1. ABSTRACT

The aim of this project is designing a heating system in a family house in order to achieve the satisfaction of the owners. This heating system will be designed to provide as much energy as possible in a renewable way.

The work of the project is going to be divided in different parts: first of all knowing everything about the building, the location, the dimensions, the number of rooms it has and also about the features of the weather in the place where is located, Mallorca. In this point will be included the calculations of the heat transfer through the walls, the windows and the roof and heat that the house needs in order to provide users with the most optimal conditions of comfort.

The second and the most important part of the project is the designing of the system. In this part all the features of the system will be described, as well as the different parts it has and the way it works. The first think treated is the different elements that make up the system and the function they have. Then the calculation designs are made, to know how many panels, meters of floor heating, the system will need. Finally it is made a description of the way the controlling temperature system works, explaining how the circuits are distributed, the processes the water follows... In this last point it is also said the importance to design a complementary system so that it can help the main in cloudy/foggy days or in really cold days.

Finally, the last part of the project includes the explanation of a secondary system that is used to take advantage of the energy from the solar panels in summer.

In conclusion in this project it is designed a controlling temperature system for a house in Mallorca, using the solar energy as the main energy source. Other systems like the complementary one for heating the water and the ones that will use the energy in summer are described, to help the house be more self-sufficient and make the living in it easier.

2. INTRODUCTION AND OBJECTIVES

2.1. INTRODUCTION

Nowadays it is hard to imagine the human life without energy, not only for the advantages it provides but for all the applications and necessities that it satisfies. Actually, the consumption of energy it is up to 10^{21} J per year, a number that shows the dependence the humans have to it. Even more, the human being is increasing the energy consumption and if the society continues to consume in that rhythm, we will finish with the natural resources because the consumption is faster than what the nature is able to generate. This means that in a sooner or later future, the humans will need to find other ways to obtain all the energy. These ways might be the renewables energies. It is because of this the importance to take advantage of using renewables energies.

2.2. OBJECTIVES

The main objective of this project is designing a heating system using renewable energies. Apart from that, other objectives are learning the way of designing a control temperature system, acquiring knowledge of the solar energy implementation, studying the best way for realising the heat in one heat system and finding ways for using the energy in summer, because in that period the amount of sun is bigger and the house will not need to be heated.

3. LOCATION AND DESCRIPTION OF THE BUILDING

3.1. LOCATION OF THE FAMILY HOUSE

The building that is going to be studied is a family house. It is located in a small village in the centre of Malloca (Spain). The house is divided in two floors and it has a total surface of 225,5 m^2.

Location: Camí del Rafal del Polls, 1, 07320 Santa Maria del Camí. Baleares (Spain)

Image 1: Map location

Image 2: Family house 1st view

Image 3: Family house 2nd view

3.2. BUILDING DIMENSIONS

In order to facilitate the calculations, the house is divided in sections. Each section consists of one or more rooms in which heat transfer is calculated.

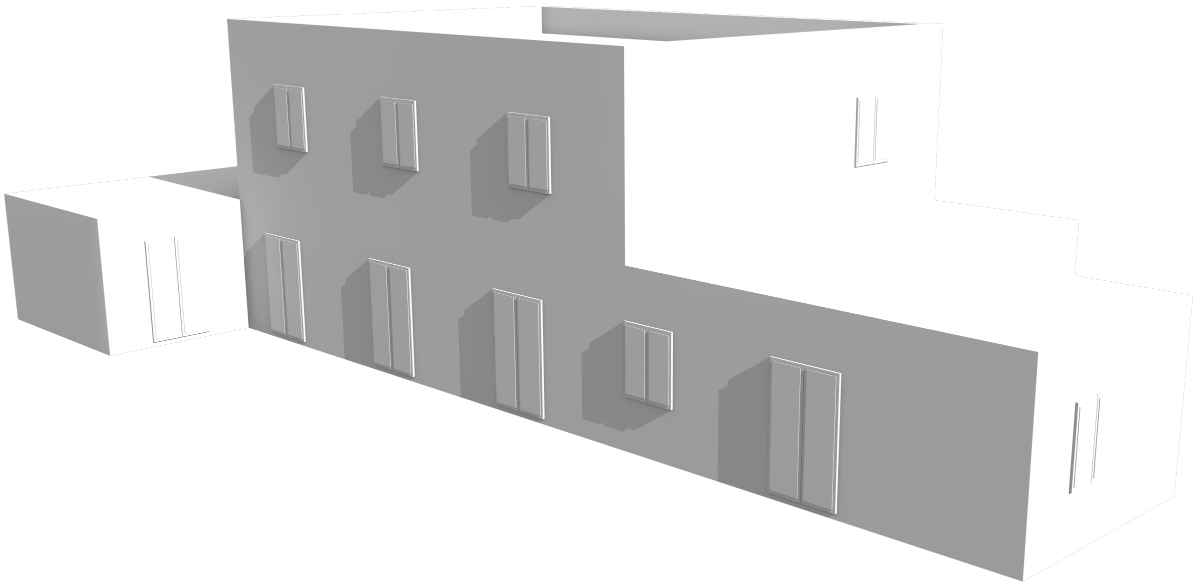


Image 4: Frontal view of the family house

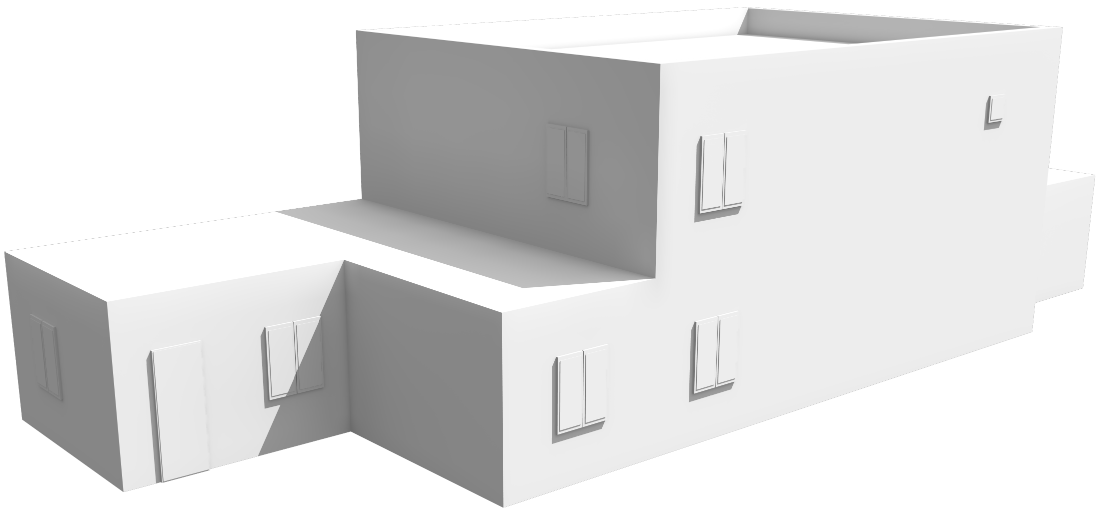


Image 5: Lateral view of the family house

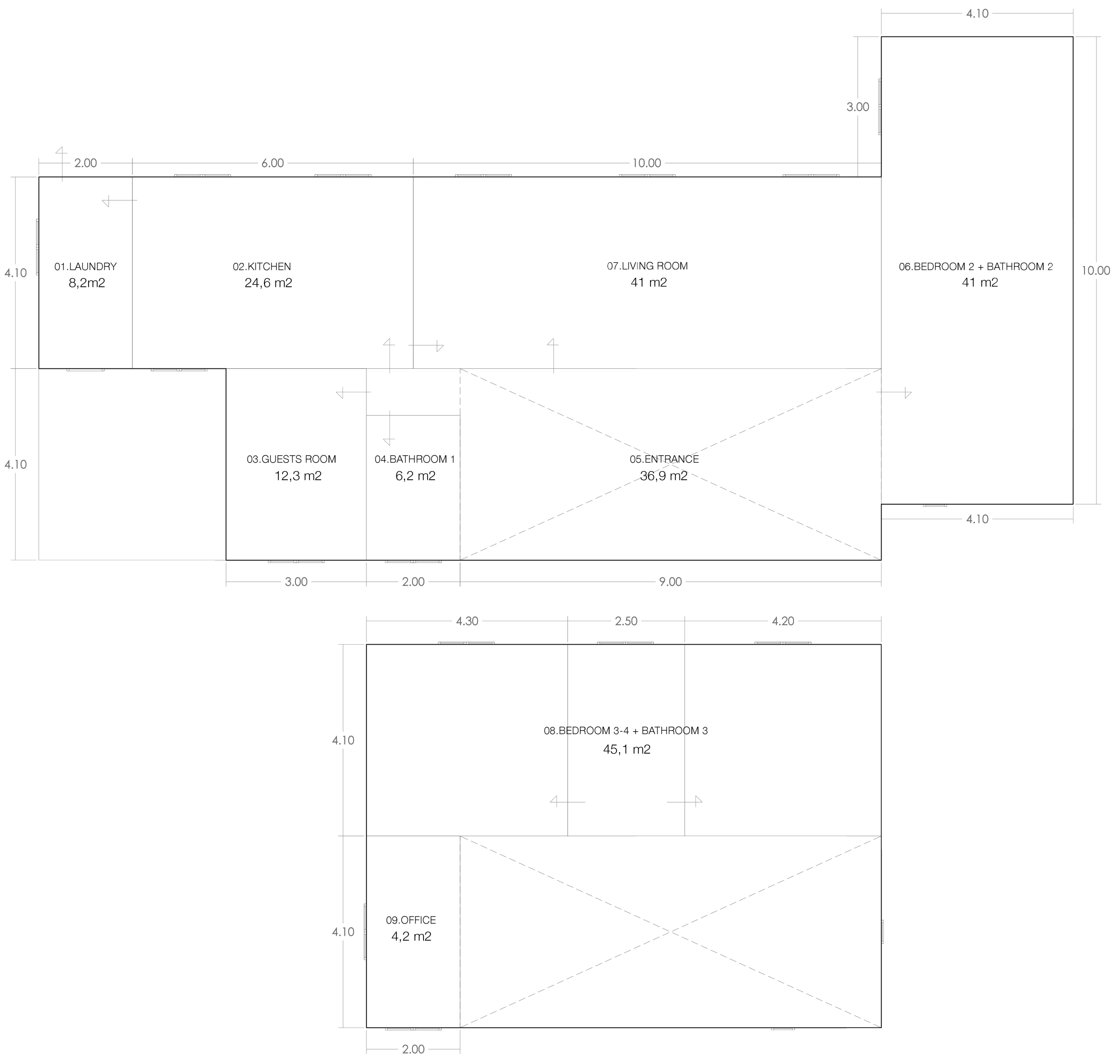


Image 6: Distribution and dimensions of the house

3.2.1. Exterior walls

To know the house's heat transfer first of all it is necessary to calculate the surfaces through whose the heat is transferred. In this point the wall surfaces in contact with the outside are calculated.

- Main floor:

Section 1: Laundry room

$$S_1 = 4{,}1 \cdot 2{,}65 + 2 \cdot (2 \cdot 2{,}65) = 21{,}465 \text{ m}^2$$

Section 2: Kitchen

$S_2 = 6 \cdot 2{,}65 + 2 \cdot 2{,}65 = 21{,}2\ m^2$

Section 3: Guest room

$S_3 = 4{,}1 \cdot 2{,}65 + 3 \cdot 2{,}65 = 18{,}815\ m^2$

Section 4: Bathroom 1 + corridor

$S_4 = 2 \cdot 2{,}65 = 5{,}3\ m^2$

Section 5: Entrance

$S_5 = 9 \cdot 2{,}65 \cdot 2 + 4{,}1 \cdot 2{,}65 + 1{,}2 \cdot 2{,}65 = 61{,}745\ m^2$

Section 6: Bedroom 2 + bathroom 2

$S_6 = 2 \cdot (4{,}1 \cdot 2{,}65) + 10 \cdot 2{,}65 + 3 \cdot 2{,}65 = 56{,}18\ m^2$

Section 7: Dinning room + living room

$S_7 = 10 \cdot 2{,}65 = 26{,}5\ m^2$

Main floor total: 211,205 m^2

- First floor:

Section 8: Bedroom 3 and 4 + bathroom 3

$S_8 = 2 \cdot (4{,}1 \cdot 2{,}65) + 11 \cdot 2{,}65 = 50{,}88\ m^2$

Section 9: Office

$S_9 = 4{,}1 \cdot 2{,}65 + 2 \cdot 2{,}65 = 16{,}165\ m^2$

First floor total: 67,045 m^2

Total exterior wall area: **278,25 m^2**

3.2.2. Windows:

To calculate the heat loses through the windows is needed to know the window surface.

Number of windows	Dimensions
10	1 m x 1,2 m
5	1,2 m x 2 m
3	0,5 m x 0,5 m
1	0,8 m x 2,1 m

Table 1 : Number and dimensions of the windows

*The subjection windows area, made of wood, has been considered negligible.

Total windows area: **26,43 m²**

3.2.3. Roof

Section 1: 8,2 m^2

Section 2: 20,5 m^2

Section 3: 12,3 m^2

Section 4: 0 m^2

Section 5: 36,9 m^2

Section 6: 41 m^2

Section 7: 0 m^2

Section 8: 45,1 m^2

Section 9: 8,2 m^2

Total roof area: **172,2 m^2**

3.2.4. Floor

*The floor has been considered negligible because the heat transfer through it is very small in comparison with the heat transfer through the walls and the windows, and it value will not change the result of the study.

3.3. MATERIAL CHARACTERISTICS

3.3.1 Exterior walls:

Materials:	δ_1 = width (m)	λ_2 (W/K·m)
Termoarcilla	0,2	0,3
Insulation	0,04	0,05

Table 2 : Material characteristics of the exterior walls

3.3.2. Windows:

Material	k(W/m^{2}K)	R = 1/k
Climalit 4x6x4	3,28	0,3077

Table 3 : Material characteristics of the windows

3.3.3. Roof

In order to simplify the calculations, the roof will be considered the same material as the exterior walls, in that way, the heat transfer between the exterior walls and the roof will be calculated together, joining both surfaces.

4. HEAT TRANSFER IN WINTER

4.1 DESIGN CONDITIONS

4.1.1. Outdoor design conditions:

The minimum average temperature of the coldest months of the year, that in the studied location is in January and February, is 5°C. For that reason, the study of the heating system design is focused on covering the needs of heating in the above conditions.

However, the temperature is not always regular, so there could be specific days when the temperature is lower than 5°C. On one hand is very important to considerate this situation in the extremely coldest days, but on the other is true that it would not be a useful design. For that reason, this project will be mainly focused on covering the needs in the normal conditions and for the extremely ones another complementary system will be designed.

- Minimum medium temperature: 5°C

*In the Annex there are the climatic conditions that are used in the studied location, Santa Maria del Camí, Baleares (Spain) obtained thanks to 'Temperature weather' in a study between 2009 and 2015.

4.1.2. Indoor design conditions:

The recommended conditions to achieve comfort in the indoor environmental during the winter are temperatures between 19-23°C. The most recommended temperature considering a proper balance between comfort and consume is 21°C, but it has been considered 22°C, to ensure that the system is capable of providing that temperature.

- Medium comfort temperature: 22°C

4.2. HEAT TRANSFER THROUGH EXTERIOR WALLS

The heat transfer has been divided in two parts, according to the material. First of all, heat transferred by the walls and the roof is calculated, and then the heat transferred by the windows. That heat is due to convection and conduction; heat due to radiation will be treated later.

S_{walls} = 278,25 m^2

S_{roof} = 172,2 m^2

S_{TOT} = 441,385 m^2

T_{out} = 5 ºC = 278,15 K

T_{int} = 22 ºC = 295,15 K

$$Q = k \cdot S \cdot \Delta T$$

$$k = \frac{1}{\frac{1}{\alpha 1} + \frac{\delta 1}{\lambda 1} + \frac{\delta 2}{\lambda 2} + \frac{1}{\alpha 2}}$$

α = coefficient of heat transfer ($W/m^2 \cdot K$)

δ = wall width (m)

<u>Air properties:</u>

Cp = specific heat capacity ($J \cdot g^{-1} \cdot K^{-1}$)

λa= thermal conductivity (W/(m·K))

ρ = density (kg/m^3)

μ = dynamic viscosity (kg/(m·s))

Pr = Prandtl's number

ν = kinematic viscosity (m^2/s)

4.2.1 OUT: α1 calculation

T_{out} air= 5 ºC = 278,15 K

T_{out} walls = 7 ºC = 280,15 K

$$Tm = \frac{Tout\ air + Tout\ walls}{2} = 279{,}15\ K$$

Air properties (Tm = 279,15 K, P = 101325Pa):

Cp = 1004

λa = 0,0244641 W/(m·K)

ρ = 1,26461149919 kg/m^3

μ = 1,74436773188·10^{-5} kg/(m·s)

Pr = 0,715883765522

$$\upsilon = \frac{\mu}{\rho} = \frac{1{,}74436773188 \cdot 10^{-5}}{1{,}26461149919} = 1{,}379370449 \cdot 10^{-5}\ m^2/s$$

Nu = Nusselt number

Gr = Grashof number

β_m = reverse the average temperature

Δt = temperature variation

g = gravity = 9,81 m/s^2

l = characteristic dimension = 2,65 m

· Table Gr – Pr:

Gr.Pr	**C**	**n**
0 ÷ 1·10^{-3}	0,45	0,0
1·10^{-3} ÷ 5·10^{2}	1,18	0,125
5·10^{2} ÷ 2·10^{7}	0,54	0,25
2·10^{7} ÷ 10^{13}	0,135	0,333

Table 4 : Gr-Pr, C and n coefficients

$$Nu = C \cdot (Gr \cdot \mathrm{Pr})^n = 227{,}9272754$$

$$Gr = \frac{g \cdot l^3}{v^2} \cdot \beta_m \cdot \Delta t = 6874437335$$

$$\beta_m = \frac{1}{Tm} = 3{,}582303421 \cdot 10^{-3}\ K^{-1}$$

$$\Delta t = (Tout\ walls - Tout\ air) = 2$$

$$\alpha_1 = \frac{Nu \cdot \lambda a}{l} = \frac{227{,}9272754 \cdot 0{,}0244641}{2{,}65} = 2{,}104164399\ W/m^2 \cdot K$$

4.2.2 IN: α2 calculation

T_{in} air= 22 ºC = 295,15 K

T_{in} walls = 20 ºC = 293,15 K

$$Tm = \frac{T\ in\ air + T\ in\ walls}{2} = 294{,}15\ K$$

g = 9,81 m/s^2

l = 2,65 m

Air properties: Tm = 294,15 K; P = 101325Pa

Cp = 1004

λa = 0,0255741 W/(m·K)

ρ = 1,20012340643 kg/m^3

μ = 1,82476773188·10^{-5} kg/(m·s)

Pr = 0,716375865743

$$\upsilon = \frac{\mu}{\rho} = \frac{1,82476773188 \cdot 10^{-5}}{1,20012340643} = 1,520483412 \cdot 10^{-5}\ m^2/s$$

·Table Gr – Pr: *

C = 0,135

Pr = 0,333

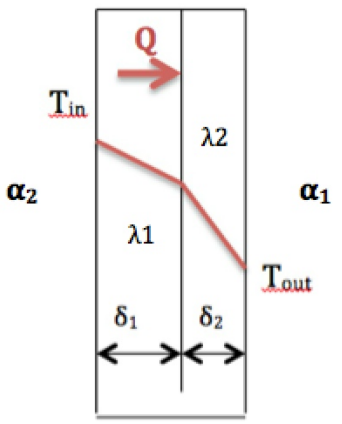
$$Nu = C \cdot (Gr \cdot \mathrm{Pr})^n = 209,968366$$

$$Gr = \frac{g \cdot l^3}{\upsilon^2} \cdot \beta_m \cdot \Delta t = 5369135931$$

$$\beta_m = \frac{1}{Tm} = 3,399626041 \cdot 10^{-3}\ K^{-1}$$

$$\Delta t = (Tout\ walls - Tout\ air) = 2$$

$$\alpha_2 = \frac{Nu \cdot \lambda a}{l} = \frac{209,968366 \cdot 0,0255741}{2,65} = 2,026321505\ W/m^2K$$



λ1 = 0,3 W/K·m
λ2 = 0,05 W/K·m
δ1 = 0,2 m
δ2 = 0,04 m

$$k = \frac{1}{\frac{1}{\alpha 1} + \frac{\delta 1}{\lambda 1} + \frac{\delta 2}{\lambda 2} + \frac{1}{\alpha 2}}$$

$$k = \frac{1}{\frac{1}{2{,}104164399} + \frac{0{,}2}{0{,}3} + \frac{0{,}04}{0{,}05} + \frac{1}{2{,}026321505}}$$

$$= 0{,}4106068276\ W/m^2K$$

$$Q_{walls} = 0{,}4106068276\ \frac{W}{m^2} \cdot 450{,}45\ m^2 \cdot (295{,}15 - 278{,}15)$$

$$= \mathbf{3144{,}28337\ W}$$

4.3 HEAT TRANSFER THROUGH THE WINDOWS

$S_{windows} = 26{,}43\ m^2$

$k_R = 3{,}28$

$$Q = k \cdot S \cdot \Delta T$$

$$k = \frac{1}{\frac{1}{\alpha 1} + \frac{1}{k_R} + \frac{1}{\alpha 2}}$$

$$k = \frac{1}{\frac{1}{\alpha 1} + \frac{1}{3{,}28} + \frac{1}{\alpha 2}}$$

4.3.1 OUT: α1 calculation

T_{out} air= 5 ºC = 278,15 K

T_{out} window = 8 ºC = 281,15 K

$$Tm = \frac{Tout\ air + Tout\ window}{2} = 279{,}65\ K$$

<u>Air properties (Tm = 279,65 K, P = 101325Pa):</u>

Cp = 1004

λa = 0,0245011 W/(m·K)

ρ = 1,26235043805 kg/m^3

μ = 1,74704773188·10^{-5} kg/(m·s)

Pr = 0,71590088723

$$\upsilon = \frac{\mu}{\rho} = \frac{1{,}74436773188 \cdot 10^{-5}}{1{,}26461149919} = 1{,}383964135 \cdot 10^{-5}\ m^2/s$$

· Table Gr – Pr: *

C = 0,135

Pr = 0,333

$$Nu = C \cdot (Gr \cdot \mathrm{Pr})^n = 260{,}1463237$$

$$Gr = \frac{g \cdot l^3}{\upsilon^2} \cdot \beta_m \cdot \Delta t = 1{,}02250017 \cdot 10^{10}$$

$$\beta_m = \frac{1}{Tm} = 3{,}575898444 \cdot 10^{-3}\ K^{-1}$$

$$\Delta t = (Tout\ walls - Tout\ air) = 3$$

$$\alpha_1 = \frac{Nu \cdot \lambda a}{l} = \frac{260{,}1463237 \cdot 0{,}0245011}{2{,}65} = 2{,}405234374\ W/m^2 \cdot K$$

4.3.2 IN: α2 calculation

T_{in} air= 22 ºC = 295,15 K

T_{in} walls = 19 ºC = 292,15 K

$$Tm = \frac{T\ in\ air + T\ in\ walls}{2} = 293{,}65\ K$$

g = 9,81 m/s^2

l = 2,65 m

Air properties: Tm = 293,65 K; P = 101325Pa

Cp = 1004

λ = 0,0255371 W/(m·K)

ρ = 1,20216686532 kg/m^3

μ = 1,82208773188·10^{-5} kg/(m·s)

Pr = 0,716360151626

$$\upsilon = \frac{\mu}{\rho} = \frac{1{,}82208773188 \cdot 10^{-5}}{1{,}20216686532} = 1{,}515669567 \cdot 10^{-5}\ m^2/s$$

·Table Gr – Pr: *

C = 0,135

Pr = 0,333

$$Nu = C \cdot (Gr \cdot \mathrm{Pr})^n = 209{,}968366$$

$$Gr = \frac{g \cdot l^3}{\upsilon^2} \cdot \beta_m \cdot \Delta t = 5369135931$$

$$\beta_m = \frac{1}{Tm} = 3{,}399626041 \cdot 10^{-3}\ K^{-1}$$

$$\Delta t = (Tout\ walls - Tout\ air) = 3$$

$$\alpha_2 = \frac{Nu \cdot \lambda}{l} = \frac{344{,}23866 \cdot 0{,}0230951}{2{,}65} = 2{,}026321505\ W/m^2K$$

$$k = \frac{1}{\frac{1}{2{,}405234374} + \frac{1}{3{,}28} + \frac{1}{2{,}026321505}} = 0{,}8236261787\ W/m^2K$$

$$Q_{windows} = 0{,}8236261787 \cdot 26{,}43\ m^2 \cdot (295{,}15 - 278{,}15)$$

$$= \mathbf{370{,}06\ W}$$

$$Q_{TOT} = Q_{walls} + Q_{windows} = \mathbf{3514{,}35\ W}$$

4.3. RADIATION

The heat transfer due to radiation is considered negligible because the radiation's value in winter is small and also there are few hours of sun. Radiation through the walls is almost zero and radiation through the windows is a little bigger but as the surface is lower, it is also negligible. For that reasons, it is considered that the radiation does not affect the study.

4.4. HEAT TRANSFERRED IN EACH SECTION OF THE HOUSE

- Section 1: Clothes room
  - $Q_{1,walls} = 0{,}4106068276 \frac{W}{m^2} \cdot 21{,}465\ m^2 \cdot (295{,}15 - 278{,}15) = 149{,}8324844\ W$
  - $Q_{1,windows} = 0{,}8236261787 \frac{W}{m^2} \cdot 2{,}88\ m^2 \cdot (295{,}15 - 278{,}15) = 40{,}3247377\ W$
  - $Q_{1,roof} = 0{,}4106068276 \frac{W}{m^2} \cdot 8{,}2\ m^2 \cdot (295{,}15 - 278{,}15) = 57{,}23859177\ W$

- Section 2: Kitchen
  - $Q_{2,walls} = 0{,}4106068276 \frac{W}{m^2} \cdot 21{,}2\ m^2 \cdot (295{,}15 - 278{,}15) = 147{,}9827007\ W$
  - $Q_{2,windows} = 0{,}8236261787 \frac{W}{m^2} \cdot 4{,}8\ m^2 \cdot (295{,}15 - 278{,}15) = 67{,}20789692\ W$
  - $Q_{2,roof} = 0{,}4106068276 \frac{W}{m^2} \cdot 20{,}5\ m^2 \cdot (295{,}15 - 278{,}15) = 143{,}0964794\ W$

- Section 3: Guest room
  - $Q_{3,walls} = 0{,}4106068276 \frac{W}{m^2} \cdot 18{,}815\ m^2 \cdot (295{,}15 - 278{,}15) = 131{,}3346468\ W$
  - $Q_{3,windows} = 0{,}8236261787 \frac{W}{m^2} \cdot 1{,}2\ m^2 \cdot (295{,}15 - 278{,}15) = 16{,}801974\ W$
  - $Q_{3,roof} = 0{,}4106068276 \frac{W}{m^2} \cdot 12{,}3\ m^2 \cdot (295{,}15 - 278{,}15) = 85{,}85788765\ W$

- Section 4: Bathroom
  - $Q_{4,walls} = 0{,}4106068276\ \frac{W}{m^2} \cdot 5{,}3\ m^2 \cdot (295{,}15 - 278{,}15) =$ $36{,}99567517\ W$
  - $Q_{4,windows} =\ 0{,}8236261787\ \cdot 1{,}2\ m^2 \cdot (295{,}15 - 278{,}15) =$ $16{,}801974\ W$
  - $Q_{4,roof} =\ 0$

- Section 5: Entrance
  - $Q_{5,walls} = 0{,}4106068276\ \frac{W}{m^2} \cdot 61{,}745\ m^2 \cdot (295{,}15 - 278{,}15) =$ $430{,}9996157\ W$
  - $Q_{5,windows} =\ 0{,}8236261787\ \cdot 0{,}5\ m^2 \cdot (295{,}15 - 278{,}15) =$ $7{,}00082252\ W$
  - $Q_{5,roof} =\ 0{,}4106068276 \frac{W}{m^2} \cdot 36{,}9\ m^2 \cdot (295{,}15 - 278{,}15) =$ $257{,}573663\ W$

- Section 6: Bedroom 2 + bathroom 2
  - $Q_{6,walls} = 0{,}4106068276\ \frac{W}{m^2} \cdot 56{,}18\ \ m^2 \cdot (295{,}15 - 278{,}15) =$ $392{,}1541568\ W$
  - $Q_{6,windows} =\ 0{,}8236261787\ \cdot 2{,}65\ m^2 \cdot (295{,}15 - 278{,}15) =$ $37{,}1043594\ W$
  - $Q_{6,roof} =\ 0{,}4106068276 \frac{W}{m^2} \cdot 41\ m^2 \cdot (295{,}15 - 278{,}15) =$ $286{,}1929588\ W$

- Section 7: Dinning room + living room
  - $Q_{7,walls} = 0{,}4106068276\ \frac{W}{m^2} \cdot 26{,}5\ \ m^2 \cdot (295{,}15 - 278{,}15) =$ $184{,}9783758\ W$
  - $Q_{7,windows} =\ 0{,}8236261787\ \cdot 7{,}2\ m^2 \cdot (295{,}15 - 278{,}15) =$ $100{,}811844\ W$
  - $Q_{7,roof} = 0$

- Section 8: Bedroom 3,4 + bathroom 3
  - $Q_{8,walls} = 0{,}4106068276\ \frac{W}{m^2} \cdot 50{,}88\ m^2 \cdot (295{,}15 - 278{,}15) = 355{,}1584816\ W$
  - $Q_{8,windows} = \ 0{,}8236261787\ \cdot 3{,}6\ m^2 \cdot (295{,}15 - 278{,}15) = 50{,}40592214\ W$
  - $Q_{8,roof} = \ 0{,}4106068276 \frac{W}{m^2} \cdot 45{,}1\ m^2 \cdot (295{,}15 - 278{,}15) = 314{,}8122547\ W$

- Section 9: Office
  - $Q_{9,walls} = 0{,}4106068276\ \frac{W}{m^2} \cdot 16{,}165\ m^2 \cdot (295{,}15 - 278{,}15) = 112{,}8368093\ W$
  - $Q_{9,windows} = \ 0{,}8236261787\ \cdot 2{,}4\ m^2 \cdot (295{,}15 - 278{,}15) = 33{,}60394809\ W$
  - $Q_{9,roof} = \ 0{,}4106068276 \frac{W}{m^2} \cdot 8{,}2\ m^2 \cdot (295{,}15 - 278{,}15) = 57{,}23859177\ W$

Section	Q_{walls} [W]	$Q_{windows}$ [W]	Q_{roof}[W]	Q_{TOT}[W]
1	149,8324	40,3247	57,2386	247,3958
2	147,9827	67,2079	143,0964	358,2870
3	131,3345	16,8019	85,8579	233,9943
4	36,9957	16,8019	0	53,7976
5	430,9996	7,0008	257,5737	695,5741
6	392,1541	37,1044	286,1929	715,4514
7	184,9783	100,8118	0	285,7902
8	355,1585	50,4059	314,8122	720,3766
9	112,8368	33,6039	57,2386	203,6793
TOT	1942,2729	370,0634	1202,0104	**3514,3229**

Table 5 : Heat transfer between each surface

5. CONTROLLING TEMPERATURE SYSTEM

After calculating the heat transfer in winter that the system will need to face, and after the study of the two possible ways to provide the energy to the building, it is time to design the system. This system will need to release the optimum heat so that the house has the desired temperature, one of the main objectives of this project.

To achieve that objective, it will be required that a part of the system provides the necessary heat so that it can be released in the optimum quantity. The type of energy that will provide this heat is the solar energy. If a comparison is made between the two solar energies, it's easy to see which type of energy is more suitable for our system; the thermal solar energy will be the responsible for providing heat to our system.

The possibility to use only the photovoltaic solar energy was considered, transforming the electricity from the photovoltaic panels using an electric boiler, but it was less effective and more expensive than the chosen.

5.1. ELEMENTS OF THE SYSTEM

From now, the features of the system will be described, as well as the parts it contains and the way it works. To begin, the different parts of it are described.

· **Solar panels:** As it was said, this part of the system is responsible to provide the necessary energy. To know how many panels are required, it is used the heat calculated in point 3. Those 3514,3 W shows the amount of energy that is required in case the temperature is 5 ºC.

Image 7: Solar panels

· **Thermostat:** This part of the system is responsible of controlling the temperature, what means that will detect when the water has to start heating and moving through the house. In other words, this part is the brain of the system that makes the decisions. To control the temperature, the thermostat uses temperature sensors, that will detect when the temperature of the house is outside the desired rang (desired temperature ± 2 ºC). It has to be a rang to avoid the system turning on and off so many times. This might be an example of the electronic circuit of the thermostat:

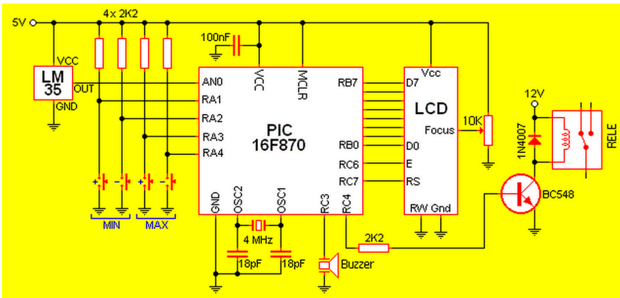


Image 8: Electronic circuit of the thermostat

· **Pipes**: Through this conduit the water is transported through the entire house. The material, which they might be composed by, has to bear high temperatures. One good option is copper.

Image 9: Pipes

· **Tank**: Here is where the water is going to stay to be heated, and then moved to the pipes. The dimensions of this tank are determined for the size of the studied system and the amount of pipes throughout the house.

Image 10: Tank

· **Bomb:** The bomb is the responsible for moving the water through the circuit. It gives enough energy to the water so that it can go to all the pipes of the house.

Image 11: Bomb

In conclusion, the system will be composed by thermal panels, one big tank that will contain the water, one thermostat, one bomb and the pipes whose the water will be moved. The number of solar panels will be determined in the next point.

5.2. CALCULATION DESIGN

5.2.1. Underfloor heating

To calculate the longitude of the underfloor heating system is required to know the area that will need to be heated as well as the thermal demand in this area. Each section will have an individual heating system, what means that the calculations are carried out separately in each section of the house to achieve all the rooms at the desired temperature, 22°C.

Section	Floor area	Q_{TOT}[W]	Thermal demand [W/m²]
1	8,2	247,3958	30,1702
2	24,6	341,4851	13,8815
3	12,3	246,5591	20,0454
4	8,2	53,7976	6,5607
5	36,9	693,7243	18,8001
6	41	715,4514	17,4500
7	41	285,7902	6,9705
8	45,1	720,3766	15,9728
9	8,2	203,6793	24,8389

Table 6: Calculation of thermal demand

Once the thermal demand in each section is known, is time to design the circuit. The first thing that is necessary to decide is where the collectors will be. At least, one collector per floor is required and the best option is locate them in the centre of each floor. After that, the longitude of the circuit in each room, which depends of the heating area, the distance between pipes and also the distance between collector and heating area, can be calculated.

$$L = \frac{A}{e} + 2 \cdot l$$

L = circuit length (m)

A = heating area (m^2)

e = distance between pipes (m) = 0,2

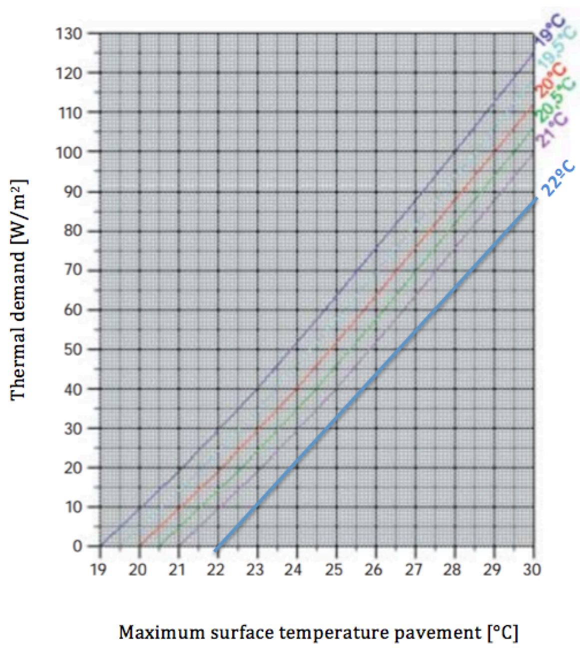
l = distance between collector and heating area (m)

The distance between pipes is always the same, 0,2 meters, and the distance between collector and heating area will be displayed graphically.

Section	A (m^2)	l (m)	L (m)
1	8,2	13	67
2	24,6	8	139
3	12,3	7,5	76,5
4	8,2	5	51
5	36,9	4	192,5
6	41	11,5	64,02
7	41	4	213
8	45,1	2	229,5
9	8,2	6	53

Table 7: Longitude of the pipes of the heating system

The next step is knowing the average temperature of the pavement surface, which depends of the thermal demand in each section and the desired interior temperature. Each section has a different thermal demand but the desired interior temperature is the same in the entire house, so the temperature of the pavement surface will be different in each room. Below there is a graph, which relates this data and reveals the pavement temperature for each section.



Graphic 1: Temperature pavement - Thermal demand

Section	Thermal demand [W/m²]	Ti [°C]	Ts [°C]
1	30,1702	22	24,7
2	13,8815	22	23,4
3	20,0454	22	24
4	6,5607	22	22,5
5	18,8001	22	23,8
6	17,4500	22	23,6
7	6,9705	22	22,5
8	15,9728	22	23,5
9	24,8389	22	24,4

Table 8: Surface pavement temperature

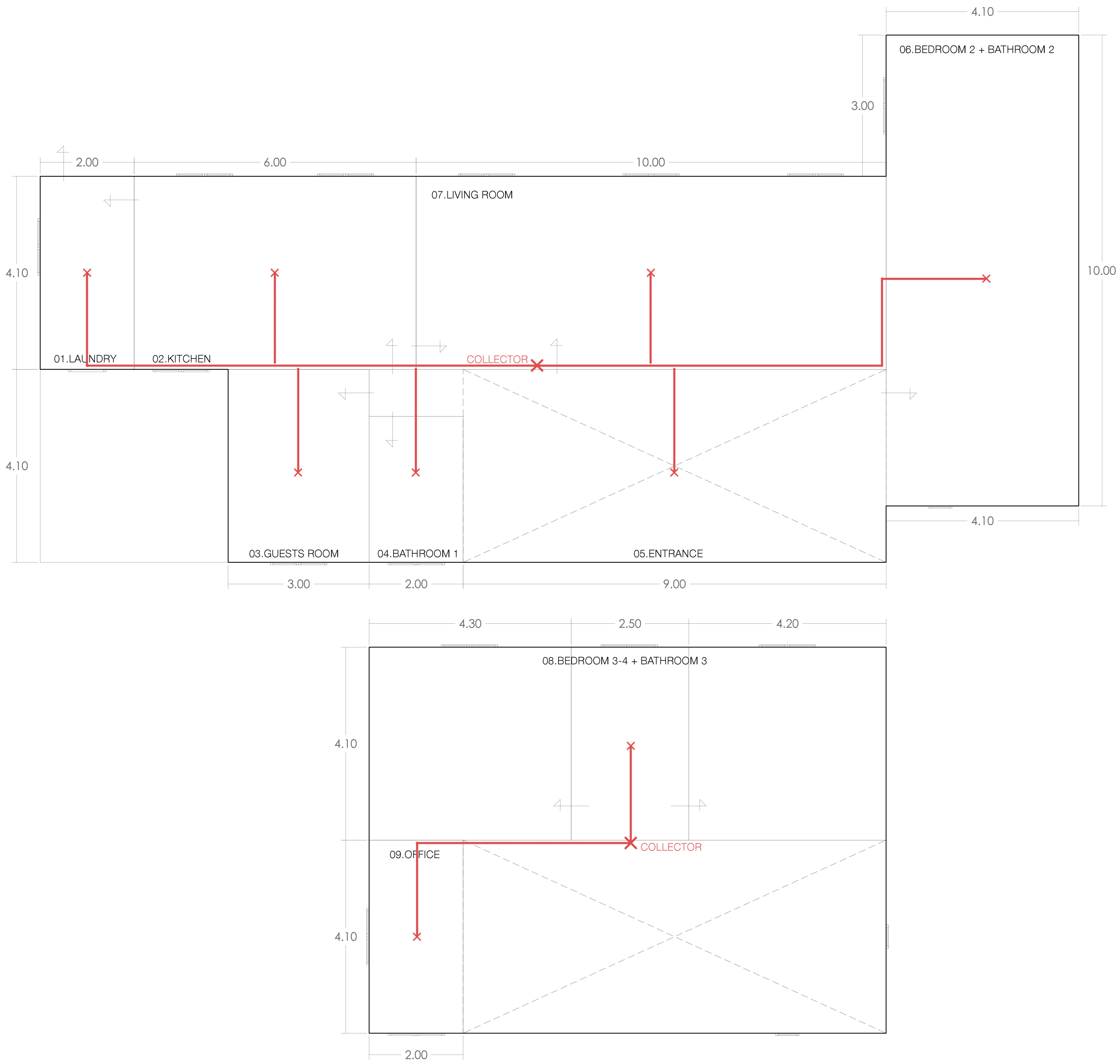


Image 12: Main pipes distribution

Once the surface temperature and the required length are known, is time to calculate the temperature of the water inside the pipes in each section. In this calculations the thickness and the material characteristic of the pipes are involved as well as the floor heating transfer coefficient.

$$Q = K_a \cdot [T_{ma} - T_i]$$

$$K_a = \frac{1}{\frac{e}{\lambda} + \frac{1}{\alpha}}$$

T_{am} = average water temperature

T_i = room temperature

e = layer thickness [m]

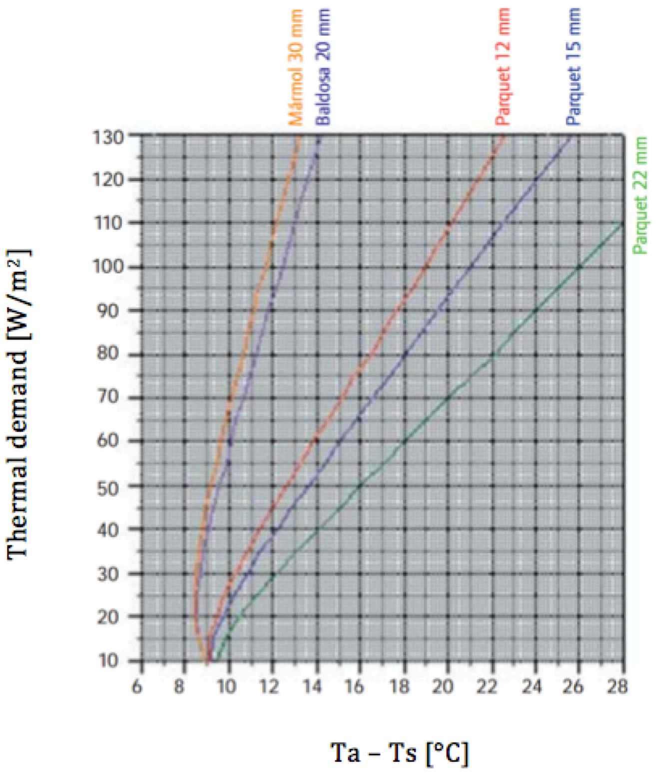
λ = thermal conductivity of the material layer [W/m°C]

α = floor heat transfer coefficient [W/m²°C]

$$K_a = \frac{1}{\frac{0,02}{0,81} + \frac{1}{0,02}} = 0,02\, m^2 °C/W$$

$$Q[W/m^2] = 0,02 \cdot [T_{ma} - 22]$$

In the following chart the temperature's difference between the water and the surface is found. Once that temperature is known, it's easy to determinate the temperature of the water, using the temperature of the surface. The graphic also relates the material and the thickness of the floor with the thermal demand.



Graphic 2: Difference of water and surface temperature - Thermal demand

Section	Pavement	$Q[W/m^2]$	Ts [°C]	Ta [°C]
1	Ceramic tile	30,1702	24,7	33,1
2	Ceramic tile	13,8815	23,4	31,7
3	Ceramic tile	20,0454	24	32,3
4	Ceramic tile	6,5607	22,5	31
5	Ceramic tile	18,8001	23,8	32,1
6	Ceramic tile	17,4500	23,6	31,8
7	Ceramic tile	6,9705	22,5	31
8	Ceramic tile	15,9728	23,5	31,7
9	Ceramic tile	24,8389	24,4	32,6

Table 9: Water temperature in each section

Timp = Impulsion temperature = max(Ta) = 33,1°C

Tret = Return temperature = 33,1 - ΔT = 33,1 – 10 = 22,1°C

It was considered that the difference of temperature between the impulsion and the return is 10°C.

The next important aspect to consider is the water flow through the underfloor heating circuit, which is function of the thermal power emitted in each section, the specific heat and the temperature's difference.

$$Q = m \cdot Cp \cdot (Timp - Tret)$$

m = water flow [kg/h]

Cp = specific heat [1kcal/kg°C]

Section	Q [W]	Q [kcal/h]	m [kg/h]	m [l/s]
1	247,3958	212,7221	21,2722	0,0059
2	341,4851	293,6243	29,3624	0,0081
3	246,5591	212,0027	21,2003	0,0059
4	53,7976	46,2576	4,6258	0,0013
5	693,7243	596,4955	59,6496	0,0166
6	715,4514	615,1775	61,5178	0,0171
7	285,7902	254,7353	25,4735	0,0071
8	720,3766	619,4124	61,9412	0,0172
9	203,6793	175,1327	17,5133	0,0049

Table 10: Values of the water flow

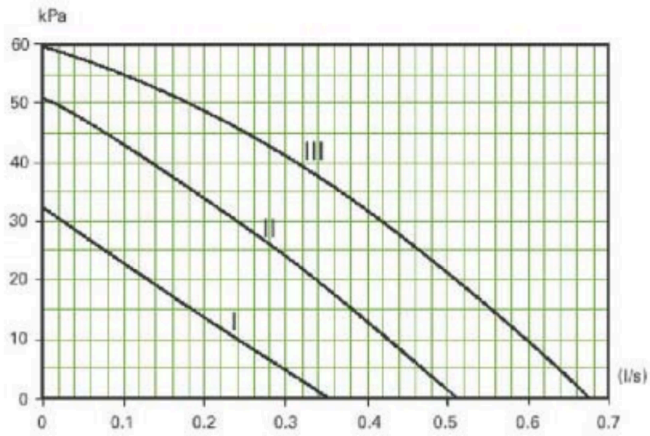
Total impulsion flow: **0,084043336 l/s**

Once the flow and the circuit's length in each section are known, it is possible to find the pressure required to push the water in each room. The maximum pressure required in the circuit, determines the power of the bomb that is needed to push the water.

Section	L [m]	m [l/s]	Pressure drop [kPa/m]	Pressure drop [kPa]
1	67	0,0059	0,0104	0,6963
2	139	0,0081	0,0143	1,9831
3	76,5	0,0059	0,0104	0,7950
4	51	0,0013	0,0022	0,1168
5	192,5	0,0166	0,0292	5,6284
6	64,02	0,0171	0,0301	1,9282
7	213	0,0071	0,0125	2,6637
8	229,5	0,0172	0,0313	6,9528
9	53	0,0049	0,0086	0,4574

Table 11: Values of the water flow

Maximum pressure drop: **5,6284 kPa**



Graphic 3: Pump selection

DISTRIBUTION OF THE UNDERFLOOR HEATING

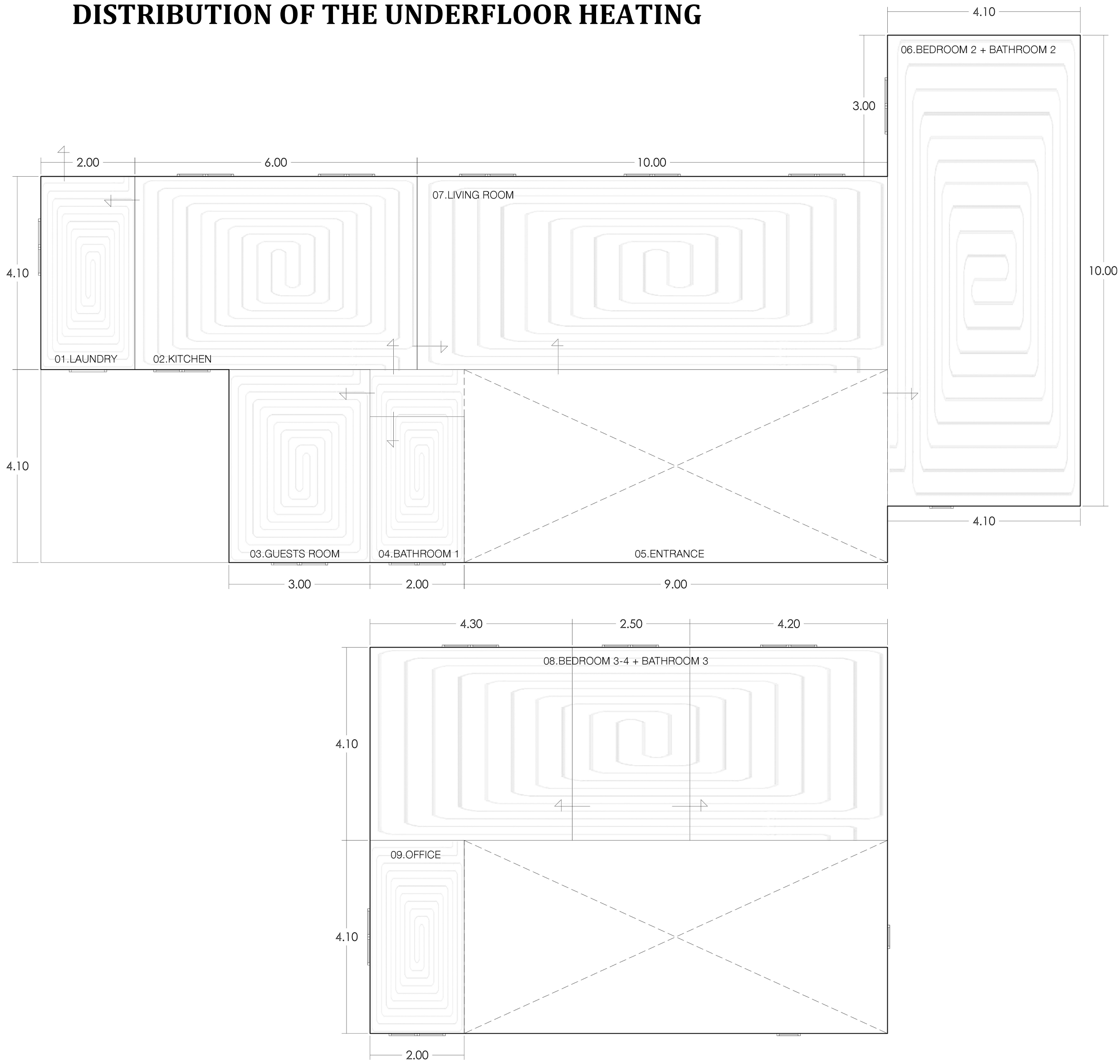


Image 13: Underfloor heating distribution

5.2.2. Number of panels

Once the features of the solar panels are known, it is time to calculate the number of panels that will be required to generate all the needed energy. To do it, will be necessary the demanding heat and the quantity of energy that each solar panel is able to produce. As it is known, the providing heat has to be 3514,3 W, when the temperature is 5ºC, so it is time to calculate the producing energy of each solar panel.

q_K = specific heat flux collector capture
I_s = medium intensity of global solar radiation
T_s = temperature of the substance in the collector
T_e = ambient air temperature
k = heat transfer from the working fluid to ambient air
F = the efficiency of heat transfer from the absorber to the working substance
τ = permeability overlays
α = absorption of the absorbent layer

$$q_K = F \cdot [(\tau \cdot \alpha) \cdot Is - k\ (Ts - Te)]$$

$\tau \cdot \alpha = 0,7$
F = 0,9
Is = 640 W/m^2
k = 2 $W/m^2 \cdot K$
Ts = 33,1ºC = 306,25 K
Te = 5ºC = 278,15 K

$$q_K = 391,8\ W/m^2$$

After that, the number of panels that will be necessary can be calculated. But there is one important idea to consider, the 3514,3 W it's the power that the system has to provide during all the day, but during the winter in the studied l location (Mallorca) there are only 9 hours of sun per day. That means that with 9 hours, the system will need to capture enough energy for 20 hours per day (instead of 24 because it is not necessary to provide energy during 24h). This idea is shown in the following procedure:

3514,35 W → 3514,35 J/s

Necessary energy during all the day: 3514,35 J/s * (20 * 3600) s = 253,03 MJ

Power that has to be collected: 253,03 MJ / (9 * 3600) s = 0,007801 MJ/s → 7809,67 W

So the panels during the 9 hours of sun will need to provide 7809,57 W. Now it is possible to calculate the number of panels that will be necessary:

Surface of panels = 7809,67 W / 391,8 W/m^2 = 19,93 m^2

Knowing that each panel has 1,03 m x 2,03 m = 2,0909 m^2

Number of panels = 19,93 / 2,0909 = 9,53 → **10 panels**

5.3. DESCRIPTION OF THE CONTROLLING TEMPERATURE SYSTEM

As it was explained before, the thermal solar energy uses the heat of the sun to increase the temperature of the water. Therefore, the way this system works is quite simple; it takes the hot water that has been heated by the thermal panels and it move it through all the house. It is useful to say that this heated water could also be used for the shower, the sink and other equipment that needs warmed water. This idea will be treated later.

On the other hand, if it is summer and the temperature does not need to be increased, the system will not have the necessity to work. In that case, the system may have another function, as it was said before, providing the heated water for the shower, the sink and others.

Therefore, the first step is heating the water of the tank, using the solar panels. This tank is inside the house, so that slows down the cooling process of the water inside it. That water, when it is ready for being moved through all the circuits of the house, has to be at the temperature between 32-35ºC. A temperature sensor measures the temperature inside the tank.

However, if it was for the system this temperature will not always be possible. At night for example, if the system keeps working there may be one moment that the whole temperature of the water will decrease. This might not be a problem for two reasons; first of all at night the system does not need to work at all and what's more, another complementary system will be designed to prevent possible temperature decreases not only at night but during really cold or cloudy/foggy days. It is important to say that this complementary system can be turned off and on consequence the water will decrease. This action could be used at night for example, before going to sleep. The explanation and the features of this system will be extended in point 6.

Once the water is ready it is moved through the pipes of the house. Each room has it owns circuit. After passing through the last pipe of the circuit, the water returns to the tank in order to be heated again. Using the valves, there will be also the possibility of turning one or more circuits off, which can be useful when some parts or rooms of the house are not occupied. Using the valves, the required flow in each circuit is controlled, so that each circuit works in an optimum way. These flows are shown in *Table 10*.

In conclusion the system heats the water and then move it using a bomb through the different rooms of the house. If chosen, another parallel system would be able to help it in punctual moments.

6. AUXILIAR SYSTEM

In this point the alternative system is described, as well as the features and the way it works. Before to talk about it parts, it is worth to know how this system works. When the temperature inside the tank is less than 32ºC, this system starts working unless the boiler it is turned off. Once the system is started, the gas boiler heats the water coming from the tank and when heated it is returned at the temperature of 40ºC. When the whole water in the tank reaches the temperature of 35ºC, the system turns off automatically.

The parts of this system are:

· **Gas Boiler:** Using a closed circuit between the tank and the gas boiler, this gas burner increases the temperature of the water inside the tank. As it name says, the fuel that uses is gas. As it was said, there is also the ability to turn it off and let the water temperature decrease (in the case the main system is not working).

Image 14: Gas boiler

· **Pipes:** The pipes in this system are the same than in the other system. Through this conduit the water will be transported from the tank to the boiler and vice versa. The material, which they will be composed by, has to bear high temperatures. One good option might be the copper.

· **Bomb:** The bomb is also the same than in the main system and it is the responsible of moving the water through the circuit. It gives enough kinetic energy to the water so that it can go from the tank to the boiler and come back. It is situated next to the tank.

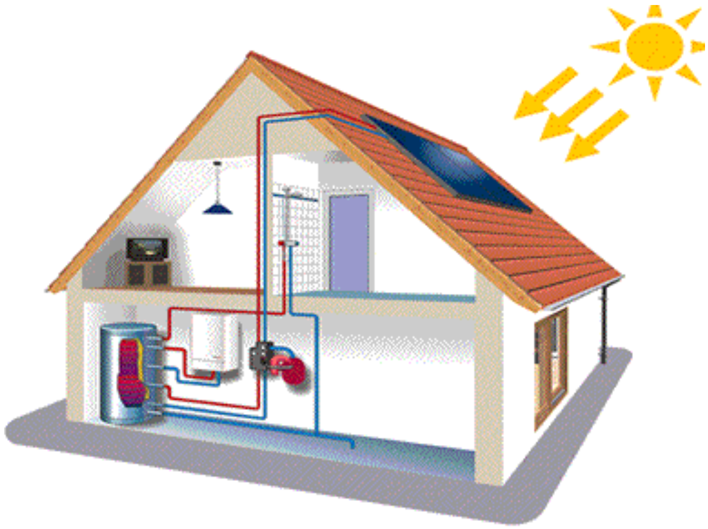


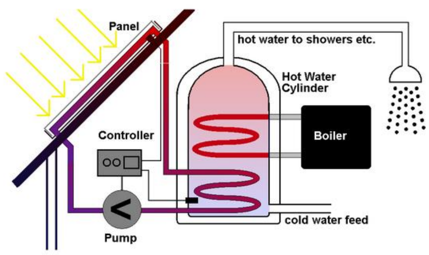
Image 15: Representation of the system

In conclusion, this system is a complement to the principal system, that if chosen, in punctual cases like a really cold day (less than 5 degrees), a cloudy or foggy day, or at night might be used to help to heat the water inside the tank. It is important to have in mind that this system is using gas, what means it operation cost is higher than in the main system, so when it is possible its use will be avoided.

7. HOW TO USE THE ENERGY IN SUMMER

In this point different ways of using the energy excess in summer are considered. One option to consider is leaving this energy in the sun, what means preventing the sun rays to touch the thermal panels, locating an opaque surface in front of the panels. This surface could be manually controlled from inside the house and this might help to have a better control of the whole system. However, this option is not the most appropriate, considering that these panels are not cheap, so to amortize them they have to be in use but not with an opaque surface in front of them. Anyway these opaque surfaces will be installed, just in case.

The first possible way might be using the heated water for heating the water of the showers, the sink and others like the swimming pool. This way will be carried out, but it won't use all the amount of energy released by the thermal panels in summer, that it's much higher than in winter. Therefore, it is a nice and useful option, but there is the necessity to find others. In the following images it is shown different examples of this idea.



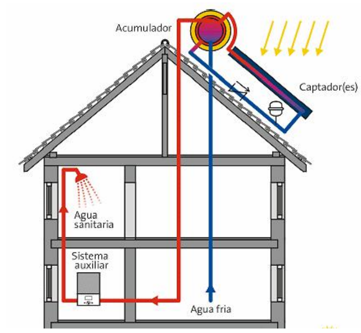


Image 16,17 : System to provide the hot water in the house

Another possible way of using the heat of the hot water is implementing an absorption refrigerator system, which uses a heat source to provide the energy needed to drive the cooling process. Therefore, this system uses the heat of the water to refrigerate the house, like an air conditioning system, a system that in

Mallorca is really necessary taking into account that in summer you can reach temperatures of 35 ºC or more. This application would allow saving all the electricity that an air conditioning uses, that it not low.

In conclusion, apart from the domestic water system, an absorption refrigerating system will be implemented that will save lots of electricity, not only in summer but in any hot sunny day. In the following image it is shown how this system looks like.

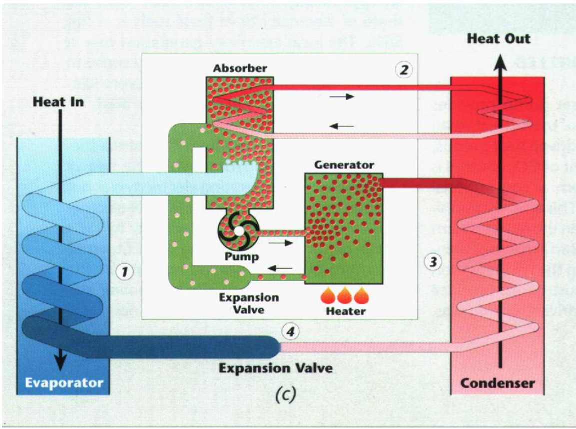


Image 18: Representation of the absorption refrigeration system

8. COST ESTIMATION

One of the main motivations of this project is reducing the environmental impact. However it has to be verified that the installation is economically viable.

- Fixed costs:

Elements of the Controlling temperature system

DESCRIPTION	UNITS	UNIT COST	COST
Solar panels OPS-V210	10 u	895 €/u	8.950 €
Underfloor heating UPONOR	225 m^2	-	10.381,90 €*
Tank 1000 l MVV 1000RB	1 u	1623 €/u	1623 €
Bomb UPS 32-80B Grundfos	1 u	870,7 €/u	870,7 €
TOTAL			**21825,6 €**

Table 12: Cost estimation of the controlling temoerature system

* Detailed cost estimation is attached in the annex

Elements of the Auxiliary system

DESCRIPTION	UNITS	UNIT COST	COST
Gas Boiler: ecotecplus VMW 306 VAILLANT	1 u	1690 €/u	1690 €
Bomb UPS 32-80B Grundfos	1 u	870,7 €/u	870,7 €
Copper pipes d=42mm Outkumpu	50 m	8,75 €/u	437,5
TOTAL			**2998,2 €**

Table 13: Cost estimation of the auxiliary system

- Installation costs

DESCRIPTION	UNITS	UNIT COST	COST
Solar Panels OPS-V210	10 u	100 €/u	1000 €
Underfloor heating UPONOR	225 m^2	35 €/m^2	7876 €
TOTAL			**8876 €**

Table 14: Cost estimation of the instalation

TOTAL COSTS: 33.698,8 €

9. CONCLUSIONS

The use of renewable energies is increasing in our society and it is possible that in a future all the energy will come from renewable ways.

The most appropriate way for the control temperature system in the studied family house is the solar thermal energy, that using water as a heat exchanger moves the heat from the thermal panels to the rest of the building.

In the designing system, as most of the systems that use solar thermal energy, the temperature of the water is not so high, what means that the best way to release the heat is using heating floor that needs less water temperature than other ways like radiators.

The studied system needs a complementary system that helps in really cold days, in foggy/cloudy days or at night. This system uses a gas boiler to heat the water, but its operation cost is much higher than in the main system. This means that when possible, its use will be avoided.

In summer the system will have more heat and the building will not need to be heated but cooled. To solve this problem an absorption refrigerator system is implemented, that works like an air condition system. In this way, all the needed electricity to use the air conditioning system will be saved. Apart from this system, another one will be used for providing hot water to the showers, the sinks and others.

The total cost of the main system is high, but in a future it is worth it. Another point to take into account is that the house is mostly being heated in a renewable way, something to be proud of.

10. BIBLIOGRAPHY

- http://www.aeeolica.org. Information source of renewable energies. October 2014

- http://cte-web.iccl.es. Construction materials. November 2014

- http://www.appa.es/09fotovoltaica/09tecnologia.pphp Information source of photovoltaic panels. November 2014

- http://www.idae.es. Insitituto de la Diversificación y Ahorro de la Energía. December 2014

- http://www.energy.ca.gov/reports/2001-09-04_500-01-020.PDF. Information source of renewable energies. September 2001

- http://www.mcgraw-hill.es/bcv/guide/capitulo/8448171691.pdf.

-http://www.vtsmexico.com/catalogo/producto/panel-solar-vs-hep140sl.php. Panel solar characteristics

http://www.aemet.es/documentos/es/serviciosclimaticos/vigilancia_clima/radiacion_ozono/radiacion_solar/2013/InformeRad_Solar_2013_12.pdf. Weather information. December 2013

- http://www.temperatureweather.com/mediterr/tiempo/es-tiempo-en-espana-mallorca.htm. Weather information

- http://www.engineeringtoolbox.com/emissivity-coefficients-d_447.html. Weather information

- http://www.eoi.es. Organitzation industrial school- October 2014

- http://www.buderus.es. Gas boiler information. December 2014

- http://www.salvadorescoda.com Information resourse pipes. December 2014

- http://www.uponor.com Information resourse of the underfloor heating system.