hps/day	3.64	4.20	4.86	5.32	5.48	5.50	5.48	5.37	5.00	4.34	3.70	3.41

Table 4.2.2.2 Sun peak hours

4.2.3 Number of solar panels calculation

By following the equation below the number of solar panels can be calculated. These calculations must be done in the worst situation, which is in December. *Sanyo HIT 215 NHE Series* panel peak power is 215 W.

$$Number\ of\ solar\ panels = \frac{Necessary\ energy\left(Wh/day\right)}{Panel\ peak\ power\left(Wp\right)\cdot Solar\ Radiation\left(hps/day\right)}$$

$$Number\ of\ solar\ panels = \frac{10010\left(Wh/day\right)}{215\left(Wp\right)\cdot 3.41\left(hps/day\right)} = 13.65\ solar\ panels$$

As it can be seen 14 solar panels must be installed. It is able to work with 12 or 24 V as a consequence of having an even number of panels.

4.2.4 Solar panels connection

This installation has 14 solar panels with a power of 215 W and a voltage of 24 V.

4.2.4.1 Series connection

The advantages of connecting solar panels in series are that the current get smaller and therefore wires sections are lower. However, the main disadvantage of this type of connection is that voltages will be really high so it is dangerous. Besides, if there is a failure the entire installation would be out of service but at least they are easy to solve.

4.2.4.2 Parallel connection

This type of connection would be the opposite as the one explained above because of not having to add all voltages. In the other hand, wires sections would be much bigger because the current is higher. This makes the installation a little bit more expensive.

4.2.4.3 Connection election

If all advantages and disadvantages are taken into account a mix connection has been chosen. In this case 7 solar panels are going to be connected in series and the 7 solar panels left as well. Then these two installations are going to be connected in parallel. The reason why it is made so is that the voltage is not high and so the current so the wire section is not too big.

If all solar panel are connected as mention above the following information is got:

$$I_{max}\ panel = \frac{P_{max}\ panel\left(W\right)}{V_{max}\ panel\left(V\right)}$$

$$I_{max}\ panel = \frac{215\left(W\right)}{42\left(V\right)} = 5.13\,A$$

$$P_{max}\ solar\ installation = V_{max}\ panel \cdot I_{max}$$

$$P_{max}\ solar\ installation = 7 \cdot 42 \cdot 2 \cdot 5.13 = 3016.44\,W$$

4.2.5 Minimum distance between solar panels

The distance d, measure along the horizontal row between obstacles of height h, which can cause shadows shall ensure a minimum of 4 hours of sun around midday on winter solstice. This distance d is greater than the value obtained by the expression:

$$d = \frac{h}{\tan\left(61^{o} - latitude\right)}$$

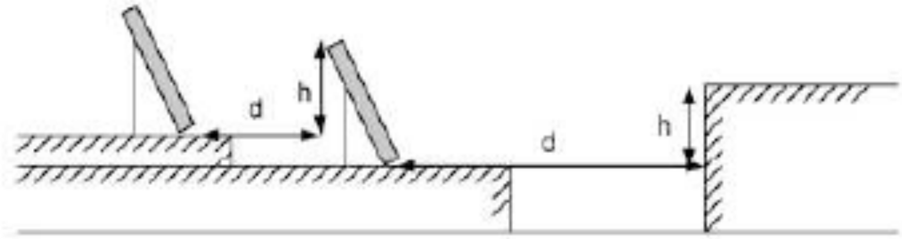

Figure 4.2.5.1 Distance between solar panels rows

Applying h to the difference between the top part of the row and the bottom of the next and substituting the values on the equation above the minimum distance is obtained:

$$d = \frac{1}{\tan\left(61^{o} - 42\right)} = 2.9\,m$$

4.3 Inverter

An inverter is a circuit used to convert DC power to AC power. Its function is to change an input DC voltage into an output AC voltage with the magnitude and frequency wanted. Inverters are used in wide variety applications.

The installation of the inverter in this case is going to be used to convert DC power generated by solar panels into AC power in order to be injected into the network supply.

A simple inverter consists of an oscillator, which controls a transistor that is used to break the incoming stream and generate a square wave. This square wave feeds a processor that softens it and makes a quite similar sine wave. It also produces the necessary output voltage. The output voltage waveforms should be sinusoidal so a good technique to accomplish this is to use the PWM technique.

4.3.1 Inverter election

Once the installation values have been calculated with a power of 3016.44 W and a current of 5.13 A a single phase inverter can be elected. Taking into account these values, which have been calculated in sections above, an inverter has been chosen.

Xantrex GT is a high yield and efficient inverter. It has a yield of about 95 %. It is also easy to install, modern and with a functional design. It increases solar panels reception to the network due to its high power efficiency in conversion and high thermal efficiency. This minimizes heat losses.

When the inverter is going to be installed it has to be mounted to a wall, then connect DC input to the solar panels array and the AC output to the network. *Figure 4.3.1.1* explains a typical installation.

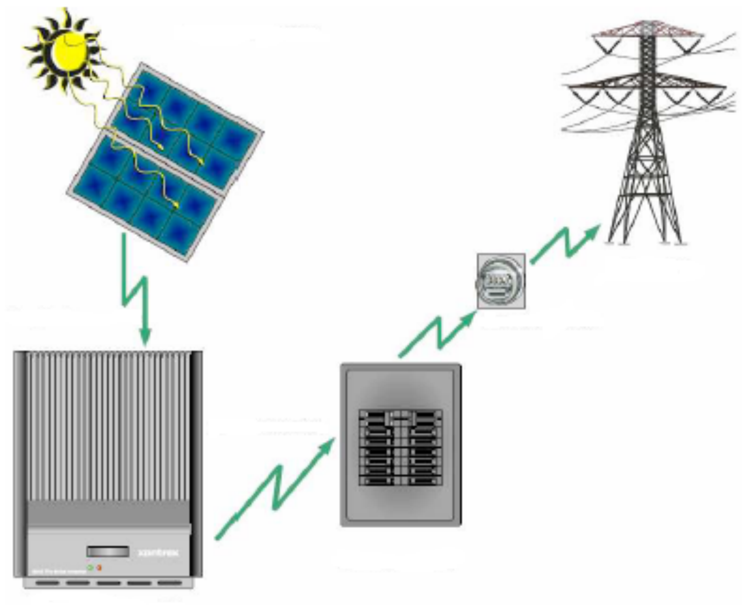

Figure 4.3.1.1 Installation diagram

4.3.2 Technical characteristics

Xantrex GT 3.8 SP	
Maximum AC output (W)	3800
Nominal AC output (W)	3300
Waveform	Pure sinusoidal wave
AC Voltage (V)	195 – 253 AC (230 VAC)
AC Frequency (Hz)	49 – 51 (50 Hz)
Input DC voltage range (V)	195 – 600
Voltage range in maximum power	195 – 550
Current distortion AC	< 3 %
Power factor	> 0.99
Maximum inverter efficiency	95.30 %
Euro-efficiency	94.50 %
Output maximum current (A)	19 AC
Current protection (A)	20
Night consumption (W)	1

Table 4.3.2.1 Technical characteristics

CHAPTER 5

5.1 Energy and CO_2 savings

In this point the aim is to show the amortization and savings got in all the installations. In that purpose table 5.1.1 shows kWh prices that it has been taken.

	kWh cost
kWh electric (€)	0.191212
kWh gas (€)	0.116127
kWh diesel (€)	0.102123

Table 5.1.1 kWh costs

5.1.1 Solar thermal energy system

Number of collectors	3
Collectors surface (m^2)	5.67
Minimum solar contribution (%)	50
Solar fraction reached	0.636

Table 5.1.1.1 Solar thermal installation data

Month	Solar Radiation (MJ/m^2)	Energy needs (kWh)	Energy production (kWh)	Solar Contribution
January	5	576.67	164.35	0.285
February	7.4	507.84	208.72	0.411
March	12.3	533.42	341.39	0.640
April	14.5	488.31	334.49	0.685
May	17.1	490.17	364.69	0.744
June	18.9	460.41	370.17	0.804
July	20.5	461.34	416.59	0.903
August	18.2	475.75	423.89	0.891
September	16.2	474.36	425.50	0.897
October	10.2	504.59	340.60	0.675
November	6	516.21	213.71	0.414
December	4.5	576.67	163.2	0.283
Annual	12.57	505.48	313.94	0.64

Table 5.1.1.2 Solar contribution

The following table shows the energy needs and the energy production throughout the year.

Annual data	
Annual energy needs (kWh)	6065.74
Annual energy production (kWh)	3767.3

Table 5.1.1.3 Annual data

With the values of the table below energetic savings calculations can be made and the amortization period as well. The following table shows a comparison between different types of energy.

	Electricity	Gas	Diesel
Annual economic savings (€)	720.35	437.48	384.73
Installation cost (€)	7730	7730	7730
Amortization (years)	10.7	17.7	20.1

Table 5.1.1.4 Savings and amortization times

Average life of these installations is approximately 20 years. Since then some changes should be done.

Once the amortization time is completely done CO_2 emissions are going to be calculated. In order to do this calculation different energy emissions have been searched because it varies depending on the source.

Energy source	CO_2 grams per kWh generated	Annual energy production (kWh)	Annual CO_2 emissions savings (kg)
Carbon	950	3767.3	3578.94
Fuel	750	3767.3	2825.48
Natural Gas	480	3767.3	1808.30
Combine cycle	350	3767.3	1318.56

Table 5.1.1.5 Annual CO_2 emissions savings depending on the energy source

5.1.2 Solar panels energy system

The price of kWh sold to "*Red Electrica"* (Spanish network company) is 0.4464 €. In order to do a correct energy calculation a surface of 1.05 m^2 and a yield of 19.3 % in accordance to catalogue have been chosen.

Month	Effective radiation ($kWh/m^2/day$)	Energy ($kWh/m^2/day$)	Energy ($kWh/m^2/day$)	Incomes
January	3.64	10.33	320.14	142.91
February	4.20	11.92	333.64	148.94
March	4.86	13.79	427.44	190.81
April	5.32	15.09	452.80	202.13
May	5.48	15.55	481.97	215.15
June	5.50	15.60	468.12	208.97
July	5.48	15.55	481.97	215.15
August	5.37	15.24	472.29	210.83
September	5.00	14.19	425.57	189.97
October	4.34	12.31	381.70	170.39
November	3.70	10.50	314.92	140.58
December	3.41	9.67	299.91	133.88
Annual incomes				2169.71

Table 5.1.2.1 Solar panels system incomes

Once annual incomes are calculated the following table shows the amortization time of the solar panels system.

Solar panels system amortization	
Installation cost (€)	29791.17
Annual incomes (€)	2169.71
Amortization (years)	13.7

Table 5.1.2.2 Solar panels system amortization

As it can be seen in less than 14 years the investment is recovered. Total live of this type of installation is about 40 years so benefits of an approximate amount of 56412.46 € will be received.

Back up in table 5.1.1.5 CO_2 emissions were calculated and the same process is going to be done in the following table so as to see CO_2 emissions savings.

Energy source	CO_2 grams per kWh generated	Annual energy production (kWh)	Annual CO_2 emissions savings (kg)
Carbon	950	4860.47	4617.45
Fuel	750	4860.47	3645.35
Natural Gas	480	4860.47	2333.03
Combine cycle	350	4860.47	1701.17

Table 5.1.2.3 Annual CO_2 emissions savings depending on the energy source

5.1.3 Geothermal energy system

In order to do calculation in this section it has to be considered when the installation is used during the coldest and the warmest moths. It use is approximately of about 5 hours per day. The following table shows its consuptions

	Months	kWh/day	kWh/month
Winter thermal load	November	61.2	1836
	December	61.2	1897.2
	January	61.2	1897.2
	February	61.2	1713.6
	March	61.2	1897.2
Summer thermal load	June	129.85	3895.5
	July	129.85	4025.35
	August	129.85	4025.35

Table 5.1.3.1 Climate installation consumption

When the system is heating a quarter of the heat energy obtained should be provide (400 % of yield) and when is cooling it needs just a fifth (500 % yield).

	Heat geothermal pump	Diesel low temperature boiler	Gas boiler
Annual energy needs (kWh)	21187.4	21187.4	21187.4
COP	4.5	0.94	1.1
Energy consumption	4708.31	22539.79	19261.27
Annual cost (€)	900.29	2301.83	2236.75

Table 5.1.3.2 Economic comparison

In the following table there is a comparison between different systems to warm the house but they are not capable of cooling the house. This comparison gives us an idea of the savings when using a geothermal pump over all systems. A part from this there is going to be an amortization that is calculated in the table below.

Geothermal heat pump system amortization	
Installation cost (€)	46011.1
Annual economic savings (€)	3151
Amortization (years)	14.6

Table 5.1.3.3 Geothermal heat pump amortization

The average life of this system is over 25 years and it is able to see that in more than 14 years the investment is recovered and till then benefits will begin.

The following table shows the annual CO_2 emissions savings comparing with different energy sources.

Energy source	CO_2 grams per kWh generated	Annual energy production (kWh)	Annual CO_2 emissions savings (kg)
Carbon	950	16479.09	15655.14
Fuel	750	16479.09	12359.32
Natural Gas	480	16479.09	7909.96
Combine cycle	350	16479.09	5767.68

Table 5.1.3.4 Annual CO_2 emissions savings depending on the energy source

5.1.4 Other savings factors adopted

- In order to save up 50 % of water, some devices are going to be put on taps.
- Dual flush valve installation in toilet will save 40 % of water.
- Rainwater collection throughout the roof channels in order to be transported to a tank and use it in irrigation.
- Low energy bulbs consumption.

CHAPTER 6

6.1 Economic quote

6.1.1 Climate control installation

Description	Number	Price per unit (€)	Total price €)
Crosslinked Polyethylene Pipe 16x1.8	2442	1.98	4835.16
Crosslinked Polyethylene Pipe 32x2.9	42	6.49	272.58
Insulation panel	412	15.91	6554.92
Tie clips	14	0.26	3.64
Perimeter base	200	1.58	556.16
Flowing and retardant additive	3	115.21	345.63
Collector system brass 10 (1 1/4’’)	1	861.69	861.69
Collector system brass 11 (1 1/4’’)	1	956.41	956.41
Flow meter	21	43.87	921.27
Underfloor collector boxes	2	161	322
Variable temperature control	2	1558.82	3117.64
Heat water – water pump reversible	1	6384	6384
Polyethylene pipe 32x2.9	5	176	880
Drillings	500	40	20000
Total installation cost			46011.1

6.1.2 Solar thermal installation

Description	Number	Price per unit (€)	Total price €)
Solar collector	3	635	1905
Accumulator	1	3515	3515
Hydraulic group	1	480	480
Mixing valve	1	100	100
Condensing boiler	1	1730	1730
Total installation cost			7730

6.1.3 Solar panels installation

Description	Number	Price per unit (€)	Total price €)
Solar panels	14	1854.38	25961.32
Inverter	1	2951.21	2951.21
IN/OUT counter	1	109.64	109.64
General switch 32 A	1	41.87	41.87
Earth leak breaker 40 A	1	52.28	52.28
Total installation cost			29791.17

Description	Total price €)
Climate control installation	46011.1
Solar thermal installation	7730
Solar panels installation	29791.17
Total quote	83532.27

CONCLUSIONS

The energy consumption when heating water will be reduced a 62 % comparing with other houses of this area because of the solar thermal installation. Besides this systems will be amortized.

As it has been seen in the project heating system used an innovative system such as the use of geothermal pump that will produce energy savings of 78 %. Then the temperature is transferred to the house through an underfloor heating system whose temperature is nearly ideal and uses low-temperature water so that there is going to be an energy saving. In order to perform this installation a significant investment is required but this system will be amortized in 14 years, which is interesting because it has a total life of about 25 years. It is an expensive installation due to the fact that it is necessary to drill very deep.

Moreover the solar panel installation is connected to the network so it will produce incomes and in less than 14 years it is amortized and producing only incomes. The total life of the installation is approximately 40 years.

Furthermore with the installation of the water saving devices, the water consumption will be reduced a 50 %.

Environmentally talking it is able to see a substantial reduction in CO_2 emissions. This is thanks to the installation of all of the installations explained throughout this project. With solar thermal system is able to reduce more than 3 tons of CO_2 emissions, with the geothermal pump 10.7 tons and finally, with the solar panels installation CO_2 emissions will decrease more than 3 tons. So the house will reduce 17 tons annually.

Therefore if houses like this were more common as this one significant savings either in energy or CO_2 emissions would be achieved. It is also true that this type of houses need a high investment but it is not a long time to recover the investment.

Besides, the project described would be perfectly feasible in real life.

Finally, such a sustainable way of build houses is going to be a fact in the future because not only non renewable energy are more expensive but the environment is a gift that must be looked after.

BIBLIOGRAPHY

Fernandez Salgado, J. M (2007). *Guia completa de la energia solar fotovoltaica.* Madrid: AMV Ediciones

Ruiz Moya, C. (1997). *Carga termica de climatizacion.* Barcelona: Grupo Editorial CEAC

Aplicaciones de calefaccion y climatizacion. Manual tecnico. (http://www.uponor.es)

Manual de aislamiento en la edificacion. Isover.

Reglamento electrotecnico para Baja Tension (REBT).

Reglamento Instalaciones Termicas en Edificios (RITE)

http://www.soliclima.com

http://www.isover.net

http://www.geotermiasolar.com

http://www.geornova.com

http://www.cointra.es

http://www.sitiosolar.com

http://www.icaen.net