Case Study of an efficient construction (Class A) in Granada

Notes and report on methods and construction techniques used to build a detached house in the difficult climate zone C3

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Preamble

This document is a summary report of the construction techniques and methods used in the climate zone C3 according to the classification of The Spanish Technical Building Code.

In the climatic zone that corresponds Granada you will find harsh winters and hot summers with high sunstroke..

The spread of temperature is very extreme even during a single day between minimum and maximum temperatures.

Winter conditions see temperatures going down to -5° C, the average annual minimum temperature is around 8°C while the summer can reach peaks up to 41° C (the average annual maximum temperature is around 24° C).

Under these conditions, the project needed to use constructive methods able to insulate the cold in winter while protecting against the sunshine with high summer temperatures.

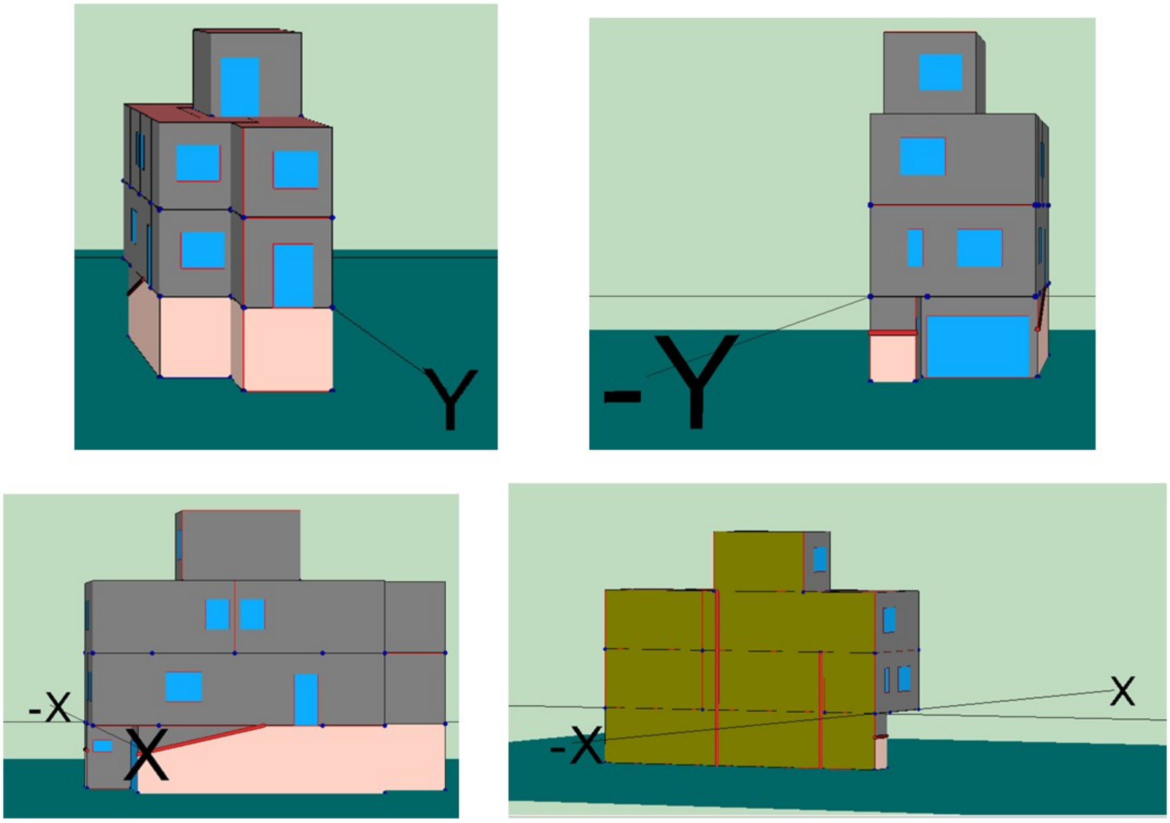
The urban characteristics of southern Europe, where households have little space due to the density of the building and little land, limit many constructive solutions e.g. the orientation of the building (such as with this building where the house is semiattached to another building) or the use of trombe walls (http://en.wikipedia.org/wiki/Trombe_wall) (which in this case give no predictable guarantees , in future it might be possible that its operational benefits are destroyed with the development of nearby buildings)

These restrictions given, the basics of this project to achieve an energy efficiency of Class A lie in the following points:

* Provide an excellent insulation for the entire shell of the house that will reduce the losses of warmth in winter and chill in summer.
* Provide a system of shadowing for the openings of the windows and doors which permits to regulate the grade of sun stroke in each moment.
* Provide one of the most energy efficient air conditioning systems receiving its necessary heat from the solar panels, which provide hot water and heating but is capable to produce cooling as well.
* Reduce as much as possible the days of using climatization to enjoy the lowest energy cost of a mechanical ventilation system with heat recovery of the high efficiency that has furthermore a capacity of cooling to ventilate the house when the temperature outside is more favorable

Previous energy study

The previous energy study at the beginning of the construction made by a qualified industrial engineer using the official software of the Spanish ministry of industry and energy (Lider y Calener VyP), allowed the detailed simulation of the behaviour of the house in this climatical zone.



Graphs from the computer simulation with Calener VyP

It was clear from the very first moment that in case of omitting one of the improvements mentioned in the previous section, the house would be down classified to B, which is not bad, but basically the extreme temperatures in summer are the reason to demand systems that provide shadow and mechanically ventilate including recovery of heat and coolness.

Datos para la etiqueta de eficiencia energética

	Edificio Objeto		Edificio Referencia	
	por metro cuadrado	anual	por metro cuadrado	anual
Consumo energía final (kWh)	12,0	2028,3	79,4	13473,7
Consumo energía primaria (kWh)	31,1	5279,6	96,2	16327,3
Emisiones CO2 (kgCO2)	7,7	1306,8	22,0	3733,7

Summary table of energy generated by Calener V report (Building Object)

Furthermore from all elements to be considered, if you have to leave out something due to your budget, you should never leave out the insulation, because the cleanest and cheapest energy is one you never consume. And the insulation saves heat loss as well as coolness loss.

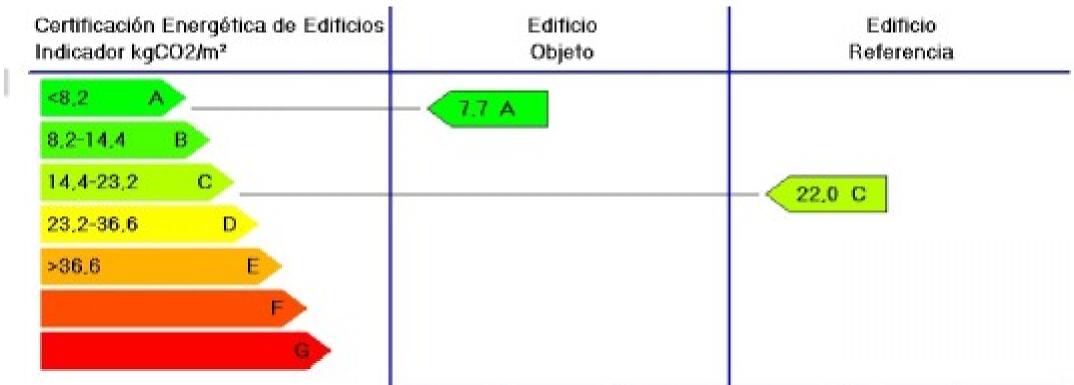
Thus the elements of passive savings (those, who do not need energy for their functioning) like the insulation of the facade, the roof or the foundation in contact with the exterior, which includes the windows and the systems to provide regulable shadows, comprise the most important means of saving,

In this zone, it costs more energy to provide comorable coolness in summer with up to 41°C heat than heating when the temperature is down to -5°C in winter, so although the insulation benefits both situations, air conditioning systems are more energetically penalized to get it cooler when the outside temperature is very high.

A possible improvement in this situation might have been the search for geothermal based climatization, however, much to our regret the prices of the systems we considered were not competitive nor economically feasible for this project. It is possible, that the situation will change in the years to come but at the moment of the start (2011) of this construction this did not come into the range of our possibilities, even though we tried with options offered by companies of this sector.

To save on energy for heating and cooling, I finally opted for a heat pump capable of delivering heat or coolness(floor radiation heating and cooling) and for hot water consumption with solar panels.

The mechanical ventilation reduces even more the necessity to start the heating or cooling and hence needs less energy consumption.



	Clase	kWh/m²	kWh/año	Clase	kWh/m²	kWh/año
Demanda calefacción	A	5,4	916,5	C	43,8	7433,4
Demanda refrigeración	A	7,2	1221,9	C	13,8	2342,0
	Clase	kgCO2/m²	kgCO2/año	Clase	kgCO2/m²	kgCO2/año
Emisiones CO2 calefacción	A	4,0	678,9	C	14,0	2376,0
Emisiones CO2 refrigeración	B	2,7	458,2	D	5,3	899,5
Emisiones CO2 ACS	A	1,0	169,7	D	2,7	458,2
Emisiones CO2 totales			1306,8			3733,7

Simulation of the targeted house (A) compared to an insulated house according class C

Details of contructive elements

For a better visual identification of the construction in process I will attach photos taken on site for the explanation of each element.

Whenever possible I have maintained a chronological order except in those cases, when things happened simultaneously, I have ordered them in sections describing the execution of each constructive element so they remain grouped in categories.

To clarify even more the overall vision involving the application of all these building elements, we provide two tables separating passive elements (no energy cost in performance) and active elements (which require energy input).

First we present the passive elements (The lower the u-value, the better)

Summary Table of elements for passive energy savings		
Constructive elements	**Thermal transmittance**	Brand/enterprise
Exterior walls with Styro Stone Neopor 35 cm	U=0,14W/m^2°C	Styro Stone
Ceiling of basement and last floor with floor blocks of EPS of 25 cm	U=0,29W/m^2°C	Empolime S.A.
Roof insulation with XPS boards ov 10 cm	U=0,31W/m^2°C	Glascofoam
Windows AVANT ALU PLUS, with wooden frame and injected pu-foam, outside aluminium and triple glass with Krypton	U_{marco}=0,90W/m^2°C $U_{cristal}$=0,50W/m^2°C	Iberadria
Mallorquinas y Celosías REGUSOL O-120 with oval aluminium louvres of 12 cm	Shadowing depending on the sun and according to demand	Giménez Ganga
Exterior door TermoPro TPS 010	U=1,20W/m^2°C	Hörman
Rockwool of Lana de Roca de 5cm for dry-lining inside the gypsum boards	U=0,69W/m^2°C	Rockwool

Summary table of elements for active energy savings		
Element of Installation	**Efficiency**	**Brand**
Heat pump of high efficiency Estia, Inverter Class A	Up to 80% of savings n standard consumption $COP_{(calor)}$=4,08 $EER_{(frio)}$=2,70 factor de KW de calor/frio obtenidos a partir de un KW electrico	Toshiba
Mechanical ventilation system double flux with high efficiency heat recovery Siber VMC DF	92% savings in climatization Recuperación de calor interior mediante intercambiador de placas con pared adiabática, o al detectar mejor temperatura externa usar el aire exterior introduciendolo directo al interior de la vivienda (bypass)	Siber
Thermostatical valves for bypassing and mixing ESBE VMC322	Incremento del aporte de agua caliente solar sin provocar consumos, mediante acción termostática pasiva (0w). Cuando la temperatura del solar es apta se desvia a consumo directo, evitando gastos energéticos de la Estía	ESBE
Impulse water pump for floor heating Grundfos Alpha 2L 25-60, with energy classification A	Consume entre 15w y 45w adaptandose a la demanda y controlada por la unidad Estía que la conecta solo en momentos de uso	Grundfos
Recirculation of warm water with high efficiency pump intelligently controlled Grundfos Comfort auto adoption 15-14 PM	Evita desperdicio de agua caliente y energía, memorizando y prediciendo cuando sueles abrir los grifos para obtener agua caliente instantánea, con un consumo de entre 3w y 15w limitado a los 15 minutos previos a los momentos habituales de consumo de agua caliente.	Grundfos
Pipe insulation to cover the pipes for warm water to avoid losses of heat	Es un elemento pasivo pero pertenece a la instalación de los sistemas activos de agua caliente de consumo y de suelo radiante con un valor de conductividad térmica: λ=0,037W(mºC) a 40ºC	Isocell

Outside these tables remain those elements which contribute to the energy efficiency, but due to the present legislation they have been converted into obligations for the construction of new Spanish houses, e.g. solar panels which have to be installed.

Outside remain as well the systems of light installations which in any case are of LED of high efficiency, but elements of the building that can easily be replaced without incurring works of modifications of the facilities and for this reason are considered as smart house elements.

Siding with permanent insulating formwork

To make this part working I had to make contact with 2 different companies to guaranty a correct implementation.

My interest was to leave the knowledge to a local builder so the work could be combined with the formation and assistance in setting up the formwork by the enterprise Styro Stone, who sent a technician who helped in the setting up of the formwork and trained the local builders.

The shell belongs to the work of brick layers, although the workers were not brick layers, but workers of the formwork builder, but the most required skill is the experience in shutter systems and pouring of concrete.

In the pictures we can see the close collaboration by the members of the 2 companies in setting up the material. Niko Jutzi from Styro Stone speaks Spanish perfectly and the following photos show the complete process of 4 days in which the complete termination of the ground floor was done in only 4 days of work.

Day 1 19.04.2011 – Instruction on site

Prior to the vertical orientation of the wall one needs to errect at least 4 layers as a whole to balance any difference in the level of the slab.

Areas are marked with blue paint where windows will be, with red points those areas, were the doors will be to ease the set up without errors.

The external insulation is 15 cm of Polystyrene and the internal is with 5 cm resulting in a total of 20cm of insulation for the shell in spite of the 6 cm of insulation used in traditional systems with brick (in the best of cases)

[In Spain, no authority really checks the fulfillment of the required insulation, note by the translator to explain “in the best of cases”]

Day 1 , 19.04.2011, Setting of the first 4 layers before vertical orientation.

The verification of the level was always supervised by the technician of Styro Stone in collaboration with the local builder.

Day 1 19.04.2011 – Verification of level and vertical orientation of the walls

To sustain the perfect vertical orientation of the wall, you have to wedge every point that offers the slightest dent in the level of the slab and to maintain this vertical orientation, you have to follow up with the trestles on the inside which have the double function of keeping the walls straight and providing the security you need for the coming pour of concrete into the core of the formwork without risks.

As you can see, the workers of the local builders use the system of trestles provided by Styro Stone

Drilling into the slab to fix the trestles tightly into the structure.

Day 1 – 1904,2011 Installation of inner scaffolding by the local builders

The work on site of the technician of Styro Stone guaranteed the verification of the installation and teaching of the key techniques to guaranty the setting of the new construction system.

Day 1 – 19.04.2011 – Verifying the vertical orientation of the trestles of Styro Stone

Once the vertical orientation of the wall of the thermally insulating elements are guaranteed by the first 4 layers, one can proceed to seal the lower part of the wall with pu-foam enclosing the whole perimeter to prevent the leakage of concrete..

Thus you won't have any problem with the following floors.

Day 1 19.04.2011 - Sealing of the lower part with pu-foam following the wall

In the picture you can see the sealing of the lower part of the wall in contact with the slab, using pu-foam. In the areas where space was left for the doors only two layers are left with the intention to cut them afterwards to complete the gap and which functions only to guaranty the perfect lineage plump of the wall. The junction with the columns are sealed with foam, too.

Day 2 20.04.2011 - Completion of the wall in full height with the help of Styro Stone

In only one day one has finished the wall up to the complete height, leaving open the gaps of the windows with elements that are cut out afterwards. One seals also the exterior zone of the wall with insulating pu-foam and one has supported the areas of the corner where due to the existence of a structural column one had to strengthen the shuttering to prevent any movement during the pour of the concrete, programmed for the following day.

Day 3 25.04.211 – Checking the viscosity and gravel size of the concrete by Styro Stone

The local builder has contracted the concrete to pour, following the recommendations of the Styro Stone technician concerning the viscosity, the gravel size of the concrete and the size of the tube of the pump to guaranty the concreting of the core of the formwork.

Day 3 25.04.14 – Pouring of concrete in a lower zone, from the window sill

To have a consistent fill of the formwork with concrete, one follows the indications of Styro Stone to start filling the wall in the lower zones through the gaps of the windows until the first layers of the formwork are filled.

Thus one achieves that when one pours from above the complete height of the floor the concrete does not flow out of the edges of the window sill

Day 3 25.04.2011 - filling up to the lower edge of the window

The indicated viscosity allows an instantaneous filling up to the lower area of the window.

Day 3 25.04.2014 filling of the formwork until its complete height

The filling of the formwork up to the complete height is an operation that follows immediately the same day.

Due to the high seismic risk in Granada you can see the reinforcement of the structural columns without damaging the insulation, due to the fact that the the15cm of exterior insulation cover the whole exterior front of the columns.

Furthermore, the system comes with special elements for the last layer of the formwork which extend the insulation on the outside surrounding the floor/ceiling until the next floor to omit any energy loss by allowing thermal bridges.

day 3 25.04.2011 – Reinforcement of the wall with rebars

The concrete wall is reinforced by using vertical rebars through the complete height, although the columns have been calculated to bear the high seismic grade in Granada alone.

Due to this one does not bring in additional horizontal rebars, because the system of columns is already calculated in this structure, in distinction to the traditional way of this formwork which allows the complete reinforcement of the wall being insufficient without columns.

Day 3 25.04.2011 – Support in the area close to the columns

In the area close to the columns Styro Stone recommends supporting before pouring concrete, because the hard ties have been cut out to leave space for the columns. A plywood and an acrow prop was sufficient to withhold the pressure of the concrete.

The following days – Perimetral scaffolding for safety reasons in the next storey

To secure safety for the workers, we have contracted a scaffolding company to set up a scaffold following European standards, which allows to work with safety in the following stories and on the outside

To avoid damaging the exterior insulation, arms from the scaffold reach through the windows to be fixed to the interior trestles which are fixed to the floor and ready made ceiling of said storey.

In between the storeys the floor needs 21 days to cure, for that reason the complete height of the building was finished the following month. The second and third storey was only made by the workers of the local contractor without the need of support of the technician of Styro Stone.

Following days – finishing of gaps for windows and doors

One cuts the remaining elements of the gaps for windows and doors.
To finish the gaps, one adds on the elements which allow for the windows and shutters to be attached.

Fixing of the preframe for the windows and shutters to provide the shadow

As the gap receives two elements, a mixed preframe was built in, from wood for the wooden windows and from galvanized steel for the aluminium shutters which provide the shade for the glass.

The fixing of both preframes is done directly into the concrete, removing the necessary insulation in the moorings.

Sealing and application of insulation by injecting polyurethane in mooring points

To make sure the elimination of thermal bridges you have to put back the insulation, you removed and seal this area injecting pu-foam to fill any fissure with insulation after terminating with the fixation of the preframes.

To finish with the works allowing to set the windows into the gap, we use a stone made impermeable by a white polymere concrete without any joints making a perfect union with the frame of the window to take up the water flushing in the exterior area.

The window sill with the polymere concrete stone

Further on you will see, that the frame of the windows will allow you to add more boards of insulation to the perimeter of the gap covering part of the external frame giving another 5cm of insulation in jambs and lintels in addition to the other 5 cm already exiting from the Styro Stone solutions, which is another 10cm of insulation outside the whole outline of the window (jambs and lintels) without counting the other 5 cm which cover the interior of the house.

The Styro Stone system could provide these 10cm of insulation at the sides of the gap for windows because the endpieces of 5 cm allow the flexibility to add simply 2 instead of 1. Yet, the reason for not doing so and opt for additional insulation boards is based in the improvement of this insulation of windows which comes from covering part of the exterior frame with this extra overlapping insulation after the setting of the window, this allows one to buy a window frame a little bit cheaper than in the passive houses which have insulatio values even better than the energy class A, giving similar levels of insulation for the frame of the window, than the mentioned frames covered by the mentioned insulation and obtain an efficiency close to a window of a passive house for a much lower cost.

But these said extra insulation boards and its setting is task of the specialized contractors for cladding the facade as well as doing the rendering and take care that there are no other thermal bridges. A more detailed description with more insight depth will be found in the chapter dedicated to the rendering.

Upper and lower insulation of the shell

Given that the walls highly insulate the whole perimeter of the building you also need to improve the thermal insulation values of the floor from the ground and the roof of the last floor which are in contact with the outside.

This is the reason why the local builder used in these floors and roofs floor blocks of insulating polystyrene to improve the thermal surrounding in these areas.

Insulating floor blocks in the floor of the ground floor (seen from ceiling of the basement)

Insulating floor blocks in the ceiling of the last floor

Additional to this insulation, we have also added 10cm of XPS boards to the roof, as we will see further on.

Before we proceed with the installation of the thermal insulating boards in the roof, one has to waterproof said roof with a material compatible with the insulation used in the facade, by using layers of EPDM which unlike bituminous membrane do not need to be put on with heat, because it's sealing is achieved by chemical vulcanization, similar to wheel tyres.

waterproofing with EPDM by Firestone, much better than bituminous membrane

The solution of the chosen inverted roof leave the waterproofing in the first layer and the insulation as second layer giving it a better duration of the waterproofing, being protected against the thermal changes by the installed insulation. Although the EPDM by Firestone gives a guaranty of 50 years.

On the Styro Stone facade there is already applied a first layer of the rendering Coteterm-M with a fibreglass mesh, which was applied while the scaffold was still there.

As you can see in the picture, the overlapping of the waterproofing need to overlap with the insulated facade on the outside of the insulated blocks of polystyrene, thus making it impossible to use the bituminous membranes as they are based on the application of heat in respect to the integrity of the whole insulation. (Note from translator: Cold bituminous emulsions may be used)

Thus one achieves also the additional benefit, that the boards of insulation installed in the roof make direct contact with the insulation of the facade sealing thermally the shell of the building without leaving thermal bridges.

The solution for the insulation was based in boards of XPS (Extruded Polystyrene) up to a total of 10 cm width which is added in this case to the width of the already existing insulation with floor blocks of polystyrene in this ceiling.

Because the boards of 10cm width are more expensive, one can decrease the costs of insulation by mounting 3 layers with a first board of 4 cm and 2 boards of 3 cm on top of it (making 10 cm).

The reason why the overlapping of the waterproofing of EPDM rise many centimeters of the ground is due to the width of the insulation to install, one has to join the layer of compression of 5cm of concrete plus paving with the overlapping of the waterproofing to a considerable height of the ground.

The reason for overlapping the membrane is the elevation of the EPDM by so many cm and owing to the thickness of insulation installed, you have to join the compression layer of 5 cm of concrete, plus the flooring, which makes the overlapping of the membrane elevate to a considerable height from the floor.

geotextile lamina to protect insulation and impermeabilisation

To protect the layer of waterproofing and the boards of insulation against aggressive property of concrete of the compression layer which goes against the floor, one has to introduce geotextile layers which you can see in the white of the picture and whose function is to give better durability to the system along with the inverted roof insulation.

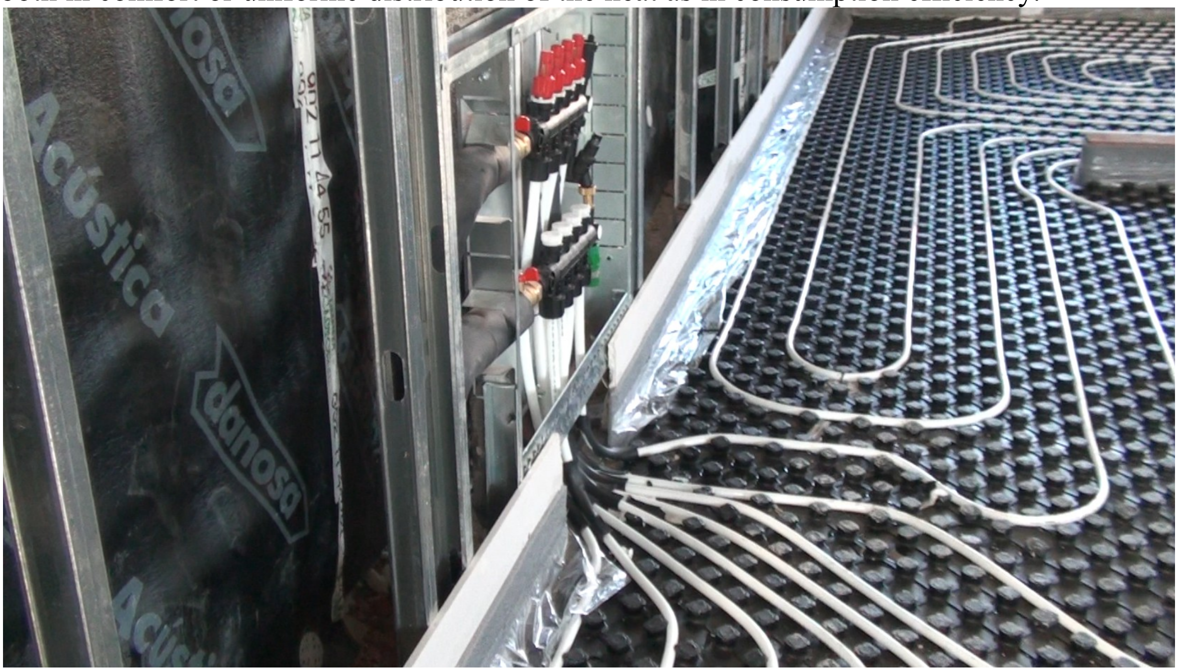
Difference in height of the floor of the door due to the insulation of the roof in the last floor

Insulations and installation in floors

Once finished with the waterproofing of the roof one began with the installation of the interior, starting with the addition of insulation boards to sustain the installation of the floor heating, which is a heating of low temperature, more energy efficient, particularly if the heating system installed like in this case is a air-water heat pump, whose most efficient working zones are achieved with temperatures lower than 40°C, that is why it is called low temperature heating.

The ideal temperatures to work a floor heating you adjust like a glove by means of the ideal temperatures of a system of heat pump.

We did not consider radiators which operate above 70°C being less efficient, consuming energy to heat water up to these temperatures to get the same result or even worse than the system with floor heating, both in comfort or uniforme distribution of the heat as in consumption efficiency.



Low temperature heating system in floor heating of the brand Uponor

In this photo you can appreciate parts of the dry-lining necessary in the area of the separating wall, to what is added 5cm of rockwool insulation, as we see later.

You need to remember that the insulating layer of the floor heating is being strengthened by the ceiling system using the insulating floor blocks in between the floors and of the roof but due to the limitations of the calculation program Calener VyP (used in the initial project) and the program CE3 (used after finishing the building to obtain the Energy Certificate), the calculations of the Energy A Classification could have been even better in case the said programs could include low temperature heatings.

To not obstruct the transmission of heat of the floor heating, we decided to finish the floors of the house with a material unlike wood, with a durability and a smaller width better fitting to the system. Wood is a good insulator, that is why a floor of said material is not serving well for the transmission of heat from the floor heating to the habitable space.

This is why we selected a ceramic flooring of porcelaine tile imitating wood as you can see in the following picture:

Finishing the floor with porcelain tiles looking like wood

Obviously the tiling of the house was an activity executed a lot later than others which are left to be told, but this information is given in beforehand because it belongs to parts strongly related to both parts of the floor.

In the pictures appear the concrete screeds in the steps of the stairs which are used as fixation points for the handrail.

All the gypsum boards to close the stairs are filled with insulating rock wool, but to let the handrail stay fixed to the stairs, the points in which to fix the anchor points have rebars and are concreted to the point of contact with the gypsum board.

Insulation of partition and dividing walls

The house is a semi-attached house, attached to a house constructed the traditional way, it is necessary to insulate the parting wall accordingly between the two houses.

The dividing wall was made of normal bricks which made it necessary to insulate the parting wall.

According to the calculations of the previous study it would be sufficient with 5 cm insulation, selecting gypsum boards with rock wool in the whole space.

Insulation with rock wool in all partition walls

With insulation you should take care of all details, including to cover the parting walls of the stairs with the areas you do not live in like the basement, so it does not act as a thermal bridge.

Due to the low cost of insulation with rock wool I followed the recommendations of the Institute for the Diversification and Energy Saving (IDAE) in so far to also insulate all the non load bearing interior walls for the benefit of being able to climatize independent areas of the house, if they are not in use.

Internal rendering with gypsum

In the interior areas of the house where we have external walls you don't need to enhance the insulation, this is why we selected a different solution to the use of gypsum boards.

The most adequate option to use is projected gypsum to protect the insulation of the interior EPS of the house. But to guaranty it sticks well it is recommended to use a suitable adhesive for the adherence of gypsum on EPS.

Means of Adherence EPS Knauff K454 E

The application of this particular means of adherence allows to guaranty the duration of the rendering with projected gypsum and the interior insulation.

Rosy colour of insulation after application of means of adherence for the gypsum

The finishing of the joints of the projected gypsum with the plaster boards, have been executed by the same contractor specialized in both solutions (projected gypsum and plaster boards), which guaranteed a correct termination.

Detail of the fibre glass mesh applied to the projected gypsum

Additionally to prevent the fixation of the gypsum with the layer of adherence, you can see that the whole surface covered with the reinforcement of the fiberglass mesh (complete coverage from the roof to the ground) whose fibers one can see in these cuts where we had to install afterwards a preinstallation of an air condition which we had not thought of beforehand.

In the picture above you find a joint of projected gypsum and a dividing wall made from plaster boards for the passing of installations, in which you find parts of the insulating rock wool sticking out of the rectangle cut out of the gypsum board, together with a vertical white tube for the ventilation system.

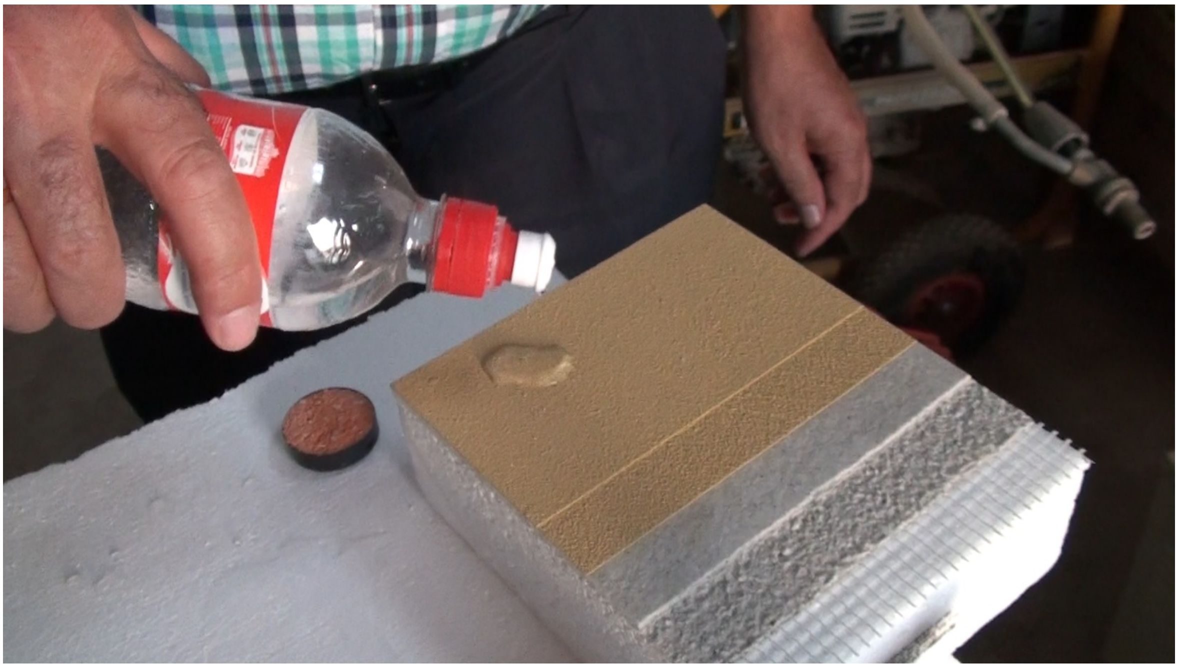
External rendering of the facade

The rendering of the facade had to be done in 2 separate steps for different reasons.

It is not convenient to finish the complete exterior finishing of the facade while works have yet to be done on the outside of the house in preparation of the exterior groundworks, but also it is not desirable to leave the exterior insulation without protection against the ultra-violet radiation of the sun, deteriorating the EPS.

For this reason it was beneficial to use the installed scaffold, to start with the first layer of rendering to protect the insulation.

This first layer is equal to the layer of coating used on the interior of the house before the gypsum, but it is different as the specific product in this case is Coteterm-M from the company Parex, a product which presents adequate guaranties for its application on EPS.



Multilayer solution Coteterm for the rendering of facades with insulation

In total you need at first 3 layers consisting of a first layer of Coteterm-M, plus a mesh of glas-fibre (Coteterm Malla STD 167) plus a second layer of Coteterm-M.

The following layers form part of the finishing in the future, when the rest of the exterior works are done to guarantee the rendering is done without being stained or deteriorated by any incident in the works still to be done.

The complete solution before being terminated requires a layer of Coteterm Fondo as base of the following layer and 2 other layers of Coteterm Estuco Flexible as final layer.

These products are flexible against expansion and therefore guaranty a duration of the insulation not producing any fissures and remain waterproof, which is important to avoid deteriorations in the adherence for possible expansions of water turning ice. It is about maximum protection of the investment in coating with insulation and the most adequate products made for this purpose.

First layer of rendering to protect the insulation against ultra-violet radiation.

The finishing of the first protective layer serves as a bridge of adherence and gives the facade a look of a ready rendered facade, although it is not.

Aspect of the first three layers after removing the scaffolding

The scaffold is withdrawn after the first part of the rendering, because it is rented, thus not to incur extra costs and for the necessity of working on the exterior soil to terrace them.

One kind of enjoys how the adjoining house which had begun on the same date, but with traditional system of bricks and still they worked on it to complete their shell.

A part of the works to render the facade consisted also in insulating certain areas that could turn out as thermal bridges like the ceiling and the roof of the basement in its exterior part in front of the garage door.

EPS insulation boards of 5 cm fixed to the ceiling of the garage door

The additional insulation boards in this external area of the garage roof, corresponds to the floor of the ground floor, this is why they add to the insulated floor blocks of EPS in said area to avoid thermal bridges in the envelope.

The fixing is threefold. They are glued with Coteterm-M plus a mechanical fixing with plastic dowel (you see the circles of the heads) plus the fixing provided by the mesh of glas fibre which is continued from the facade encompassing it all, providing continuity of the rendering.

Insulation boards in front of the floor and the laterals not covered by soil

The envelope of insulation is complete over all the possible thermal bridges.

With the aim to save costs, the parapet was not made with blocks of Styro Stone because in this said outer area insulation makes no sense.

Though, it is advisable to avoid a sudden change in material which could could provoke a joint susceptible to different dilations and which can damage the coating and the insulation of the lower floors in a way that small fissures in the rendering can allow water to seep through, which in very cold weather are a danger to the installed insulation.

For that reason and because the surface of the parapet was small, we opted to add insulation on the outside of this parapet, which had at the top a flashing made of concrete polymer which in this climate case is the most appropriate.

EPS board to maintain the continuity of the distance

This economical solution protects a much more important investment and provides durability.

The boards must be 10 cm due to the total of 20cm width of the bricks forming the parapet, technically overhanging 5cm of the ceiling, or in other words, overlapping 5cm onto the polystyrene of the Styro Stone blocks below which is 15cm wide on the outside. This obliges us to opt for boards of 10 cm to fill just the space to get in line with the facade to maintain the perfect vertical line.

Due to the heavy seismic danger in Granada said parapet is strengthened with vertical rebars which penetrate solidly into the ceiling and the openings are concreted to strengthen the joints between the rebars and the floor blocks.

The resulting facade of material with continuously identical coefficients of dilation guarantees no future fissures nor infiltrations.

Furthermore, here we proceed to one of the other means of low budget which reflects positively on the thermal behaviour of windows and outer doors, which, as we will see particularly in the section for windows, permit decreasing its costs in the solution of the adopted frame.

Though we will see with more details in the section dedicated tot the windows, the thermal property of the glass is much better than the frames

The thermal transmission of glass is certified with U=0,5W/m²°C, that is almost as double “better”as that of a good frame for a window with U=0,9W/m²°C. Normally it is less profitable to improve the frame than to improve the glass, comparatively due to the thermal transmission in the bigger surface of the glass, which has a bigger influence than the frame.

This fact suggests that with the simple means of using the rests of the insulation boards used for the coating of the building in those areas where you do not use Styro Stone, you can carry out an extra box in the gaps of windows providing the double advantage of covering the main part of the frame of the window with insulation, so as also carrying the additional benefit in the area of the jambs and lintels which already had 5 cm of insulation from the Styro Stone blocks.

In the case of the exterior balcony doors you fix the finishing to the edge of the preframe of aluminium which serves to hold the swiveling shutters and allow the passage of people.

Example of an extra insulation board to cover part of the frame in the lintel

As you can see, the insulation board of 4 cm adheres to the intermediate area that exits between the frame of the balcony window and the frame of the shuttering, which is flush with the facade.

In the case of normal windows with a shuttering system to provide shadow, the same improvement is applied with the only difference of a preframe a little bit recessed until the interior of the gap with the aim to avoid that the lattice slats standout of the facade when they are in their maximum horizontal position.

Recalling that this square aluminum preframe, which is the final holding device to receive the shutters and allows it's anchoring, stands out sideways and in part out of the hollow to be screwed to the steel galvanized profiles below the coating, which is itself tightly fixed on the central core of concrete of the wall by means of a “T”, but remain covered and furred by the first layer of protecting coating which include the fibre glass mesh during the first works on the facade.

This solution was prepared to allow to screw tightly a metal onto another metal in a most exterior area still possible to get to the core of the concrete, which makes it possible to have a preframe of the shutter in a tight position with the total independence to have it on top of the fringe of the exterior insulation of 15 cm.

The solution of Styro Stone would allow to fix directly to the center of the gap for the shutter, cause here is the core of concrete, but one wants to endow extra space between windows and shutter.

Example of supplementary insulation board to cover part of frame jambs

One needs exactly this existing space between the window frame and the preframe of alluminum sticking out as a point to fix the shutters with the aim to lodge the additional insulation boards.

In both cases it is advisable to fix the boards with the product specially for EPS, like Coteterm-M and additionally nail plastic jacks which provides a mechanical fixing to the core of the wall's concrete in said area, before the protective coating is put on.

Finished with the works that complete the solution to coat the facade with the initial layers of Coteterm-M, mesh of fibre glass and a new Cototerm-M, one proceeds in the same form to cover the last 3 layers of finishing, which as we said before consist of Cototerm Fondo as a base and the last 2 layers of Cototerm Estuco Flexible as the final coating.

The scaffold in this case was provided by the same rendering enterprise and was counted as part of the complete price.

Finishing works on the ultimate layers of the facade

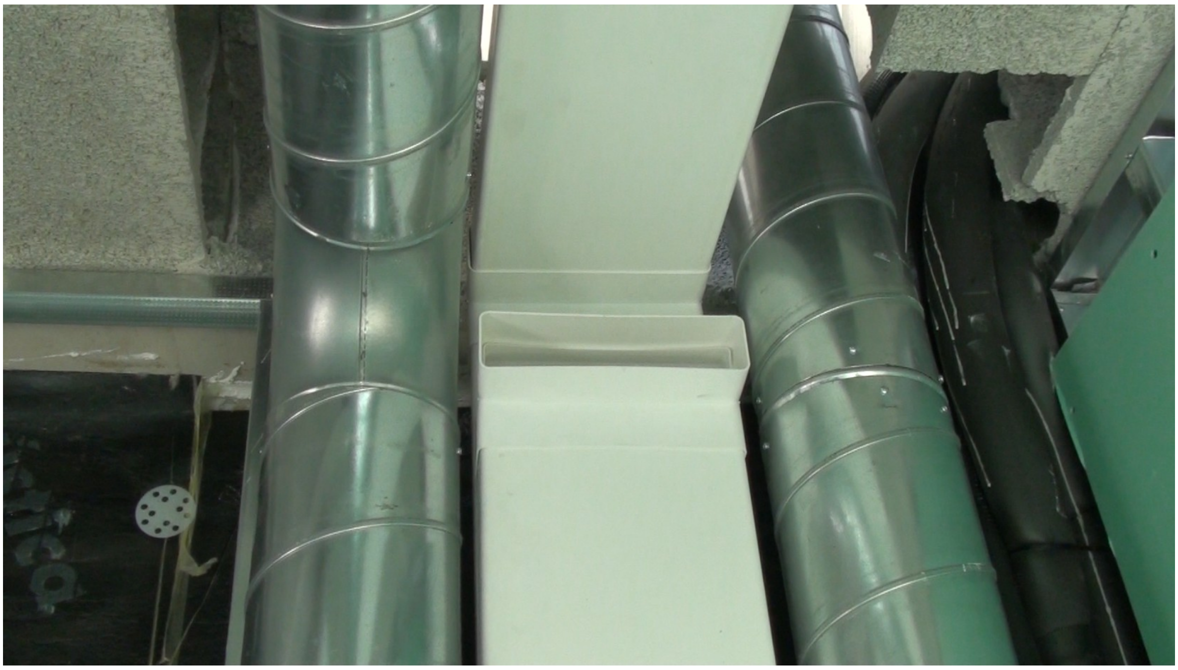
The last layer selected was in a complete white colour, cause this is the most beneficial in an area like Andalucia, particularly in summer, because it is in this summer season, when the sunshine is most aggressive.

View of the facade with the coating finished

Mechanical ventilation with heat recovery

To avoid losses of heat or cool we use a system that allows ventilation of the house without opening the windows. This saves appr. 92% of the energy used in climatization

Before installing the device which allows the ventilation with heat recovery, one has to determine the ways for the ventilation tubes which have a double circuit. The fresh air comes into the house by way of living rooms and bedrooms, while the air is extracted from canals out of the kitchen and the bathrooms.



General tubes of supply, extraction and distribution of air

Distribution net and air extraction to/from the rooms

The general tubes of the ventilation system have a big circular diameter and are of metal while the distribution channels are made from plastic pipes, allowing the passing between the small space of the ceiling and the false ceiling

Taking clean air from outside of home and ventilation of the basement

From outside of the house you take fresh air from the lower areas to avoid fumes of the installed biomass chimneys in the upper floor of the attached house.

General air filter box which leads into the households

To improve the quality of interior air, you have a box in which fits the filter that is big enough to ensure the wanted quality of interior air.

This is done for two reasons. First to oblige with the European norm of ventilation EN 13779 and the RITE, which recommends a double process of filtering the air.. Second to give a longer life for the filters of the device, which are more expensive to replace that way saving in the long run with the installation of this simple box of prefiltering

The ventilation device installed is with filtres of type F7, that is why one can opt to install filtres of F6 o G4 in the prefilter box.

FILTRACIÓN: Norma Europea de ventilación EN 13779 y RITE

CONSEJO

Recomendamos instalar un prefiltro (G3, G4) delante de la primera etapa de filtración. Estos filtros tienen eficiencias (filtración de polvo) del 80-90%. Así conseguimos alargar la vida de los filtros de alta eficacia y reduciremos el consumo energético de la instalación. De la misma manera el coste de los recambios será más bajo.

CAMBIOS DE FILTROS
Se establecerán tres límites para el cambio de los filtros:
- pérdida de presión final
- tiempo que lleva instalado
- tiempo que lleva funcionando.

El primer límite alcanzado es el que determinará la sustitución del filtro.

La primera etapa
2000 horas de funcionamiento, máximo 1 año instalado o cuando alcance la pérdida de presión final

La segunda o tercera etapa
4000 horas de funcionamiento o máximo de 2 años o cuando se alcance la pérdida de presión final

Los filtros de gas o moleculares (carbón activo) no cambian de pérdida de presión durante el funcionamiento normal, por eso recomendamos el cambio después de 5000 horas o después de 1 año.

La Norma Europea EN 13779 busca ofrecer una calidad del aire interior saludable y confortable durante todos los periodos del año, con unos costes de instalación y funcionamiento aceptables. Actualmente se ha adoptado en todos los países de la Comunidad Europea.
En España este conjunto de normas se recoje en el Reglamento de las Instalaciones Térmicas en la Edificación (RITE) que especifica el filtrado, temperatura y humedad que requiere un sistema de HVAC para ofrecer una buena calidad de aire interior (IDA) en función del aire exterior (ODA).

FILTRACIÓN DE PARTÍCULAS:

	IDA 1	IDA 2	IDA 3	IDA 4
FILTROS PREVIOS				
ODA 1	F7	F6	F6	G4
ODA 2	F7	F6	F6	G4
ODA 3	F7	F6	F6	G4
ODA 4	F7	F6	F6	G4
ODA 5	F6/GF/F9*	F6	F6	G4
FILTROS FINALES				
ODA 1	F9	F8	F7	F6
ODA 2	F9	F8	F7	F6
ODA 3	F9	F8	F7	F6
ODA 4	F9	F8	F7	F6
ODA 5	F9	F8	F7	F6

IDA Calidad de Aire Interior
1 Óptima (hospitales, laboratorios, guarderías)
2 Buena (oficinas, hoteles, aulas)
3 Media (locales comerciales, cines y restauración)
4 Baja

ODA Calidad de Aire Exterior
1 Puro (con partículas de forma temporal)
2 Limpio (concentración de partículas)
3 Sucio (contaminantes gaseosos)
4 Contaminado (contaminantes gaseosos y partículas)
5 Muy contaminado

Both the European norm and the regulation of thermal installation in Spanish buildings itemize the possible options and types of filter in a indicative table following the quality of the exterior air available and the quality of the air aimed to in the house.

During the time of pollen one can adopt the type of filter to the existing condition.

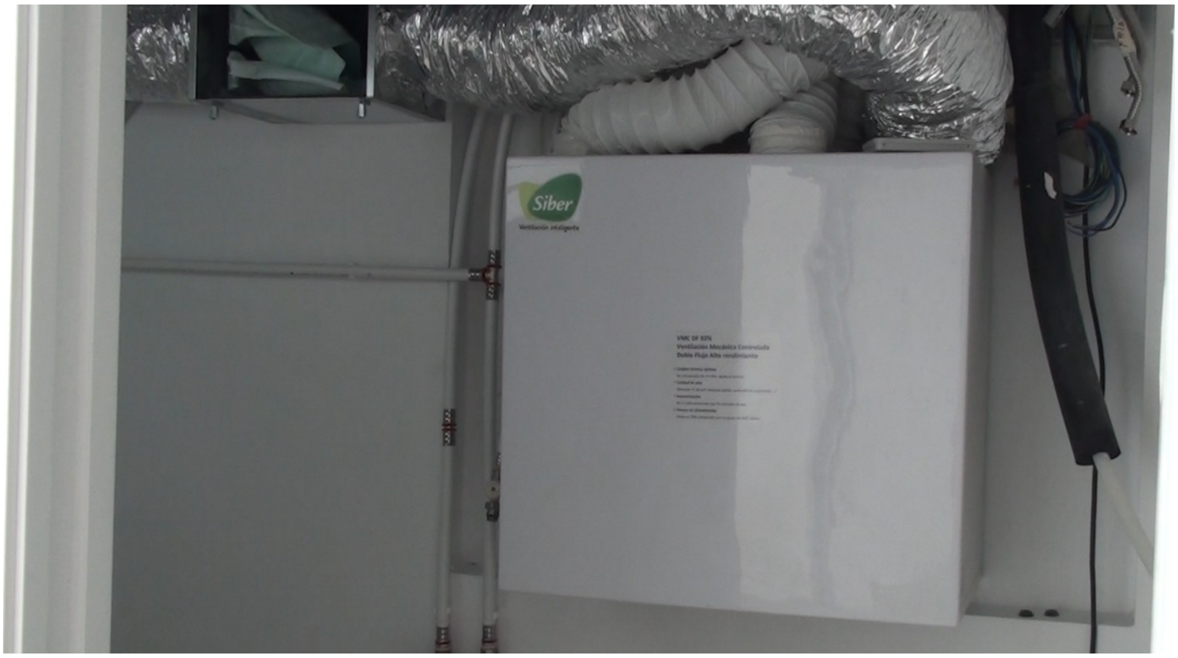
On the other hand, the tube of exhaust or chimney of the stale air of the house, by recommendation of the manufacturer, should be conveniently separated from the place where you take in fresh air with the aim to avoid the possible absorption of the stale air through the input of fresh air.

For this reason the exhaust of this stale air of the house after exchanging heat to warm up the fresh air, that comes in, will be exhausted above the roof where you find all the other exhausts for gases like the biomass kettle, chimney for wood or extraction of kitchen air.

Exhaust tube for stale air on the upper roof

In respect to the device of mechanical ventilation with heat recovery installed, we chose a model with high efficiency.

This system changes the temperature of the air in the interior of the house with the recharged air that goes into the house by use of an adiabatic wall situated inside the ventilation device, which allows the thermal transfer of both airflows in it's way to eject from the house the stale air and to suck in the fresh air



ventilation machine Siber VMC Double Flux of high efficiency

The electronics of this machine allows the programming of the freecooling, thanks to the measurements of air temperatures form the outside and inside, allows to decide if you want to bypass the system of heat recovery and blow fresh air directly e.g. in a night of summer, when the exterior temperature is better than that of the interior. This has a much lower consumption than an a/c.

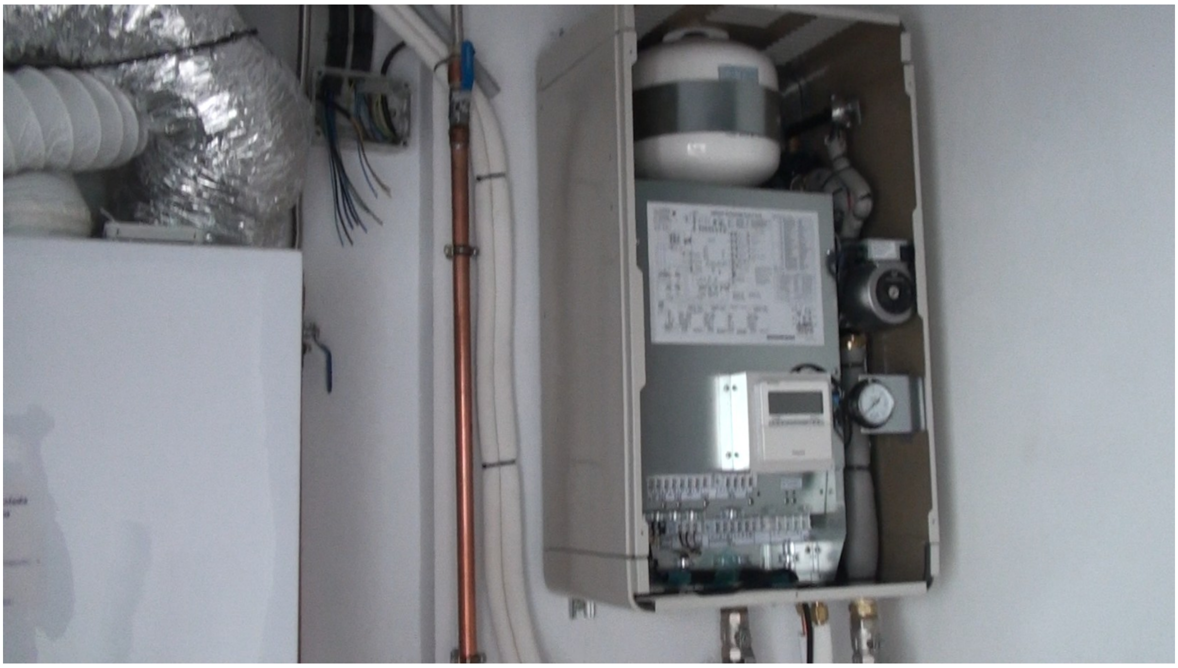
Heat pump for hot water and heating

In matters of heating and climatisation as in having hot water (ACS) we chose a system being in between the most efficient available in both cases. In respect of hot water it can be additionally heated up by the sun, optimized as we will see next.

The system of heat pump of Toshiba is known as Estia.

Exterior unit of heat pump of system Estia

The system consists of an external unit installed in the roof and an internal unit with the interchanging boards transferring the heat and the coolness to the water circuit.



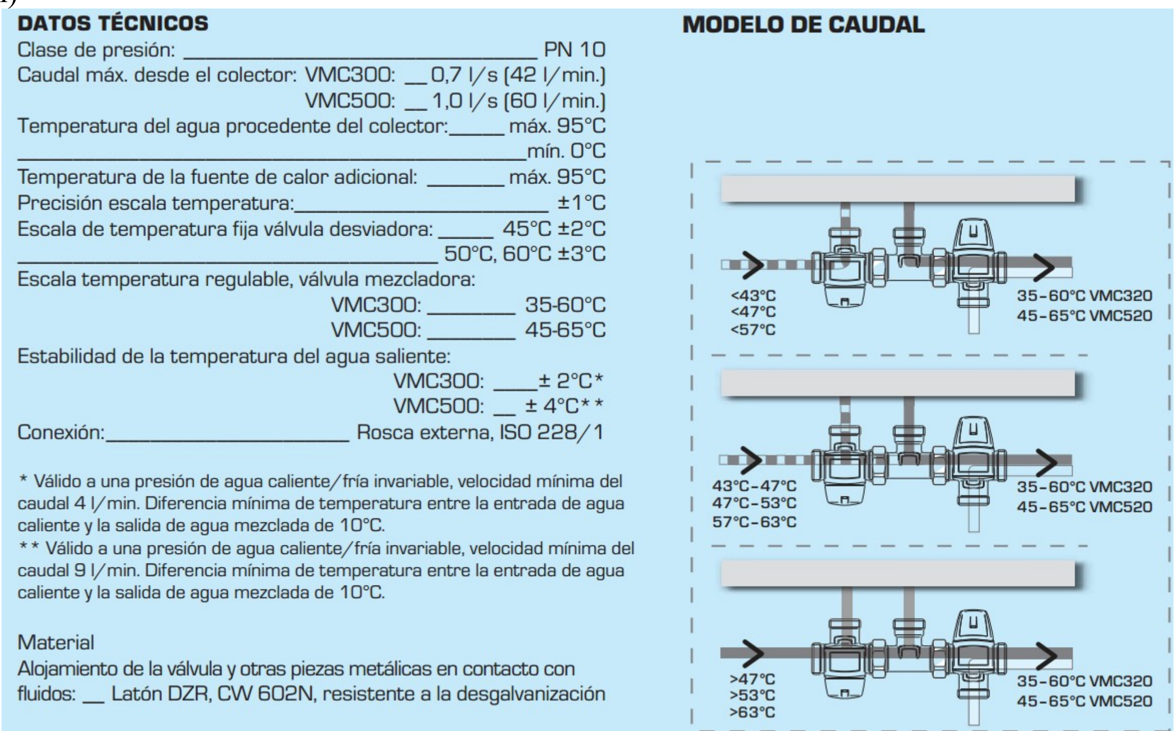
Internal unit of interchanging boards of the system Estia

The internal unit is installed in the basement and is equipped with all the electronic elements for the control of the double circuits of consumable water and the floor heating, warming alternately according to the needs of each, prioritizing the hot water for consumption automatically. As much as the system for ACS as with the floor heating have separate water tanks which are heated by the circulating through a heat pump by using a 3-way valve.

Thermostatically mix valves and selectors for solar benefits, ESBE VMC 322

This photo has been made before adding insulating tubes to avoid loss of heat in the complete installation of tubes.

One of the improvements in efficiency for the water consumption comes by favouring the amount of heat that comes from the solar boards by using a system of 2 thermostatic valves. (Mix and Selection)



Priorization of the consumption of the solar water in a passive way of the temperatures

As you can see in the technical manual, it works the following way:

Whenever the temperature of the thermosifonic solar water tank of the solar panels is higher than the optimal temperature of the water for direct consumption, the water is taken directly from the solar panel and circulated to the direct consume without passing through the water tank with warm water from the heat pump, which allows to switch off the heat pump in the warm months of summer.

In case the temperature is in an intermediate range, on entry a part passes through the water tank and a part goes to be mixed with the outgoing water of the said water tank..

If the temperature of the water from the solar panel is too cold it is sent completely to the water tank where it will be warmed by the heat pump. The water will be taken then from the said water tank exclusively.

In every case the last valve protects the installation from becoming too hot, if in case it is above 65°C at the outlet it will be mixed with cold water to obtain a temperature lower than this limit. This can be regulated.

With this system one is guaranteed the cheapest way of using electronic central heating and the water pumps consuming energy in the circulation of water, getting warm water with minimum energy cost. The physical laws of thermodynamics deal with the preparation of water by using this double thermostatic selection valve and mix without motor or expensive system of external control.

The temperature of water itself provokes the decision about where to go to provoke a maximum of energy saving

High efficiency pumps for the provision of the floor heating and the consumable water

Another improvement is in the efficiency of hot water system for floor heating and drinking water is achieved by adopting the correct pump models of a correct dimension for the task on hand.

To select correct, you consult the data of Europump, the European association of pump manufacturers and evaluate the data to opt for the models of Grundfos or Wilo which are prominent in energy efficiency.

Finally you need 2 pumps, one to circulate the water in the closed circuit of the floor heating taking part in its corresponding deposit of inertia of 100 l properly insulated. And the other you need to allow the double saving in the net of consumption of warm water and energy.

The pump that pumps the water for floor heating is one of class A, Grundfos Alpha 2L 25-60 and needs only between 15W and a maximum of 45 W, with the benefit of being electronically controlled by the system Estia, which puts it into work only when necessary.

And to save on warm water, it was a Grundfos Comfort autoadapt 15-14PM whose consumption oscillates between 3W and 15W and does not work continuously, but saving as follows:

The pump has a little memory which notes the habitual consumption during periods of 2 weeks counting every quarter of an hour in a table.

If, e.g. you use often warm water between 07:15 and 07:30, the pump will remember to take cold water from the tubes by means of the circuit, ensuring that the warm water fills the tubes so that when you open your taps you do not waste water waiting for the warm water to come.

MAKING A TAPPING CALENDAR

Every hot water tapping is logged in the calendar that covers at least one week's tapping history (Fig 2). Each calendar day is divided into 15 minutes time slots. When tapping of hot water is registered within a time slot, a T (for tapping) is noted in the calendar for this particular time slot. If no tapping is registered within a time slot, a 0 is noted. Based on the algorithm in the calendar log the AUTO*ADAPT* simply concludes when the next tapping of hot water can be expected; i.e. in those time slots where most T's have been noted over the days.

	0:00	0:15	0:30		...		7:00	7:15	7:30	7:45	8:00					...				23:30	23:45	
Today		0	0	0	•	•	•	0	T	0	0				•	•	•				0	0
Yesterday		0	0	0	•	•	•	0	T	T	0				•	•	•				0	0
		0	0	0	•	•	•	0	T	0	0				•	•	•				0	0
		0	0	0	•	•	•	0	T	0	0				•	•	•				0	0
		0	0	0	•	•	•	0	0	T	0				•	•	•				T	0
		0	0	0	•	•	•	0	T	0	0				•	•	•				0	0
		0	0	0	•	•	•	0	T	0	0				•	•	•				0	0
1 week ago		•	•	•				•	•	•	•				•	•	•				•	•
		•	•	•				•	•	•	•				•	•	•				•	•

Days

Time slots

In the example shown in Fig 2, 6T are noted in the time slot 7:15-7:30, and 2T in the time slot 7:30-7:45. This means that the circulating pump will ensure that hot water is available at the tap the next day at 7:15. According to the calendar log in the example the pump should also ensure hot water at 7:45 and 23:30.

In the example only one week's data is logged. The AUTO*ADAPT*'s control function in fact logs two weeks' data. This way the different consumption patterns of workdays and weekends can be taken into account.

In similar systems of circulating warm water you lose a lot of energy because the pump is working all day using power to move warm water into the tubes and furthermore, you lose energy in leakages of the same tubes of the building maintaining always warm water. (Whatever insulation there is, you will always lose energy)

For a hotel, this pump makes no sense, but for a one family house the habits can be translated in direct savings. This is because you do not waste water waiting for warm water in the beginning and you do not lose energy keeping the tubes warm during the day.

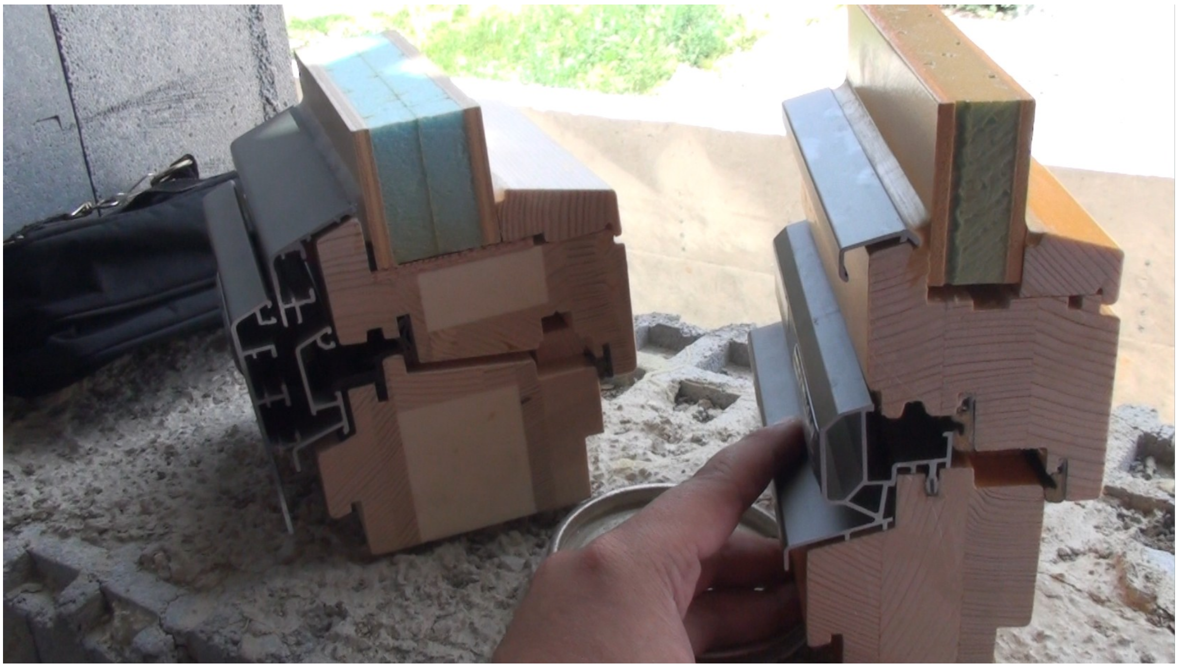
But, all the tubes of the building are thermally insulated, incorporating an insulating shell in all the tubes going and coming from the tanks for warm water, thus you only need to pump warm water to the tubes when it is needed for its immediate use.

These pumps comply with the European norms being effective in 2015 and are ahead of its time in the requirements of energy saving.

Thermally insulated by means of covering in an insulating shell all the tubes

Windows with 3 panes and high insulation frame

The choice of windows to install were determined by the minimum values of thermal transmittance calculated by the industrial engineer Jose Javier Martin Sierra college n° 1309, who was given the task of the previous energy study at the beginning of the work to avoid errors in solutions to gain class A.



2 options of frames from wood and alluminum

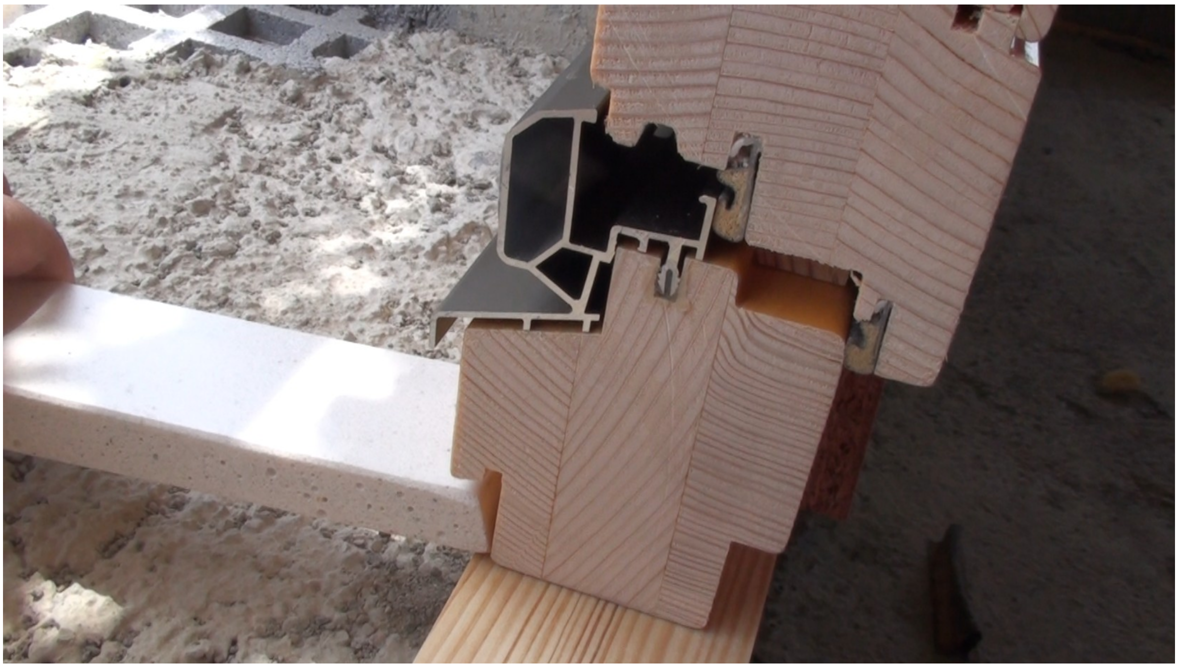
The available options made it clear that for the amount of panes only three panes would do the job if the space in between the panes are filled with krypton. For the frame the question was not so demanding half of the value transmitted is going through the glass.

In the photo you can see 2 options, to the left is a frame used in houses with the energy classification better than A or "passive houses", while the frame on the right is sufficient for the energy classification "B. (depending on case, of course)

However, I chose a frame in between the two, more going to the right option but with the improvement to include space for 3 panes and the configuration to have the outside protected by alluminium and furthermore by injections of polyurethane into the cores of the woods, as one can see in the boxes of the frame on the left, in which the insulating properties of the woods are yet improved by the addition of said material into the cores.

With this type of frame, the practical improvements in the solution described in the section of rendering the exterior, you achieve to reduce the costs of the window, amending the energy efficiency of the frame by other means, i.e. additional insulation for covering the frame from the outside.

Yet, the calculations of the certified energies of the building are done with the value of transmittance of the frame without paying heed to the possible improvement, but are impossible to say exactly without measurable objective data. Not even if you add costs.



Details of the top of the frame against the stone sill

The setting of the stone sill in a single piece of polymere concrete avoids problems with the seeping of water once sealed and does not create thermal bridges to the inside of the building. In the photo the part of the alluminium is missing, that covers the rest of the exterior wood of the window to enhance the durability by being not exposing the wood to the sun.

Detail of the material that supports the frame of the window to a perfect fit

In the process of setting, the elements are additionally improved by sealing the window at its junction with the wooden preframe, including the injection of polyurethane into the remaining joints to have a complete thermical sealing and a front against air leakages.

Injection of insulation foam of polyurethane for sealing the joints of the window

The finishing of the setting of windows was particularly supervised, because this is one of the weakest points in the enclosure, to guaranty a correct setting of all the elements to not damage the installation or the realized investment.

Details of the triple glass with two chambers with insulating Krypton gas.

You can see in the picture the serigraphs in between the panes allowing the markings of the norm, the date and the code of the product.

The gas krypton offers better insulation values than Argon making it harder to find a provider due to the low availability of producers in Spain who have access to said gas.

Exterior doors with certified insulation

There are 2 balcony doors, one to access the patio in the back from the kitchen and the other to access the upper roof, which have the same described properties as the windows, except for its bigger dimensions cause they are doors.

But, for the main exterior door of the building it would be inconvenient to use the same system with panes, I opted for an exterior door that has a type of certification for its thermal transmittance.

A conventional door would not be sufficient, mainly due to the absence of reliable data about the thermal behaviour, it would not have been “reliably” simulated correctly in the official programs used by the energy qualification, to introduce a non objective element.

On the other hand, finding a manufacturer having these certificates you observe that one of the virtues of their door system is to be equipped with a lower stride with rubber strip that seals perfectly the door when it is closed, avoiding the typical outdoor air intakes through the bottom slot of the door. The door is sealed around its perimeter..

Door Hörmann TermoPro, model TPS 010 with transmittance u=1,2 W/m²°C

Although looking for a door with the best (worst?) thermal transmittance in the market, this is the weakest point of the building, but on the other hand, due to its little surface, it will not affect the global effect of the building.

The only possible improvement in this respect would have been to seek the possibility of entry into the house through a foyer and a second door inside, but incurring an extra cost and damage of the interior layout because of the little width of the house of only 6 meters such an improvement is impossible.

Likewise, given that the utility room is in the basement, having inside the tank of warm consumption water and the inertia of the floor heating, it would not be wise to put a garage door without insulation, something that would lower the temperature inside the basement increasing the loss of warmth of said tank already insulated, which are sensitive against external temperatures and can damage your savings and probably also might damage the habitable area of your house with possible interchanges of unwanted heat when opening the kitchen door which communicates with the basement through a stair.

That is why it was decided to opt for a sectional garage door which incorporates thermal insulation and a rubber (EPDM) that seals the closure to the ground, to avoid too low temperatures in winter in this location.

The rest of the basement is not insulated by any of its walls, as it is a windowless basement and completely submerged in the ground that gives you the insulation around the perimeter except obviously for the sectional door entry. While on the roof of the basement there is no problem with thermal insulation when used EPS floor blocks to separate it from the living area of the house..

It is an improvement under proportional costs, since the insulated sectional door is not too costly compare to a non-insulated sectional door, we chose to acquire it with insulation.

Sectional door Hörmann LPU40 with sandwich panel of 42 mm insulated with polyurethane

Shutter and lattices to shade the window panes

In the climatical area of Granada, the sunshine on to the window panes in summer can increase heavily the temperature in the building, for that reason one can usually see the blinds closed in this time of summer to shade and cool the houses.

In our case, we could not choose conventional blinds, because the previous study showed that it was impossible to reach the energy classification A, due to the problem of the huge thermal bridge that brings the box of blinds, along with the problems of air leaks to the outside temperature.

In the best cases the boxes only have 2 or 3 cm of insulation which is a point of important leakage and solves nothing. And the option of putting a box outside of the building is not cheap, too.

One could also have taken windows and doors with a console that shades the whole gap, but this solution creates a security problem in the lower storey and a risk of breakage of the panes which we wanted to protect from exterior accidents.

The most feasible solution with the most advantages for regulated shade, security and protection of our investment in panes against accidents from the outside, was to equip the windows and balcony doors with blinds and shutters with mobile louvres allowing the light to pass without letting the sun shining directly onto the pane.

Detail of the preframe of blinds before the instalation

A single glimpse can show the problem of sunshine directly onto the panes and the projected shade before supplementing the systems of lattices

In the previous picture the gray preframe can be seen serving to anchor the system of shutter and mobile louvres and you can see said preframe to enhance the insulation of the gap between the frame of the window and the shutter itself.

According to the previous energy calculations performed by the qualified industrial project engineer, already mentioned in the section of windows, the minimum louvres recommended for adequate shade projection would be about 40mm with optimum inclination of 30° in case of opting for fixed louvres.

However, to facilitate the entry of light throughout the seasons and regulate adequately the warmth in winter when it is desirable, it was decided for a system with moving louvres 120mm wide, which even allow to raise the louvres with inverse slopes pointing above the horizon with the aim to profit from the system in winter, when it is not raining.

It would have been more desirable to provide windows with 2 swinging shutters that can be opened fully, but they are much more expensive than the lattices dispensing with the elements of opening the shutters, although on the other hand they have the benefit of being a system with a steel grid, which also desirable. For that reason the shutters are limited to the balcony doors.

Example of different grades of opening of the louvres in a shutter

The louvres are moved manually.

We considered the option to motorize the louvres but it remained unclear due to the relation between price and benefit of the motorization (if one could recover the investment by saving energy.)

However, to not exclude this possibility if in the future motorization systems become cheaper and IT-systems can take over the optimal decisions over the grade of opening depending on the function of the climatization, the installation was planned by preparing a corrugate tube which allows the passave of a cable from a possible motor and a mechanism close to the windows to put up later including creation of a gap in the wall for the actual manual device with a blind case.

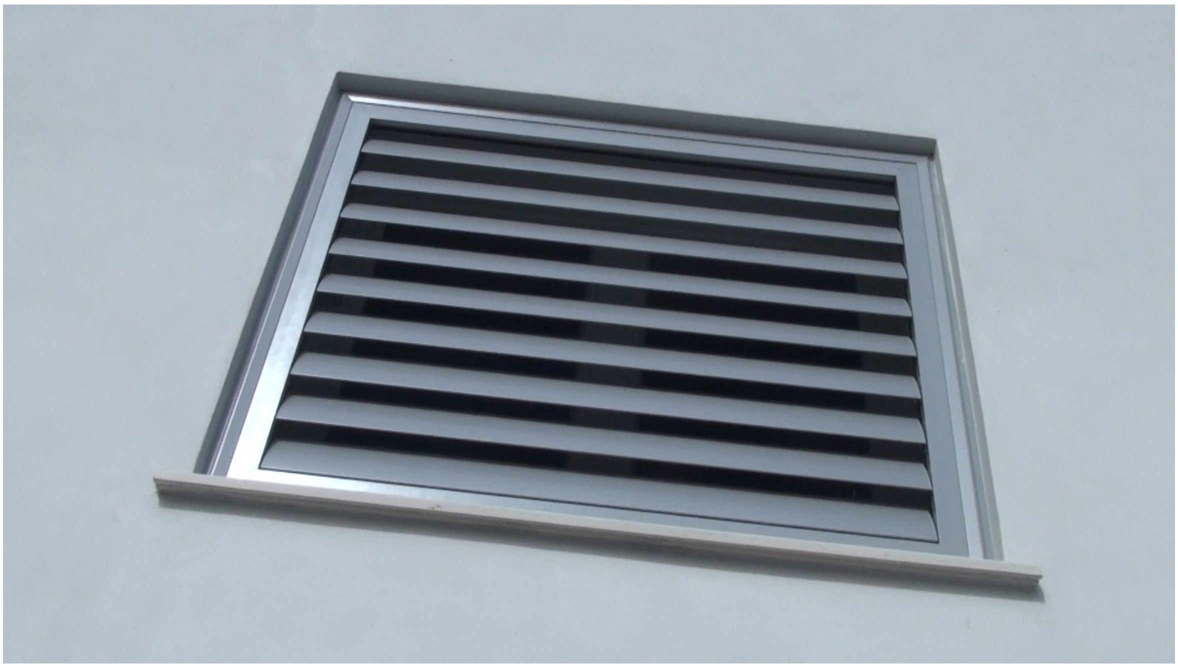
However, due to the width of the louvres, we find it neither necessary nor profitable energywise, because the louvres can be in a determined position during a whole season without the necessity to change its inclination, but for rain, snow or hail.

Example of the manual regulation which allows inclinations inverse above the horizontal

The control of the illumination with natural light can be made easier and more economic with the simple use of interior shades in case you need to lower the illumination at certain points but without the inclination of the louvres.

Example of the passing of light with the system of shutters in opened position and the rest closed

In summer when the sun is at it's highest point over the horizon, you leave the louvres open to a maximum to produce a indirect maximum of savings and presumably profit from the natural light during this period without incurring a harm to the increase in interior temperature inside, nor you have to lower the blinds to leave the house in shadows, which necissitate costs for artifical light, if you need to have a good illumination.



Shutter Regusol O-120 from Gimenez Ganga

In addition to the energy benefits this configuration of window openings will even give a security benefit for toddlers living the upper stories.

Benefit of natural light at all seasons.

The conditions of the natural light before and after the installation of the shutters has not deteriorated, there exists a considerable availability of natural light in the whole house with the louvres in slightly inclined position like in this photo.

You can imagine how the direct sun rays do not reach the panes nor the floor and yet, the flood of light is abundant including in this half closed position.

Photos from the finishings

We continue now quickly to show photos in it's final state of cranking up the installations and terminations of the work.

The first sequence shows the total of installation in the confined space of the kettle room in the basement, because it is difficult to show in a single photo all the elements together.

Flooding of water through the filter Honeywell FK 72CS to protect the installation from impurities

The water filter protecting the installation is of inoxidable steel mesh of 50 microns and counter current wash type, according to the Technical Building Code. Avoiding accumulation of impurities in the water tanks and tubes.

To and fro of water from the solar panels from the roof, insulated well

Thermostatic mixing and selecting valves to direct to consumption or the water tanks for ACS

Working as explained in the part of the heat pump for ACS and heating, optimized in saving by favouring the solar contribution,

panel changer of the heat pump Estia

This internal unit of the system Estia is receiving the heat or the coolness from the external unit through the 2 insulated tubes with white insulation and other tubes are used providing the heat to ACS and the heat or coolness to the floor heating.

It's electronics controls the 3 ways coming from the closed circuit to one system or another, giving priority to ACS.

It's electronics also manages the stop and go for the pump, which pumps warm water to the floor heating according to demand.

Connecting the interchanger of panels from Estia

Let's have a look how the closed circuit from Estia consist of these 2 tubes with black insulating shell have on the left the connection to the protected entry with a piece “Y”which is an additional filtre of protection and on the right have the 3-way valve.

3-way valve selecting the circuit to warm in between ACS and floor heating.

This valve acts electronically to select the circuit whenever necessary.

In circuit A it heats the spiral of the ACS water tank from Estia and when changing to circuit B, passes to heat (or cool) the inert water tank of the floor heating, if the floor has to act as a cooling device in summer.

Inert deposit of floor heating

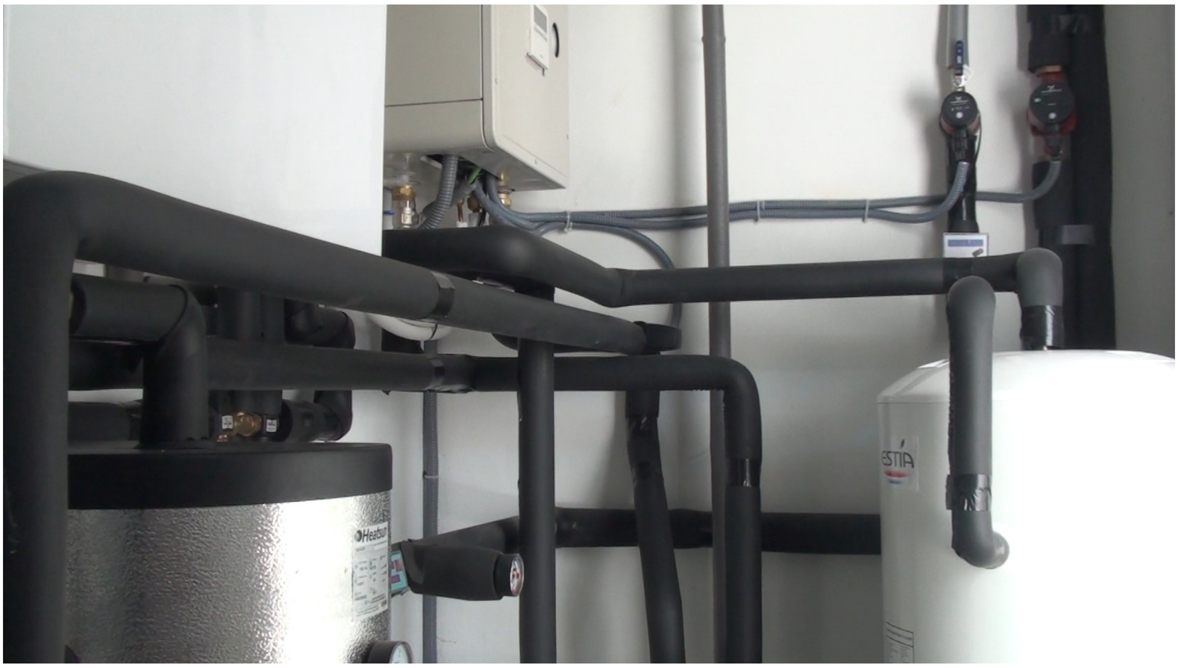
This insulated water tank of 100l provides stability to the system of floor heating. So to say, the amount of water to be heated remains very small, you get the working temperature in a short time and when on circulation the temperature goes down quickly, the heat pump starts and stops along instead of working in a steady order. The stabilization gives time so the detected changes of temperature are not brisk and the system can work optimally.

Deposit of ACS (warm sanitary water) with connection to the recirculation

This water tank is part of the circuit which brings heat to the rear jacks of the Estia, has an entry for cold water that comes prewarmed from the solar panels in the lower area. In the upper area it takes the warmer water that goes to the taps, in the middle area the water returns from the taps for a second round through the tubes allowing to have instantaneous warm water.

Above to the right, pumps for recirculation of ACS and impulse for floor heating

The pumps with the task to move water for floor heating up to the upper floors of the building use return water from the warm water taps and replaces cold water in the tubes with warm water, to replace that with real warm water, you can see above the water tank with it's tubes going to the upper floors.



View of the entire installation: Ventilation, ACS, Heating and Solar contribution

In this view which is the most ample possible for the reduced size of the installation room in the basement, you can see almost all installed elements comprising the system of heating, preparation of warm water for consumption, use of the water from the solar panes and also the ventilation machine with the heat recovery.

Installation on the roof above the flat roof of the tower of the last storey

Exterior unit of the heat pump Estia together with solar panels installed with a thermosifonic water tank of 300 l capacity.

The water that goes down from said solar water tank brings the maximum of temperature obtained from the sun, giving the savings to the heat pump Estia which does not go in to work for this reason.

Detail of the mouth for fresh air to the interior of the house

The mouths for sucking in fresh air into the interior of the house are connected to the ventilation machine with heat recovery and are adequately protected against outside events like rain and has a grid that makes it difficult for insects or bird to go in.
The small point below is a water flashing, that clears water that drips from the wall so they do not cause lichens or stains on the facade.

Detail of facade from the patio in the back, finished with all it's elements

The exterior view of the house with exterior insulation is not detectable, as you can see in this photo, the facade appears to have nothing special and imitates the style of every other conventional house in Andalucia. Although the secret is hidden by a few millimeters under the skin of the surface.

Detail of the side facade with the pedestrians access to the interior of the house

Due to the narrowness of the land, the buildable space allowed a facade of only 6 meters wide , so the house is very long and narrow.

Therefore the pedestrian's access to the house could not be at the front, and here we see the detail of the main door of the house located in the middle of the facade.

Please note, that to achieve energy efficiency, window sizes cannot be very large, nor in large numbers. Only what is necessary.

Detail of street front finished

View of the front which ends at the border marked by the attached house which has ceramics in black.

In this picture you see the garage door access, and how difficult it would have been, if the pedestrian entrance would have been next to it, including the difficulty in the inner distribution of the stairs and pathways.

It is the facade receiving the most sun, but you cannot put more windows due to the limits of the budget and the limits of the configuration of the inner distribution.

View from the living room to the kitchen

You can appreciate the finishing of the complete interior of the house in the lower floor, being the living room which executes the necessary distribution to the rest of the rooms of the house.

Future kitchen with balcony door access to the backyard

The kitchen with all it's wall installations, on one side the plugs for induction oven, kitchen bell extractor, oven, fridge etc. and on the opposite wall the plugs for water for the sink, washing and dish washing machine.

The distribution in 2 separated walls, one for water and preparation of food opposite the one for “fire” and storage is an answer to efficiency in the use of space without provoking corners and the circulation in it's use.

View to the living room and game room at the bottom, from the kitchen

In this perspective you can see how the joints of insulating EPS and the dry lining do not need any difference in finishing respect to a conventional construction system with bricks.

On the right side of the picture, the door giving access to the basement is intended to avoid to a certain level the separation of a space not habitable and not heated.

Finished bathroom with bathtub and double sink for kids

As yet we have not installed the accessories like mirrors, but we have already tested the correct working of the warm water with the solar panels and the heat pump to our satisfaction.

Toilets installed in the same bath as the previous photo

To keep everything in white colour in the whole interior is another means of saving to maximize the use of natural light.

The high costs of the system of windows and shutters, which are needed to get the energy classification “A”, does not allow us to increase the costs with big sized glasses or a bigger amount of it, therefore all the natural light available serves as a means of savings.

Toilet with sink shower in the master bedroom floor

In this photo you do not cherish the existent toilet, but you can see the beneficial effect of a minimal decoration to the use of natural light.

Master bedroom without furniture

The wall in front of us is part of the dry-lining, while the wall with the window is part of the wall with insulating blocks, which is coated with projected gypsum as we have seen in the section of the technical details of the finishings.

Likewise the view from the outside, nothing lets you suspect, that there is a different construction opposed to the traditional system inside.

The appreciation of difference only comes, when you enter from the street on a cold or extreme hot day.

Mouth air insufflation renovated with two LED low energy lighting

We remember the device dedicated to the installation for the mechanical ventilation with heat recovery has a double air circuit. In rooms where the fresh air is blown in like the living or the bedrooms, we see in the ceiling this kind of mouth. While in the humid rooms like bathroom and kitchen the stale air is extracted by an obviously different mouth like the picture below.

Extraction mouth for stale air together with the LED in the ceiling

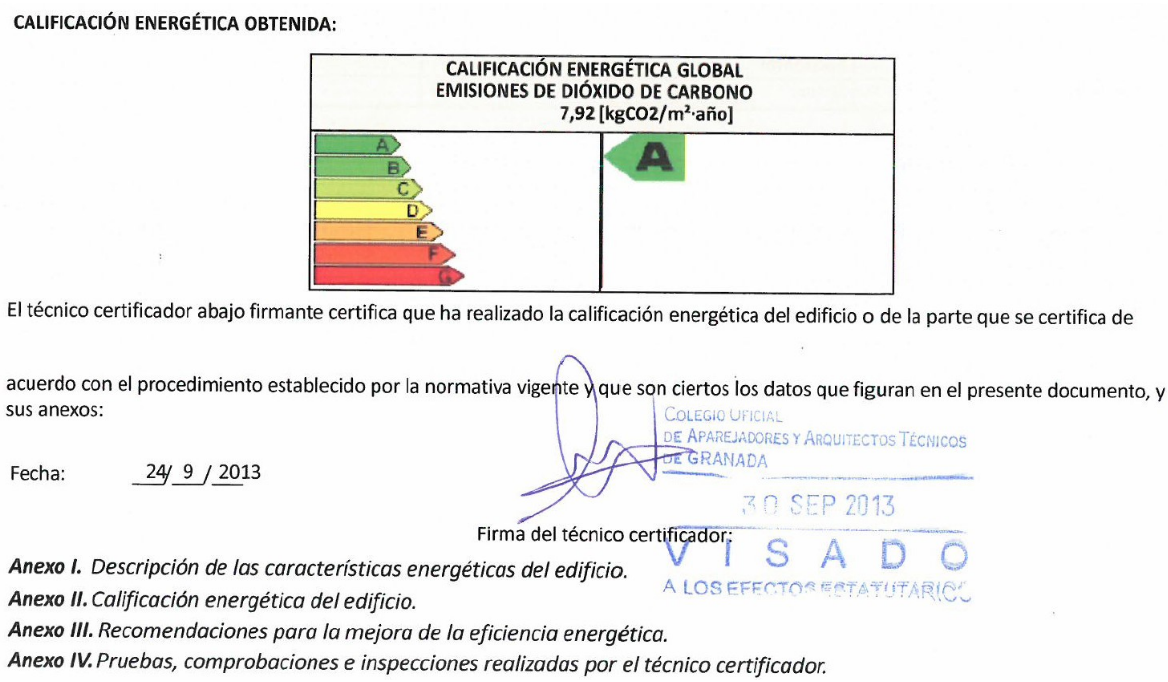
The setting of the air-mouths is strategic in a way that the mouth blowing in are as much afar from those who extract the air, thus favouring the circulation of air.

The whole illumination of the house is done by LED, consuming only 18 W, that is what we see in the picture, while in the passage way those with 9 W are used. To light up all the lights in the house we only consume 0,3kW.

Energy Certification Study

To get the energy certification for the building, the order went to the technical architect of the Granada institute Mr. Antonio Aguilera Medina with the institute number 2960, who made the required study for the certification using the informatic tool CE3 as a work base for the study of the final work.

You can see that the initial study coincides exactly with the result of the final study done for the certification


CALIFICACIÓN ENERGÉTICA OBTENIDA:

CALIFICACIÓN ENERGÉTICA GLOBAL
EMISIONES DE DIÓXIDO DE CARBONO
7,92 [kgCO2/m²·año]

El técnico certificador abajo firmante certifica que ha realizado la calificación energética del edificio o de la parte que se certifica de acuerdo con el procedimiento establecido por la normativa vigente y que son ciertos los datos que figuran en el presente documento, y sus anexos:

Fecha: 24/ 9 / 2013

Firma del técnico certificador:

COLEGIO OFICIAL DE APAREJADORES Y ARQUITECTOS TÉCNICOS DE GRANADA
30 SEP 2013
VISADO
A LOS EFECTOS ESTATUTARIOS

Anexo I. *Descripción de las características energéticas del edificio.*
Anexo II. *Calificación energética del edificio.*
Anexo III. *Recomendaciones para la mejora de la eficiencia energética.*
Anexo IV. *Pruebas, comprobaciones e inspecciones realizadas por el técnico certificador.*

Extract from the document of obtained energy qualification

It is worth to add to the figures that appear in a certificate of this type.

The savings are quantifiable and amortize more than the investment made along the life of the building. This energy saving can be estimated, but there is data one cannot measure and of similar importance is the life standard that can be offered to the occupants of the house with the most modern construction techniques that can be used instead of the traditional form.

Maybe the efficient housings were the desirable standard for the houses of official protection, precisely because for the families with lower income the energy efficiency translates directly into savings and directly in the costs over a long life.

We know that housing is done with a minimum life of 50 years without big modifications and reforms. Done this ways or in a similar mode (achieving big efficiency) it could be of great importance to reduce the more than probable energy crisis which can happen in the years to come in Europe.

For the houses already built exist solutions for the thermal cladding which can improve their condition. But in the case of new construction it is important to keep in mind the problem that might to be faced in the horizont of the life of the house with a grade of certainty rather elevated.

Analysis of the energy effeciency

The process of getting the energy certification class A required two independent studies.

The first was done by an industrial engineer like we have shown and was done before the start of the project to guaranty that one was going to choose the elements resulting in objetive energy qualification.

The second study was done after the work was done by another person, in this case a technical architect who elaborated a new study which was certified by a body of aperejadores (exist only in Spain) and technical architects meeting the official certification of the house as being class A.

But in spite of all this, I wanted to make a (low-cost) study on my own, based in objective and scientific means of the obtained results.

The two previous studies are based in the results offered by the computer programes which simulate the house and its behaviour like Calener VyP or CE3. But they are only simulations and it was my wish to check with real data obtained by measurements and verifiable after finished construction.

The fact that I could not occupy it as my permanent house, having exhausted my budget and still missing the endowment of kitchen and furniture, I've seen as a opportunity to study the actual behavior of the house, without thermal loads as those caused by appliances, heating, or the inhabitants themselves.

Thus, this presented a unique opportunity to proceed to study scientiftically the thermodynamic behavior of the house in its passive state, excluding the contributions of the heat proceeding from its inhabitants.

To proceed the study, I had first to find and purchase sufficient material with scientific precision to allow the capture of real data with little mistake. And this was only possible in locating thermometers that had low cost, reliable measurements and able to store a lot of data.

I could find the elements I needed in a company named LabJack.com that offers these characteristics with it's thermometer Digit TL, shown below these lines:

http://labjack.com/support/datasheets/digit

The technical characteristics of LabJack Digit-TL are:

* measurements of a large range, from -35°C to 85°C

* Resolution until 0,067°C in precision

*Typical error margin of only 0,1°C

* Waterproof capsule (IP68) fit for exterior measurements

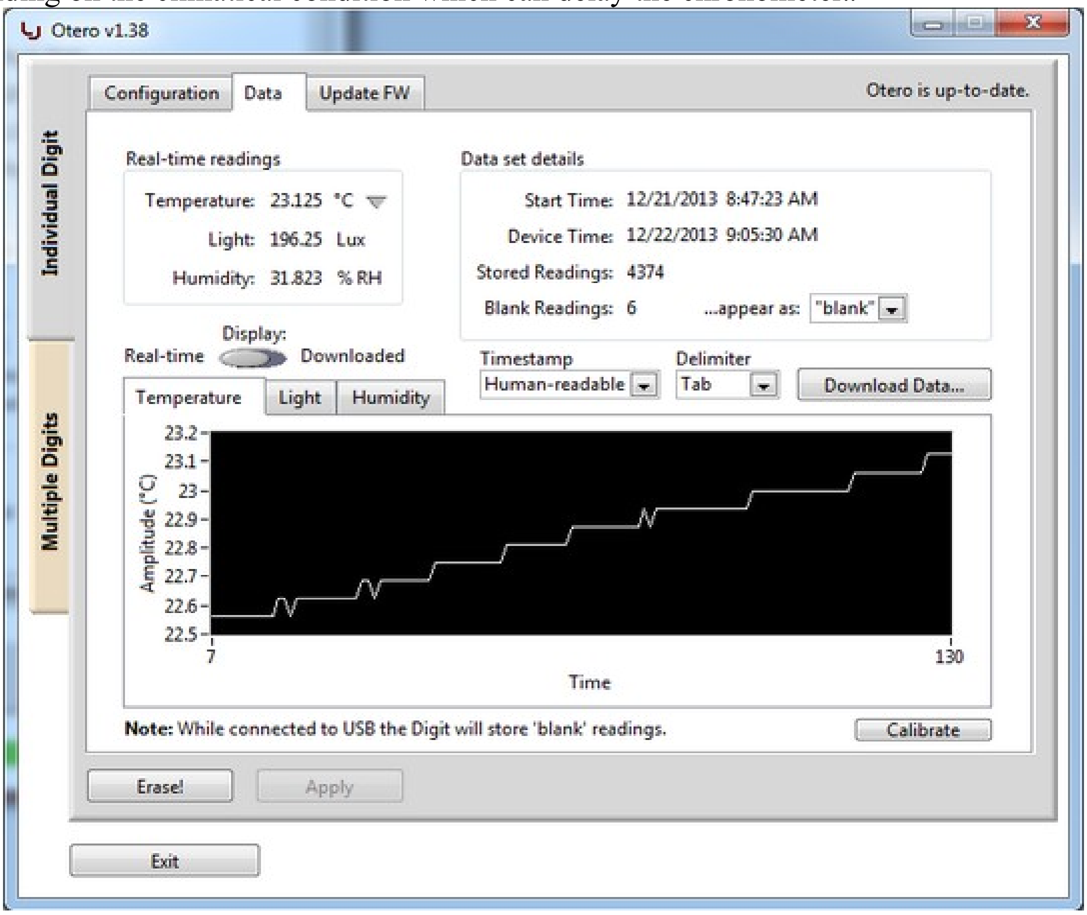
* Consumption of only 4,2 micro ampére which allow to measure during 3,6 years with a single battery

* Memory to store until 4,9 years of temperature data taken each 10 minutes without needing a computer

* and affordable price around 30€ per unit.

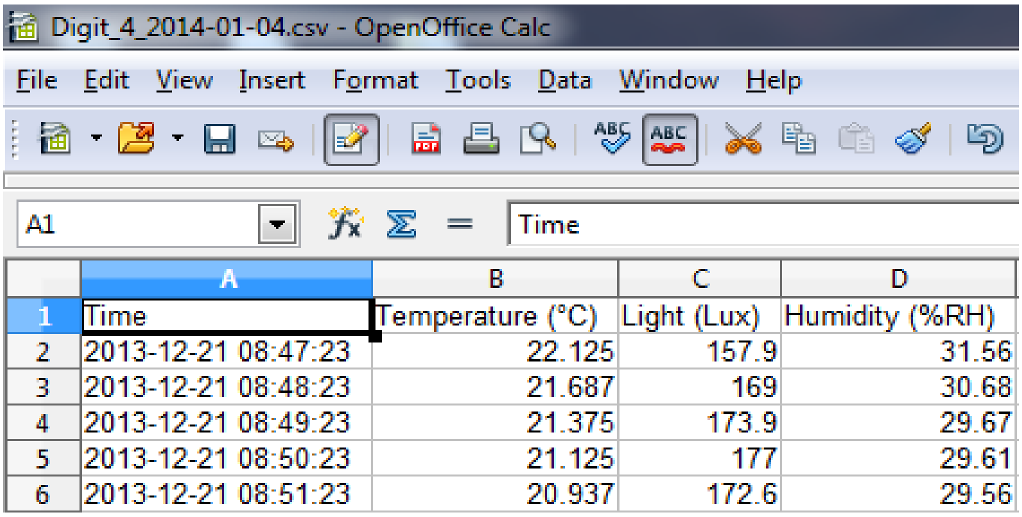
The quality of measurements is guaranteed by the electronics of Texas Instruments because it is equipped with the microchip model TMP 112 of said producer realizing reads on 12bits of precision in temperature storing it in the internal flash memory.

To load the data up to a computer for its final analysis is taken care by export them directly to Excel including dates and time with the precision of seconds with a maximum gap of 2 seconds per day depending on the climatical condition which can delay the chronometer..



View of the programe of data extraction once connected to the computer

The export of the data to Excel is shown in the following example picture :



	A	B	C	D
1	Time	Temperature (°C)	Light (Lux)	Humidity (%RH)
2	2013-12-21 08:47:23	22.125	157.9	31.56
3	2013-12-21 08:48:23	21.687	169	30.68
4	2013-12-21 08:49:23	21.375	173.9	29.67
5	2013-12-21 08:50:23	21.125	177	29.61
6	2013-12-21 08:51:23	20.937	172.6	29.56

The characteristics featured by this device of measuring one proceed in the following mode to gain the previous data for the thermodynamic study of the passive house:

I bought 4 units of LabJack Digit Tl which I spread out to the following points to measure:

* Outside the house

* Inside the basement

* Ground floor of the house

* Upper floor of the house

The reason why I placed 2 thermometers in the interior of the house was the objective to detect if there are different temperatures to be seen in the lower and the upper part of the building, due to the fact that we all know, that high temperature goes up and cold sinks down.

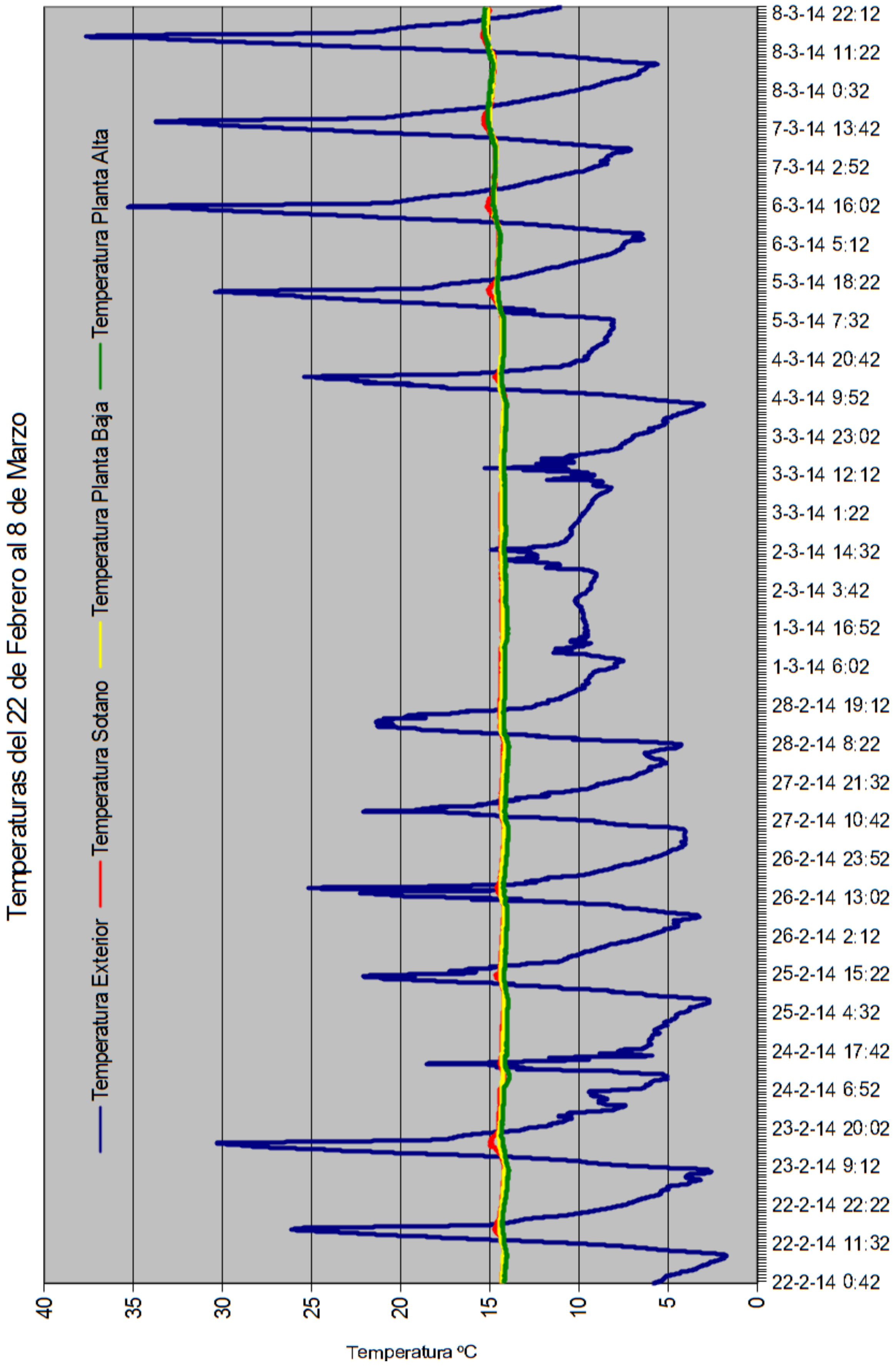
In this manner I left the measurement devices in the said key locations of the house during timespan going from end of February to the beginnings of march, which in Granada is a time of rather cold weather.

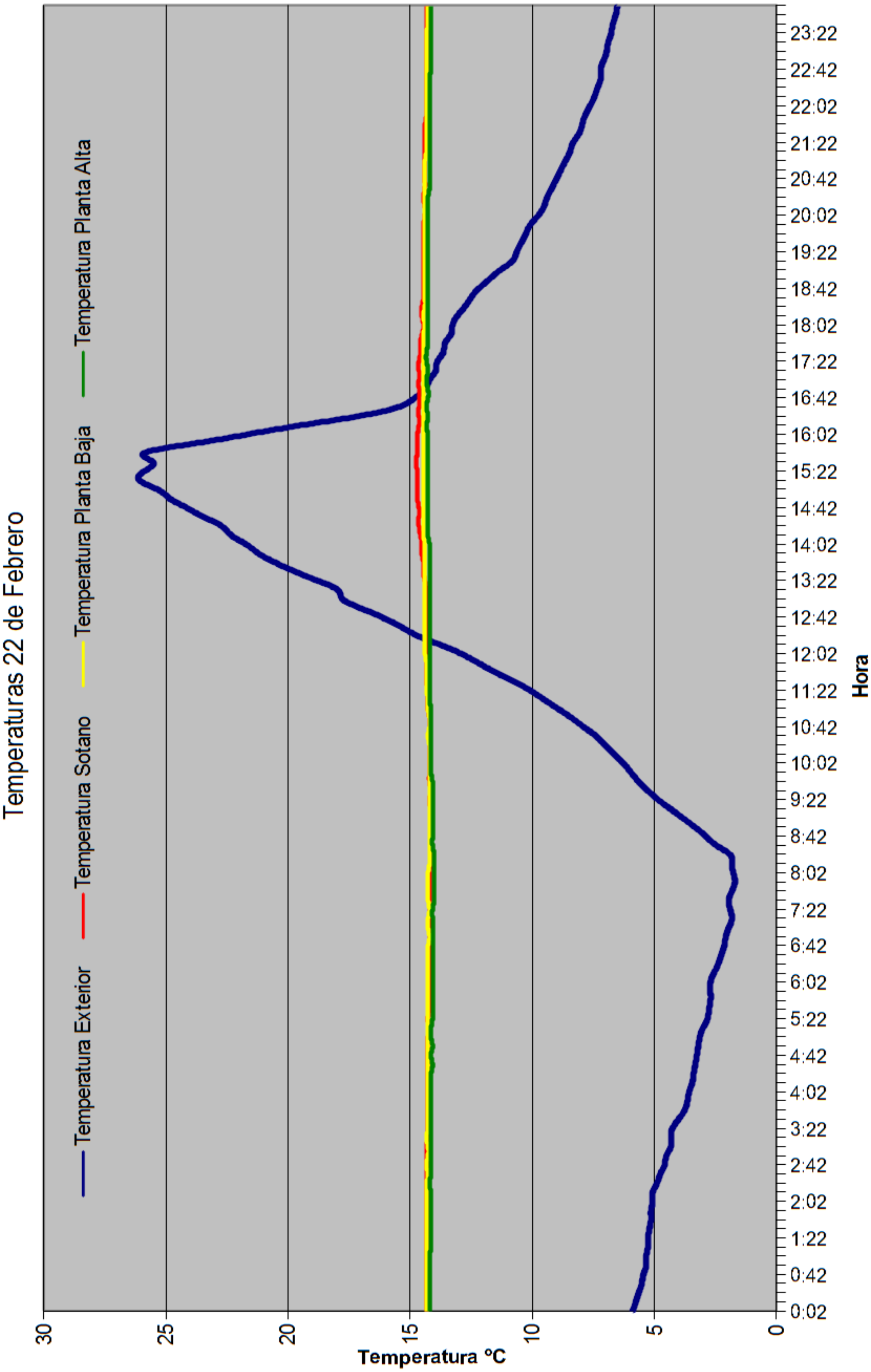
In this manner we will have a set of data for its post analysis of at least a few weeks of winter climate without heating the house.

To illustrate the data obtained I pass the graphs which are self explanatory. The first covers the behaviour of the house in all areas over the whole period that is covered by the measuring.

In the following graphs we will have a “zoom” to see what happens on the coldest and the warmest day between 00:00 of these days until 23:59 at the border to the next.

After the graphs I will comment on the obtained results in detail:


Temperaturas del 22 de Febrero al 8 de Marzo
Temperatura Exterior
Temperatura Sotano
Temperatura Planta Baja
Temperatura Planta Alta
Temperatura ºC
40
35
30
25
20
15
10
5
0
22-2-14 0:42
22-2-14 11:32
22-2-14 22:22
23-2-14 9:12
23-2-14 20:02
24-2-14 6:52
24-2-14 17:42
25-2-14 4:32
25-2-14 15:22
26-2-14 2:12
26-2-14 13:02
26-2-14 23:52
27-2-14 10:42
27-2-14 21:32
28-2-14 8:22
28-2-14 19:12
1-3-14 6:02
1-3-14 16:52
2-3-14 3:42
2-3-14 14:32
3-3-14 1:22
3-3-14 12:12
3-3-14 23:02
4-3-14 9:52
4-3-14 20:42
5-3-14 7:32
5-3-14 18:22
6-3-14 5:12
6-3-14 16:02
7-3-14 2:52
7-3-14 13:42
8-3-14 0:32
8-3-14 11:22
8-3-14 22:12


Temperaturas 22 de Febrero
Temperatura Exterior
Temperatura Sotano
Temperatura Planta Baja
Temperatura Planta Alta
Temperatura ºC
Hora
30
25
20
15
10
5
0
0:02
0:42
1:22
2:02
2:42
3:22
4:02
4:42
5:22
6:02
6:42
7:22
8:02
8:42
9:22
10:02
10:42
11:22
12:02
12:42
13:22
14:02
14:42
15:22
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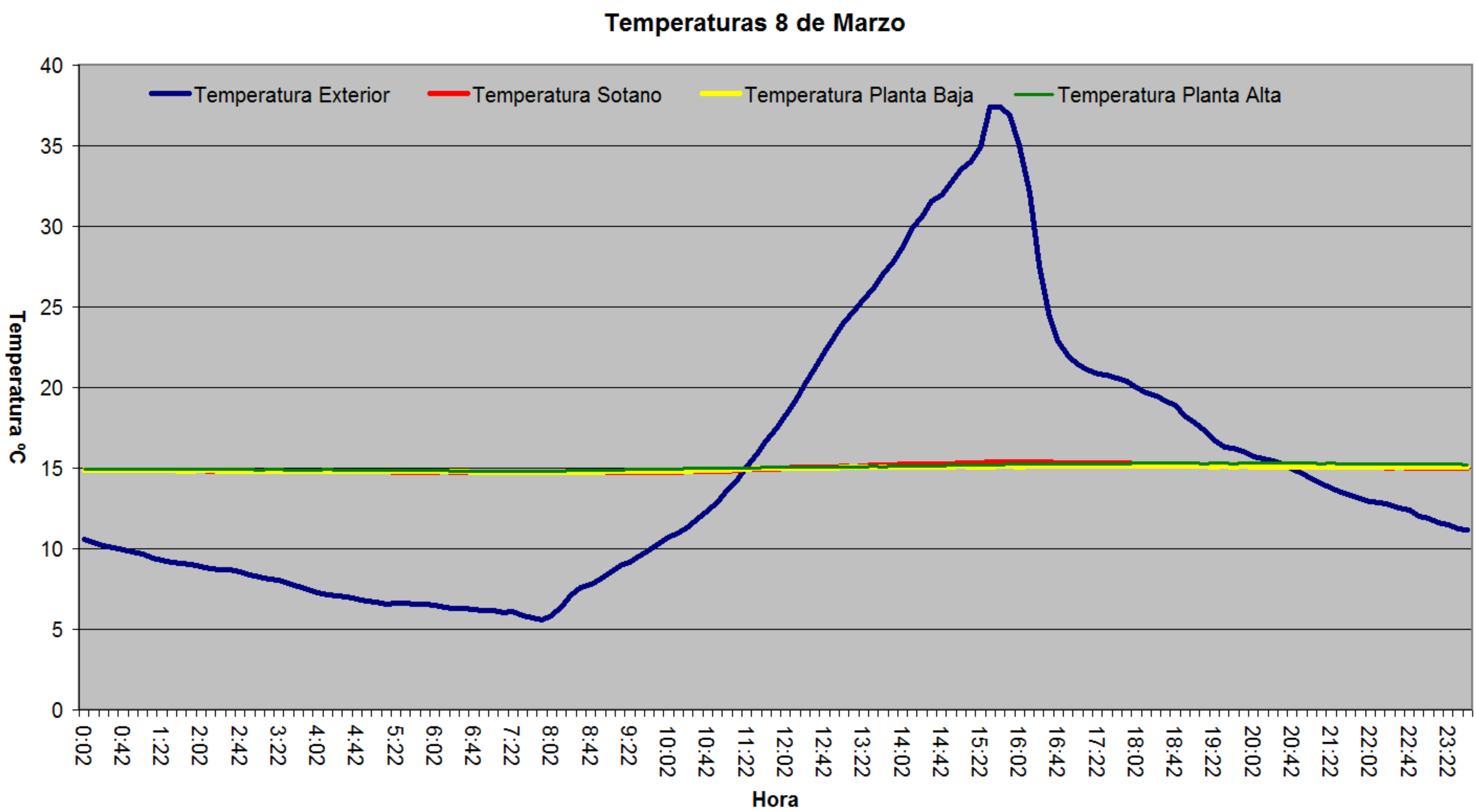
22:02
22:42
23:22


Temperaturas 8 de Marzo
Temperatura Exterior
Temperatura Sotano
Temperatura Planta Baja
Temperatura Planta Alta
40
35
30
25
20
15
10
5
0
Temperatura ºC
0:02
0:42
1:22
2:02
2:42
3:22
4:02
4:42
5:22
6:02
6:42
7:22
8:02
8:42
9:22
10:02
10:42
11:22
12:02
12:42
13:22
14:02
14:42
15:22
16:02
16:42
17:22
18:02
18:42
19:22
20:02
20:42
21:22
22:02
22:42
23:22
Hora

Detail of thermometer LabJack Digit-TL installed on the top floor of the house

After verifying the 3 thermometers working correctly, one can obtain various conclusions. First contribution of numerical values:

To look beyond the graphs, we have summarized the measurements of these 2 weeks of measurement between 22.Feb and 8. March, obtaining the maximum, minimum and average value ant the difference of temperature (thermal fork)

	Tª Exterior	Tª Basement	Tª Ground Floor	Tª Upper Floor
Minimum	1,687 ºC	14,125 ºC	14,125 ºC	13,875 ºC
Maximum	37,375 ºC	15,375 ºC	15,125 ºC	15,312 ºC
Average	11,013 ºC	14,445 ºC	14,397 ºC	14,271 ºC
ΔT (max-min)	35,688 ºC	1,250 ºC	1,000 ºC	1,437 ºC

We see the house had to bear a thermal fork of temperature of a little bit less than 35 degrees and a half, varying on the outside from a little bit more than 1 degree over 0 until almost 40 (taking into account that the exterior thermometer is in the shades), the effects producing in the change of temperature in the house are not more than 1 degree and a half in the worst circumstances.

With these dates remains to ask, what is happening in the basement which we remember does not have thermal insulation except the sectional garage door, that it behaves is a manner so similar to the rest of the house.

And the answer may be in the fact that the basement is submerged completely in the earth producing a geothermal effect similar con caves.

It is difficult to assure with certainty without having thermographic cameras which are unattainable to me, but it is possible that the 14,4°C in winter transform into 17°c in summer, being the temperature being sent by the basements ceiling.

Conclusions about the achieved objectives

There is no doubt, seeing the obtained energy certificate and the data obtained from my study and personal verification, that the objective of energy efficiency is achieved.

Furthermore the data given by the measurements confirm the success of the decisions made for the construction system.

Eg, one could see how the obtained temperatures in the upper storey of the tower only are a half grade “worse” than on the ground floor of the house and it is easy to come to the conclusion that this is in the said room , in which exists the most proportion of glassed windows in relation to the existing surface, because there is a balcony door and a window for a small room.

This confirms the quality of the window solution, supposed that with a little more surface of glass one has a relative harm of a half grad Celsius in a period of 2 weeks.

Also it turns out the relevance of the decision to take a garage door with an insulating door, because not only the water tanks of warm water have lesser energy losses, but the geothermal effect can be confirmed in the basement and can be gained of practically the whole year.

I can suspect that the transfer of the temperature between basement and the rest of the house happens due to the pillars of concrete, I could not do without because Granada is a very heavy seismic area.
Because although it is only a small surface, concrete is an excellent thermal conductor. And this may be due to the temperature balance between the basement area with geothermal influence and the rest.

Also one discovers the tremendous importance one has in the savings due to the mechanical ventilation with heat recovery, because it is a device with a minimum consumption for the climatization, the fact that it leaves the house practically equal albeit the temperatures existing outside the building, may allow switching on the heating for a day and live on the energetic revenues without switching it on for various days afterwards, no more than using the advantages of the mechanical ventilation to maintain a comfortably climatized environment.

We must also clarify that, a house not being occupied throughout the measurement performed with thermometers, the shutters were left in fully closed position, so in this study does not appear the impact that could be gained by totally opening them on a winter day with sunshine to capture the heat of the sun through the window panes.

It remains clear that the house behaves in an excellent form, without being affected by the change of temperature, that exists outside and contributes energy to maintain it in the area of comfort. I expect only a minimum. With this the estimated savings in the energy certificate of around 83% in comparison to traditional house appears to be reasonable and meet or even exceed in reality.