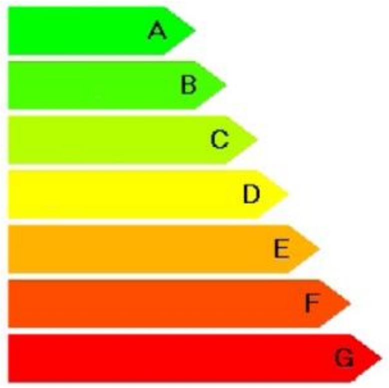
Escola Politècnica Superior d'Edificació de Barcelona
UNIVERSITAT POLITÈCNICA DE CATALUNYA

BUILDING ENGINEERING

FINAL DEGREE PROJECT

ENERGY PERFORMANCE CERTIFICATES OF EXISTING BUILDING AND PROPOSAL OF ENERGETIC IMPROVEMENT FOR A SOCIAL BUILDING IN TARADELL BELONGING TO THE COOPERATION PROJECT RELS



ANNEX I MEMORY IN ENGLISH

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ABSTRACT

In the European Union 40% of final energy consumption corresponds to buildings. In order to reduce this high percentage it is essential not only the impact on new buildings but also on existing building stock.

This project consists of the energy evaluation of a social building for rent built in 2003 in the town of Taradell (Osona) belonging to the Border Cooperation Project RELS (Rénovation Energétique des LogementS), with the participation and coordination of the Catalonia Housing Agency for improving the thermal efficiency and energy use in residential and social buildings located around the Mediterranean Sea.

This will do an energy diagnostic of the building with the original document project, historical invoices, monitoring and data collection "in situ" during a long enough time period. I also will do the energy simulation with specialized computer software (LIDER, CALENER, CE3 and CE3X) and the subsequent comparative between them to see their advantages and disadvantages. Then I will be comparing the theoretical and real values of demand and consumption.

The building use and management by users is a not less important factor to keep in mind while making an energy evaluation. In this way I will also make a survey of the neighbours in order to find out the uses and the level of comfort achieved.

From this point I will study some energy rehabilitation solutions which improve the thermal envelope of the building, the facilities efficiency, the introduction of renewable energies, and some good practice guide of use and management of the building. The achievements in satisfying the goals set by the European Directive 2010/31/UE of 20% CO2 emissions reduction, 20% renewable energy use and a 20% reduction of energy consumption of buildings compared to 1990 levels.

It will suggest, following sustainability criteria, a set of measures to improve the global building analyzing its technical, economic and environmental viability.

Finally, it will redo the energy simulation to the improved building and the results will be compared with the original values to determine the compliance degree of objectives of reducing demand and upgrade the energy rating of the building.

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INTRODUCTION

This Final Degree Project has the objective of apply and expand the knowledge acquired in the subjects of the DAC[1] ***"Environmental impact of building and energy rehabilitation"****, which consists of the following subjects: Energy Efficiency, Building and environment, and Diagnostics and building energy rehabilitation.*

My participation in the European Cooperation Project ***RELS***[2]*, in collaboration with the Catalonian Housing Agency, has allowed this work to have highly practical character by studying an already constructed building. This has also allowed me to know firsthand how it's been constructed in recent years, its shortcomings from a sustainability and energy efficiency point of view, as well as offer solutions for its energy rehabilitation.*

Likewise, it aims to deepen the use of software tools for the energy performance certification of buildings, particularly those relating to existing buildings which have recently been approved, ***CE3X*** *and* ***CE3****.*

So far, certification has been applied to new buildings with software such as ***LIDER*** *and the* ***CALENER****, but the transposition of European directives*[3] *to our country has required that most of the existing buildings should be also certified such as years ago was done with household appliances. This information, that will be available for owners, buyers, tenants or public building users, will allow the presentation of the environmental impact of our buildings and the possibilities of improvement we have ahead.*

Finally I would like to remind you that as building engineers it is important to be conscious of our significant role and the responsibility that we have in order to achieve a more sustainable buildings sector.

1 ENERGY SITUATION IN CURRENT BUILDINGS

1.1 Energy in buildings and energetic refurbishment

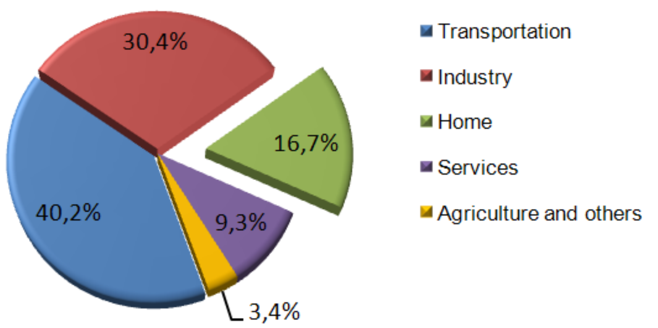
We are in one of the worst financial and economic crises of recent decades, but we shouldn't forget that we are also facing an energy and environmental crisis which it worsens each day.

Our economy is based mainly on fossil energy sources which are very polluting and non renewable. The Spanish situation is even more worrying because it's a country very dependent on foreign energy, we import more than 80% of our energetic consumption.

But with this rate of exhaustion of resources and the inexorable environmental degradation it's clear that, sooner or later, we will face a very serious situation with unpredictable consequences, such as climatic change or global warming. Thus, the awareness and concern of citizens is increasing.

Therefore it's necessary to act at all levels of society to try to reverse this trend, in this sense construction also has much to say.

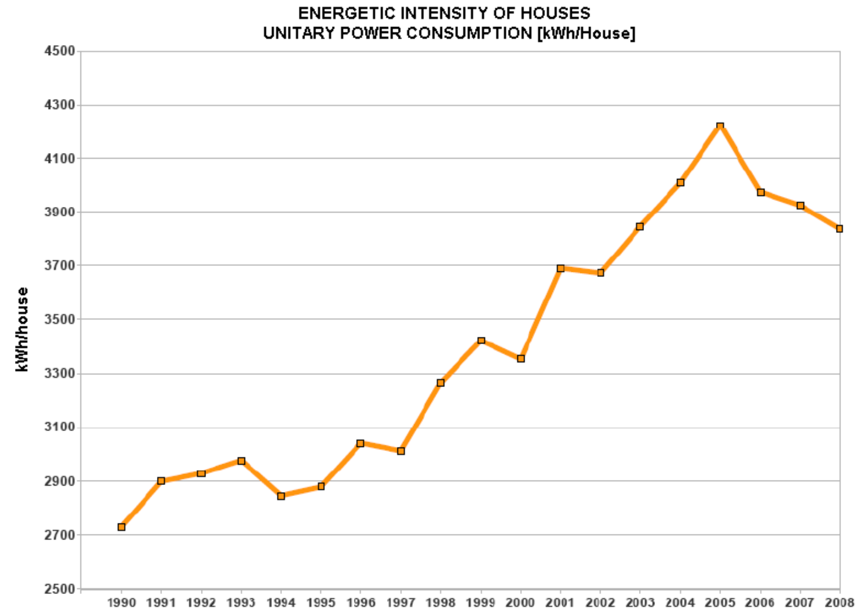
The residential sector is a key sector in the national and European current energy context. In our country it represents 17% of the total consumption and 25% of electricity consumption. In Europe this percentage is even higher reaching 41% of energy consumption.



Graphic 1.1. Final energy consumption of private household in Spain.
Source: IDAE

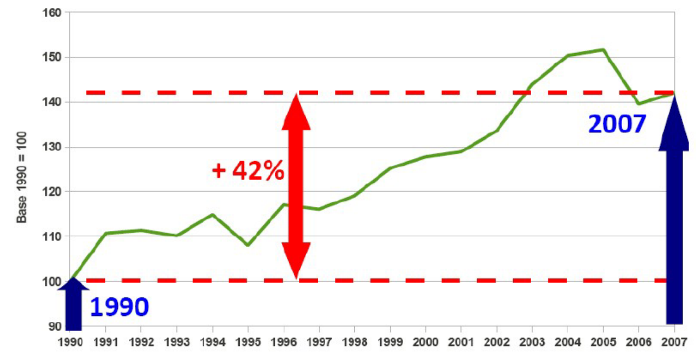
Although the construction has suffered in recent years a very pronounced crisis this sector has had a continued growth in the last few years, nowadays Spain has a house stock of approximately 25 million households[1], and therefore their associated energy demand has increased too.

1 Potential Energy savings and CO2. Emissions reduction from Spain's existing residential buildings in 2020. WWF Spain and ETRES Consultores. 2010.



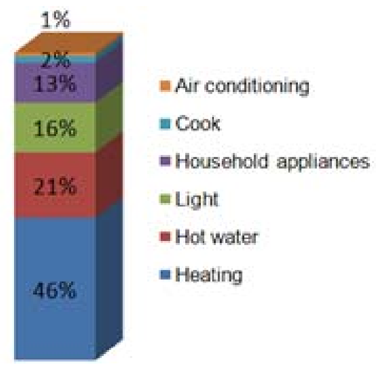
Graphic 1.2. Evolution of electricity consumption in Spanish houses.
Source: Ministry of Industry, Tourism and Trade. IDAE

In addition, only the use of energy buildings accounts for the fifth part of greenhouse gases emissions in our country.



Graphic 1.3. Evolution of CO2 emissions in building sector of Spain, 1990-2007.
Source: Ministry of Industry, Tourism and Trade. IDAE

We must remember that the average household electricity consumption is 4,000 kWh per year, being distributed according to the following percentages:



Graphic 1.4. Electricity consumption in Spanish dwellings.
Source: IDAE

Heating systems have the highest percentage with the 46%, followed by hot water with 21% and lighting with the 16%.

In our country, renovation and particularly, the deep energy renovation of buildings, offers a wide potential for development, although it has traditionally had a residual weight within the activity sector. In 2009, renovation represented only 19% of the total investment in the construction sector in Spain, versus the average 43% in the EU. Germany, for example, works in existing buildings represent 62% of the activity of the sector and new buildings a little more than 37%. The Spanish annual renovation rate is, comparatively, also very low.[2]

So 8 out of 10 existing buildings are older than two or more decades and they were not constructed with criteria of energy efficiency as those applied in the current Technical Building Code. (source: IDAE). One building which has a deficient insulation, thermal bridges and air leaks, after one year represents a significant waste of energy and money. According to studies by the European Union, and others such as WWF Spain, dwellings have a potential energy savings up to 90%.

Figure 1.5. Energy losses in poorly insulated buildings.

Source: "La Casa que Ahorra" Fundation.

With ambitious policies for energy refurbishment of the housing stock we could reduce energy consumptions and CO2 emissions by about 30% in our country, and with pay-back of even just five years. In this situation energetic refurbishment of buildings plays an important role.

It has been estimated that even with a full energy building rehabilitation, improving insulation, replacing windows, more efficient installations or renewable energy sources, it represents savings of energy and pollution about 60% front the construction of a new one. [3]

According to European aim, architecture leads towards buildings with more energy efficiency requirements than the currents ones, with designs much more sustainable and which require little or no energy (nearly zero buildings or standard Passivhaus).

[2] *"Potential Energy savings and CO2. Emissions reduction from Spain's existing residential buildings in 2020". WWF Spain and ETRES Consultores. 2010.*

[3] *"Construimos valor. Incentivos a la Construcción Sostenible". Fundación Entorno-BCSD Spain. 2008.*

1.2 Legislative framework

During the last years, the EU has undertaken initiatives to reduce energy consumption and CO2 emissions in building sector, with the objective of promoting the efficiency of buildings.

Relationship of European directives within the framework of construction:

- *Directive SAVE 97/76/CEE, 13rd of September 1993, relating to restrictions of CO_2 emissions. This was not implemented due to divergences in the procedure for environment impact assessment.*
- *Directive 2002/91/CE, 16th December 2002, relating to energy performance of buildings. This establishes requirements in terms of:*
  - *Methodology for calculating the energy performance of buildings*
  - *Energetic efficiency of new and existing buildings objects of important reforms.*
  - *Energy Performance Certificates.*
  - *Periodic inspection of boilers and air conditioners.*
- *Directive 2010/31/UE, 19th May 2010, relating to the 20/20/20 proposal by 2020, with the objective to achieve:*
  - *20% energy savings.*
  - *20% reduction in CO_2 emissions.*
  - *20% of total energy production with renewable energy.*
  - *And design new buildings with nearly zero energy consumption for the year 2020 (2018 for administration).*

The transposition of the Directive 2002/91/EC into our country is carried out by the following standards:

- *Technical Building Code (TBC), Royal Decree 314/2006, 17th March, which regulates construction parameters and energy savings.*
- *Royal Decree 1027/2007, 20th July, Regulation of Thermal Installations of buildings (RITE) and subsequent amendments. It regulates the energy efficiency of heating installations.*
- *Royal Decree 47/2007, 19th January, adoption of energy performance certificates for new buildings.*
- *And other regional and local regulations: Ecoefficiency Decree, local regulations for solar systems.*

In addition to these normative, various governments and public agencies (IDAE, ICAEN, ...) have also made plans to promote energy efficiency and renewable energies, including grants and special funding lines.

IDAE (Spain):

- *Plan action for Savings and Energy Efficiency 2008-2012.*
- *Plan action for Savings and Energy Efficiency 2011-2020.*

ICAEN (Catalonia):

- *Plan of Energy and Climate Change in Catalonia 2012-2020.*
- *Plan for savings and energy efficiency in buildings and white goods, Generalitat of Catalonia 2011-2014.*
- *Renewal plan for boilers, appliances and air conditioners 2011.*
- *Renewal plan for shops lighting 2012.*
- *Renewal plan for windows 2012.*

1.3 The nearly zero energy buildings

The topic of Zero Energy Buildings (ZEBs) has received increasing attention in recent years, until becoming part of EU policies on energy efficiency in buildings. According to the European Directive 2012/31/UE, all member states should take measures to ensure that by 31 December 2020 all new buildings are nearly zero energy consumption, or after 31 December 2018 for new buildings occupied and owned by public authorities.

However, we can see difficulties to introduce low energy building requirements in the short-term in all Member States, due to the pertaining low penetration rates, higher costs, lack of trained professionals and low readiness of the construction industry to deliver large quantities of low energy buildings in all EU Member States.

Numerous government bodies, research institutes and other organizations are actively investigating practical aspects relating to the delivering of the EU target for nearly zero energy buildings.

The Commission felt that this framework would pose a significant challenge to the construction sector to build this kind of buildings and would increase prices by 7% to 15%.

1.3.1 Concept

A nearly zero energy buildings is a built with significant energy-saving features through efficiency gains such that the balance of energy needs can be supplied with renewable technologies.

This building standard is based on a comprehensive process in project development and implementation, resulting in new buildings with a really low energy demand, but in the refurbishment of existents buildings are also possible.

The Directive does not clearly define what a "nearly zero energy building" is, either for new build or refurbishment of existing buildings. Despite the emphasis on the goals the definitions remains generic and are not yet standardized. Article 2(1a) gives a purely qualitative definition:

> *A "nearly zero energy building" is a building that has a very high energy performance. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby.*

In our country it's expected that in future revisions of CTE it will determine the conditions for when a building is considered as a nearly zero-energy buildings.

The nearly zero-energy buildings have similarities with Passive House standard, net zero energy or energy plus buildings.

*The **Passivhaus standard** for buildings provides a comfortable indoor climate in summer and in winter without the need for a conventional heating system. To permit this, it is essential that the building's space heat load does not exceed 10 W/m² living area in order to be able to use a simple air preheater. Passive Houses therefore require roughly 85% less energy for heating than the specific consumption levels of new buildings designed to the standards presently applicable across Europe.*

The Passivhaus standard for central Europe requires that the building fulfills the following requirements:

- *The building must be designed to have an annual heating demand of not more than 15 kWh/m² per year in heating and 15 kWh/m² per year cooling energy or to be designed with a peak heat load of 10W/m².*
- *Total primary energy consumption (primary energy for heating, hot water and electricity) must not be more than 120 kWh/m² per year.*
- *The building must not leak more air than 0.6 times the house volume per hour (n50 ≤ 0.6 / hour) at 50 Pa (N/m²) as tested by a blower door.*

It's estimated a range from 15,000 to 20,000 passive houses around the world. The vast majority have been built in Germany or Scandinavia. The first Passivhaus residences were built in Darmstadt, Germany in 1990.

Figure 1.6. The original 1990 Passive Houses, Darmstadt (Germany).
Source: Passive House Institute.

*A **net zero energy building** (ZEB) is a building that over a year does not use more energy than it generates. The first 1979 Zero Energy Design building used passive solar heating and cooling techniques with air-tight construction and super insulation. A few ZEB's fail to fully exploit more affordable conservation technology and all use onsite active renewable energy technologies like photovoltaic to offset the building's primary energy consumption. Passive House and ZEB are complementary synergistic technology approaches, based on the same physics of thermal energy transfer and storage: ZEBs drive the annual energy consumption less than 0 kWh/m² from the already low PassivHaus criteria of 120 kWh/m² with help from local renewable energy.*

Figure 1.7. BedZED zero energy housing (UK). Source: http://www.zedfactory.com/

Energy Plus houses *are similar to both Passivhaus and ZEB but emphasize the production of more energy per year than they consume. Zero energy buildings can be independent from the energy grid supply. This is achieved using a combination of microgeneration or photovoltaic technology and low-energy building techniques, such as: passive solar building design, insulation and careful site selection and placement. A reduction of modern facilities can also contribute to energy savings, however many energy-plus houses are almost indistinguishable from an ordinary home, preferring instead to use highly energy-efficient appliances, fixtures, etc., throughout the building.*

Figure 1.8. Heliotrope, the first Energy-plus building. Freiburg (Germany).
Source: www.rolfdisch.de

1.3.2 Techniques and usual components

Several techniques and technologies are used in combination. The heating and cooling loads are lowered by using high-efficiency equipment, added insulation, high-efficiency windows, natural ventilation, and other techniques.

Water heating loads can be lowered by using water conservation fixtures, heat recovery units on waste water, by using solar water heating, and high-efficiency water heating equipment.

Likewise, daylighting with skylights or solar tubes can provide 100% of daytime indoor illumination. Nighttime illumination can be done with fluorescents and LED's lighting that use 1/3 or less power than incandescent lights, and without adding unwanted heat.

These buildings may be designed to make dual use of energy including white goods too; for example, using refrigerator exhaust to heat domestic water, ventilation air and shower drain heat exchangers, office machines and computer servers, and body heat to heat the building. In conventional buildings this heat energy is normally exhaust outside.

All these features can vary depending in which climate zone is constructed.

- *Decrease losses of heat by insulating:*

These buildings employ superinsulation to significantly reduce the heat transfer through the walls, roof and floor compared to ordinary buildings. The good insulation protects against the cold in winter but as well against heat in summer.

Heat is lost from buildings by three different routes – ventilation, transmission, and radiation.

Ventilation heat loss occurs, for instance, through open windows and doors and, in an uncontrolled way, through small cracks and gaps in the building envelope. Heat will always flow from a warm area to a cooler area, and transmission heat loss therefore occurs because of the temperature differential between the inside and the outside of the building. This is affected by the quality of the thermal envelope, the better the insulation the lower the transmission heat loss.

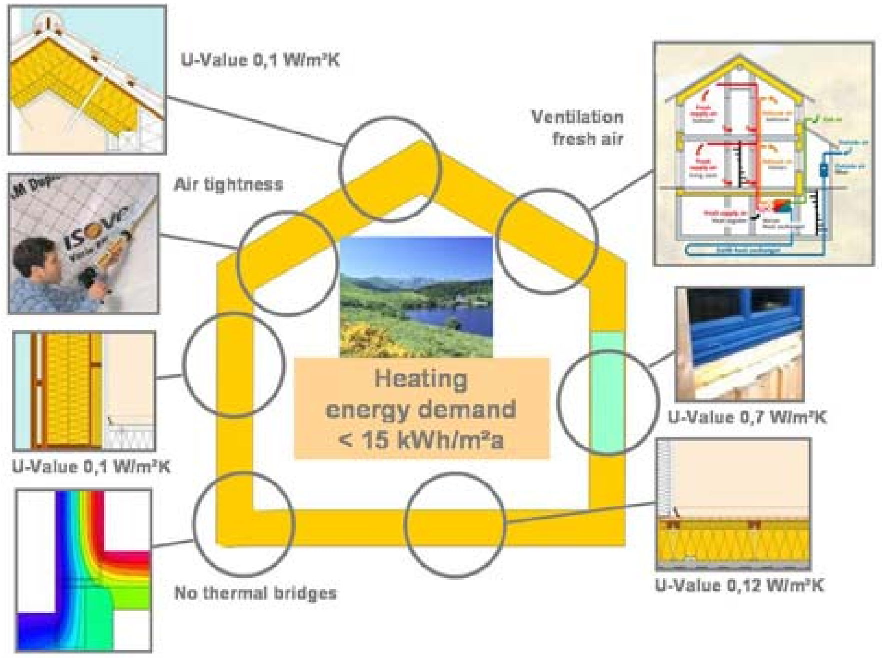


Figure 1.9. Passivhaus, excellent thermal insulation
Source: www.isover.com

- *Solar design and landscape:*

The solar building design and energy-efficient landscaping support the energy conservation and can integrate them into a neighborhood and environment.

As far as the building's geometry is concerned, a favorable relation between envelope and volume definitely helps. Less building envelope area reduces the heat loss and the cost of construction.

It is recommended that the window areas face south, but in climates needing to reduce excessive summer passive solar heat gain, can be done with a Brise soleil, trees, attached pergolas with vines, vertical gardens, green roofs, and other techniques.

Houses can be constructed with dense or lightweight materials, but it is normal incorporate some thermal mass in order to reduce summer peak temperatures. Also exterior wall color is important for reflection or absorption.

- *Avoiding thermal bridging:*

It is crucially important to have a design free of thermal bridges. These are weak points in the building envelope through which heat energy can escape, reducing the effect of the surrounding insulation and leading, potentially, to significant heat loss.

Figure below shows, with red circles mark, the typical weak points in the insulation.

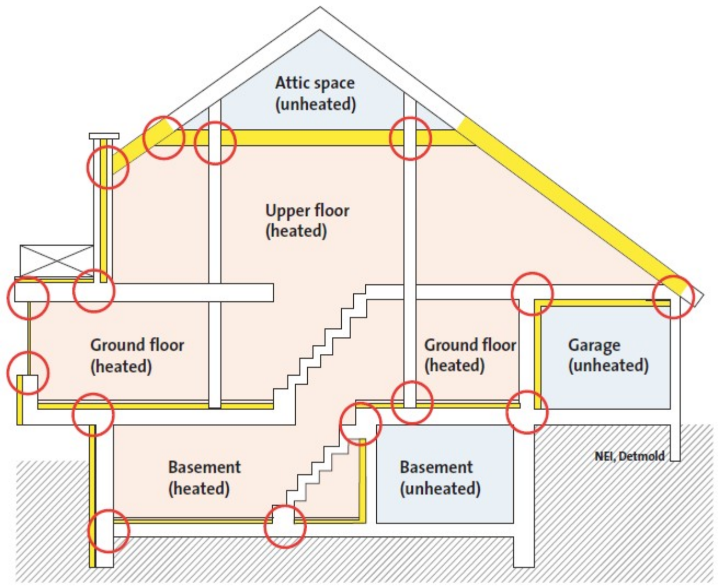


Figure 1.10. Usual thermal bridges in conventional buildings.
Source: www.isover.com

Thermal bridges are most frequently found around:

- *foundation slabs and basement ceilings*
- *stairs*
- *upper edges of walls (roof area)*
- *wall penetrations between heated and unheated areas*
- *balconies, landings and other cantilevered elements*
- *windows and roller shutter boxes*
- *rafters and support posts used in timber frame constructions*
- *anchoring elements etc.*

- *Decrease losses of heat by improving air tightness:*

The external envelope of a building should be as airtight as possible. In traditional houses energy escapes through many slits and openings, especially the roof is a critical point. These uncontrolled leaks of air cause a badly ventilated inner space, in fact it can condensate and create mould.

Air barriers and a careful sealing of every construction joint in the building envelope are all used to achieve reduce these losses.

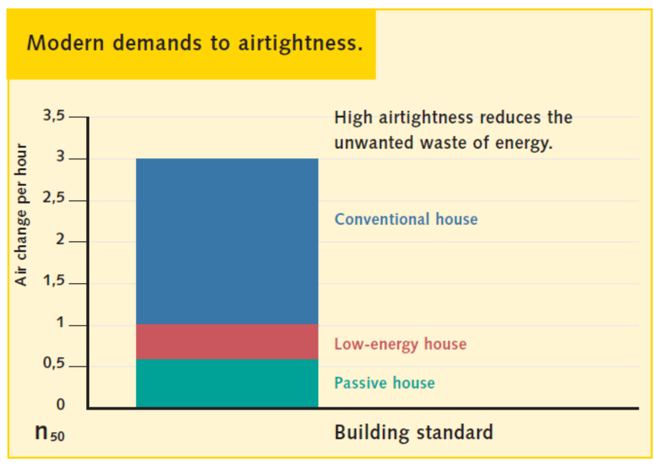


Figure 1.11. Airtightness comparative between different type of buildings.
Source: www.isover.com

- *Advanced window technology:*

To meet the requirements it's important that windows are manufactured with high R-values (low U-values, typically 0.85 to 0.70 W/(m².K) for the entire window including the frame. These normally combine triple-pane insulated glazing. But in warmer climates, like in our Mediterranean country, a window with double low-e glazing and a moderately insulating frame would be sufficient.

- *Air quality by ventilation with warmth recovery:*

Methods of natural ventilation or cross ventilation may be used when the exterior temperature is acceptable. When not, mechanical heat recovery ventilation systems, with 80% heat recovery rate and high-efficiency Electronically Commutated Motors (ECM), is employed to maintain air quality and to recover sufficient heat to dispense with a conventional central heating system.

Methods of natural ventilation or cross ventilation may be used when the exterior temperature is acceptable. When not, mechanical heat recovery ventilation systems, with a heat recovery rate of over 80% and high-efficiency Electronically Commutated Motors (ECM), is employed to maintain air quality, and to recover sufficient heat to dispense with a conventional central heating system.

This high performance heat exchanger is used to transfer the heat contained in the vented indoor air to the incoming fresh air. The two air flows are not mixed. On particularly cold days, the supply air can receive supplementary heating when required.

- *Efficient lighting and electrical appliances:*

To minimize the total primary energy consumption, the many passive and active daylighting techniques are the first daytime solution to employ. For low light level days, non-daylighted spaces, and nighttime; the use of creative-sustainable lighting design using low-energy sources such as diode-LED and compact fluorescent lamps.

It is as well advisable to use high-efficiency appliances which are often no more expensive than average ones and, as a rule, they pay themselves back through electricity savings.

- *Renewable energy:*

When energy consumption decreases 75% by measures listed above, renewable energy like thermal sun collectors, PV modules, wind mills, biomass and geothermal energy becomes very interesting.

Passive solar gain	
Measure	Optimized south-facing glazing
Specification	Close to 40% contribution to space heating demand
Superglazing	
Measure	Low-emissivity triple glazing
Specification	U-value £ 0.75 W/(m²K), solar transmission factor ≥ 50%
Superframes	
Measure	Superinsulated window frames
Specification	U-value £ 0.8 W/(m²K)
Building shell	
Measure	Superinsulation
Specification	U-value ca. 0.1 W/(m²K)
Building element junctions	
Measure	Thermal-bridge-free construction
Specification	Y (linear thermal transmittance, exterior dimensions) below 0.01 W/(mK)
Airtightness	
Measure	Airtight building envelope

Specification	less than 0.6 air changes per hour at n50
Hygienic ventilation	
Measure	Directed air flow through whole building; exhaust air extracted from damp rooms
Specification	Around 30 m³ per hour and person
Heat recovery	
Measure	Counterflow air-to-air heat exchanger
Specification	Heat transfer efficiency η ≥ 80%
Latent heat recovery from exhaust air	
Measure	Compact heat pump unit
Specification	Max. heat load 10 W/m²
Subsoil heat exchanger	
Measure	Fresh air preheating
Specification	Fresh air temperature ≥ 8°C

Table 1.12. High efficient building, usual components.

Source: http://www.cepheus.de (Cost Efficient Passive Houses as European Standards)

1.3.3 Conclusions. Advantages and disadvantages

Let's see the possible advantages of this type of buildings:

- *Energy-saving construction pays off from the very first day*
- *Safe investment into the future*
- *Added value every year through decreasing operation costs*
- *Comfortable living in all seasons*
- *Longer useful life thanks to highest quality standard*
- *Valuable contribution to sustainable climate protection*

But they can have the following disadvantages too:

- *Extra insulation material and building methods to be airtight. The extra cost of more insulation material can't be avoided. To make sure the isolation of the building is good enough we will need thicker walls of isolation.*
- *Also the house will need airtight layers, which cost extra. Also a Blower door test will give extra costs.*
- *While building this type of houses, it will need to be checked a lot to make sure it is airtight.*
- *Less free floor surface. The need of more isolation, thicker walls and roof will cause less free surface in the house with the same outside dimensions.*
- *Active ventilation system. The use of this active ventilation system is already explained. However this system will bring an extra cost to the house.*
- *Alternative heating system. For very low demand energy building this system isn't usually necessary, but most of the times it will be installed nevertheless. This system can be seen as an extra cost compared to a regular house. We can use a solar water boiler with sun collectors for example.*

Despite these negative aspects, this type of buildings has a good future because each day there are more people concerned about the environment problems and are willing to take steps to produce less CO_2 and reduce energy consumption, as we see all years, the energy price is increasing continuously.

5 MONITORING AND DATA COLLECTION

To make a correct diagnosis of a building the more information we have the better it will be. The variety of measuring instruments available nowadays makes it easy.

Below are the measuring instruments which have been used for monitoring and collecting data required to do this project. The purchase price also is included to have a slight notion of their cost or rent.

Some of this information has been collected exclusively for RELS project and it has not been included in this work.

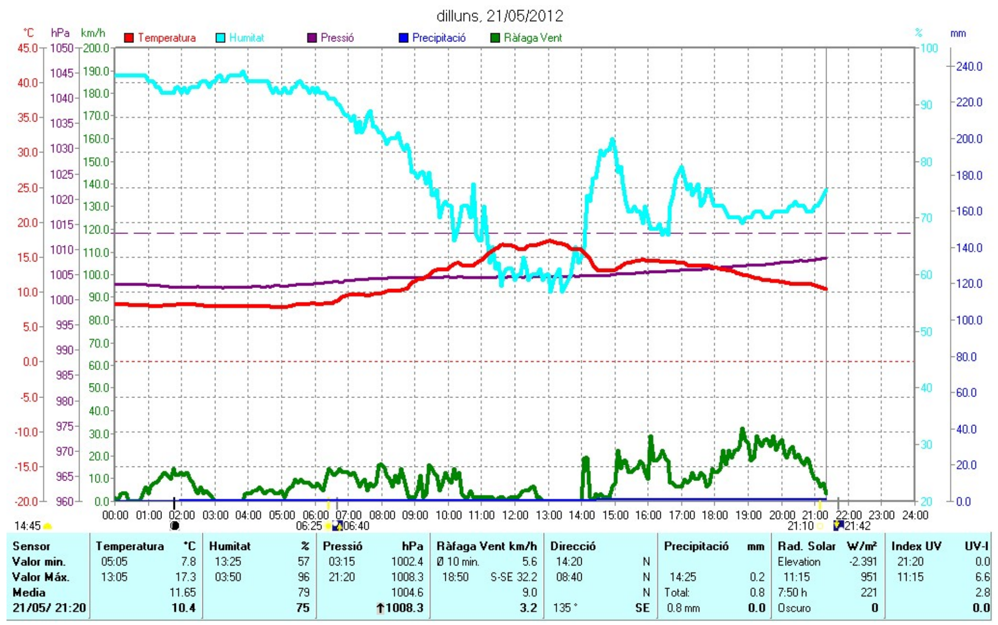
5.1 Environmental conditions

5.1.1 Climatology of Taradell. Meteorological station Davis Vantage Pro2 Plus ®

(Ownership: Mr. Pere Espinet, Taradell neighbour)

To carry out this project it has used data from the weather station that Mr. Pere Espinet has in Taradell, this is located at 500 linear meters of our building.

Most of this information is available through the web link provided by the City Council of Taradell: http://www.taradell.cat



Graphic 5.1. Meteorological station of Taradell, on 21st May

Technical specifications of the station:

Location: Taradell (Barcelona). Elevation 625 mt.

Type Station: Davis Vantage Pro2 Plus. (La Crosse WS7001 until 17-05-12).

Data since 1st June, 2005

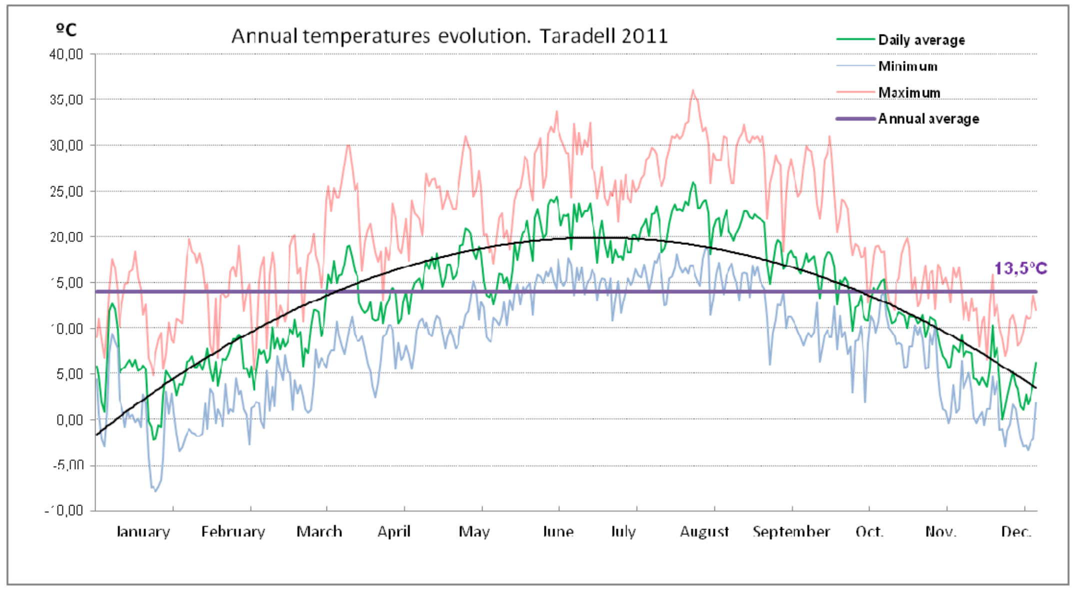
Parameters:

- *Outside temperature and humidity [C, %]*
- *Wind speed and direction [km/h, º]*
- *Precipitation [mm]*
- *Atmospheric pressure [hPa].*
- *Solar Radiation [W/m2]*
- *UV Index*

The table below shows relevant climatic information from Taradell, it indicates the evolution of temperature, precipitation and wind power since 6 years ago.

		2006	2007	2008	2009	2010	2011	Average
TEMPERATURES	Average	14,20 °C	13,06 °C	12,89 °C	13,71 °C	12,37 °C	13,49 °C	13,28
	Minimum	-5,2 °C	-7,8 °C	-6,0 °C	-8,9 °C	-9,7 °C	-7,8 °C	-7,8
	Average minimum	8,1 °C	7,0 °C	7,2 °C	7,9 °C	7,1 °C	8,0 °C	7,55
	Maximum	38,6 °C	38,8 °C	37,0 °C	38,0 °C	35,1 °C	36,1 °C	37,5
	Average maximum	22,6 °C	21,3 °C	20,5 °C	21,2 °C	19,2 °C	20,7 °C	21,2
	Frozen days (Tmax < 0°C)	0	0	0	0	0	0	0
	Frozen days (Tmin < 0°C)	61	61	60	49	76	44	60,5
	Colds days (Tmax < 10°C)	36	28	39	40	72	27	37,5
	Hot days (Tmax >= 25°C)	158	139	113	131	114	131	131
	Hot days (Tmax >= 30°C)	88	67	62	73	49	45	64,5
PRECIPITATION	> 0,0 mm	101	107	121	98	113	85	104
	> 2,0 mm	37	40	79	58	62	60	59
	> 5,0 mm	27	27	51	42	47	42	42
	> 10,0 mm	20	17	29	28	29	21	24,5
	> 20,0 mm	12	12	8	9	15	12	12
	Quantity of rain [l/m²]	662,91	574,37	885,10	758,63	948,31	803,88	781,26
WIND POWER	8 Bft	0,00 %	0,00 %	0,00 %	0,03 %	0,00 %	0,00 %	
	7 Bft	0,06 %	0,02 %	0,05 %	0,09 %	0,06 %	0,03 %	
	6 Bft	0,54 %	0,54 %	0,46 %	0,35 %	0,50 %	0,16 %	
	5 Bft	4,45 %	4,44 %	3,13 %	1,96 %	3,43 %	3,44 %	
	4 Bft	10,25 %	10,26 %	9,32 %	5,12 %	9,89 %	9,15 %	
	3 Bft	12,67 %	12,24 %	13,44 %	7,01 %	14,98 %	11,61 %	
	2 Bft	19,87 %	23,08 %	21,80 %	13,17 %	20,70 %	12,50 %	
	1 Bft	17,09 %	17,99 %	17,02 %	9,21 %	12,81 %	7,14 %	
	0 Bft	35,07 %	31,42 %	34,78 %	63,05 %	37,63 %	55,97 %	
	Average velocity [km/h]	9,2	8,9	8,7	4,7	8,3	6,4	8,5
	Wind direction	East	East	East	East	East	East	

Table 5.2. Meteorological data from Taradell, 2006 – 2011.



Graphic 5.3. Annual evolution of maximum, minimum and average in 2011

If we compare these data with those from the city of Barcelona we can see that Taradell has an average temperature 4.12 ° C lower, this results in a higher heating demand and CO_2 emissions.

However, as we'll see in the following energy certifications, in order to maintain the comfort conditions during summer days the cooling demand is negligible with the subsequent energy savings. But this savings on cooling is annulled by the increase on heating.

	Taradell	Barcelona *
Average temperature	13,28 ºC	17,4 ºC
Precipitation [l/m²]	781,26 l/m²	486,7 l/m²

Table 5.4. Climatology comparative, Taradell versus Barcelona.
Source: Barcelona council

The information collected from this station has been contrasted with the data obtained from the instruments listed below. This allows knowing the thermal and hygrometric behavior of the building and see how indoor conditions evolve according to the outdoors conditions.

5.1.2 Indoor temperature and humidity. Data loggers

● Testo ® 175-H1 and 175-T2 models

(Ownership: Acoustic and energy saving laboratory. Applied Physics Department. EPSEB)

Estimated price: 65, 00 € each one

These data loggers are used to save and read out measurements of temperature and humidity. The readings are measured, saved and transmitted to a PC by USB port and analyzed with the Testo ComSoft ®_software. This software is also necessary to program the data loggers.

Technical specifications:

testo 175-H1

Parameters ....Humidity (%RH) / Temperature (°C/°F)
Sensor ....Humidity sensor / NTC
Number of measuring channels ....2x internal
Measuring range ....0 to 100 %RH
..........-10 to +50 °C
Accuracy ....±0.5 °C
..........±3 %RH
Resolution ....0.1 °C
..........0.1 %RH
Measuring rate ....10 s to 24 h (freely selectable)
Storage temperature ....-40 to +70 °C
Operating temperature ....-10 to +50 °C
Memory capacity ....3,700 readings
Housing ....ABS/TPE
Dimensions in mm (lxwxh) ....82 x 52 x 30
Weight 80g
Battery ....Lithium (1/2 AA)
Battery lifetime ....Typical: 2½ years*
....(Measuring rate: 15 min., Operating temperature: -10 to +50°C,
..........Display: On, Status led (green LED): Off)

testo 175-T2

Parameter ....Temperature (°C/°F)
Sensor ....NTC (intern+extern)
Number of measuring channels ....2 (1x internal/1x external)
Measuring range ....-35 to +70 °C internal
..........-40 to +120 °C external
Accuracy, internal ....± 0.5 °C (-20 to +70 °C)
(System) ....± 1 °C (-35 to -20.1 °C)
..........±1 digit
Accuracy, external ....± 0.3 °C (-25 to +70 °C)
(only Logger) ....± 0.5 °C in the remaining range
..........±1 digit
Resolution ....0.1 °C (-20 to +70 °C)
..........0.3 °C in remaining range
Measuring rate ....10 s to 24 h (freely selectable)
Adaptation time t_{90} (internal) Approx. 30 min at wind speed 1m/s
Storage temperature ....-40 to +85 °C
Operating temperature ....-35 to +70 °C
Operating temperature/Display ....-30 to +65 °C
Memory capacity ....16,000 readings
Protection class ....IP 68
Housing ....ABS/TPE
Dimensions in mm (lxwxh) ....82 x 52 x 30
Weight 84g
Battery ....Lithium (1 AA)
Battery life ....Typical: 2½ years*
....(Measuring rate: 15 min., Operating temperature: -10 to +50°C,
..........Display: On, Status led (green LED): Off)

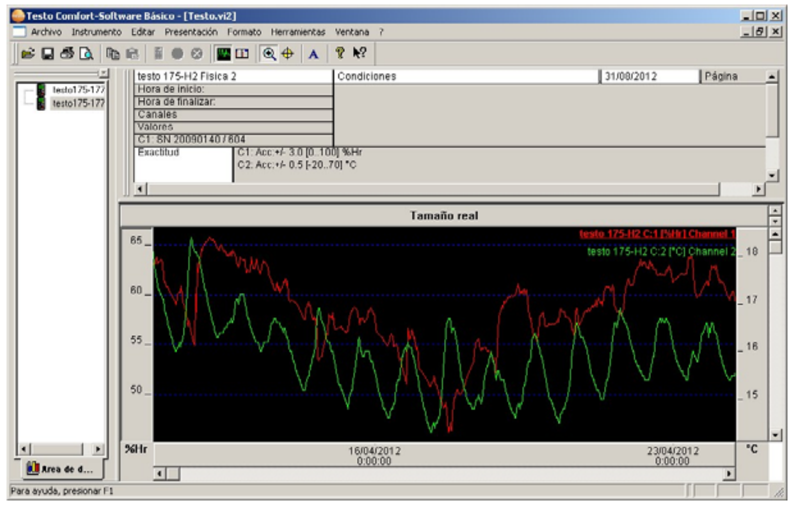


Figure 5.5. Screenshot Testo ComSoft ® software, temperature and indoor humidity.

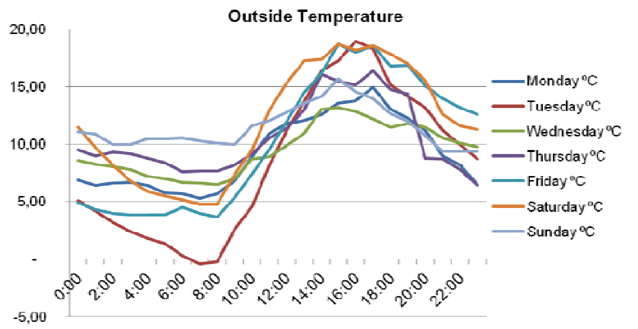
During the diagnosis phase of this project it was possible to install these data loggers in three different dwellings, two of them belong to the southern facade (first and second floor) and the other one in the north facade (second floor under the roof).

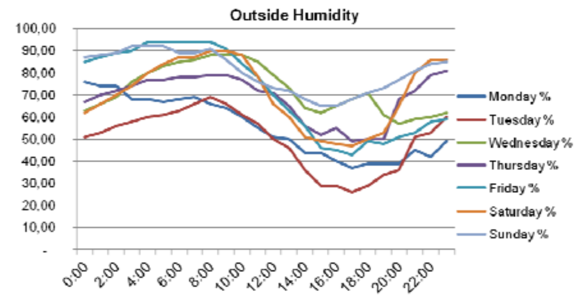
Conclusions

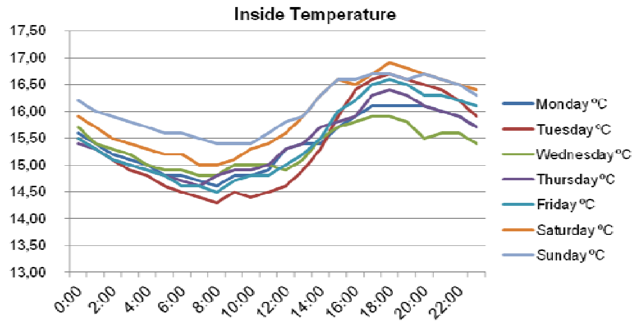
Comparing the information from the inside data loggers and the external meteorological station we can find out several conclusions.

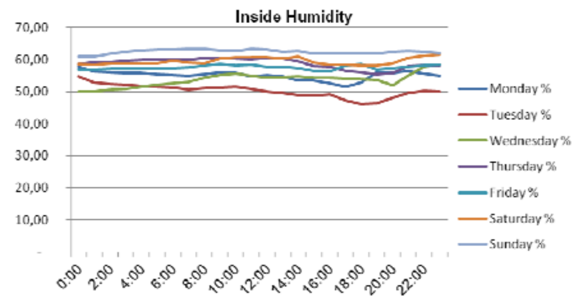
We will see the results of the 1.1st dwelling, south facade, which we have much more information.

Date: from 16th to 22th April, 2012.









As expected outside temperature is highest in the afternoon, between 15 and 17 pm, however, the minimums occur during the morning, 6 to 8 am. The dwelling maintains internal temperatures between 14.5 ºC and 16.5 ºC.

We can see clearly how the inside temperatures follows the outside temperatures but these have two hours delay approximately, and it have less extreme values too.

This fact is relevant because it gives us real information about the thermal inertia of the building envelope, and how the thermal exchange takes place between the inside and outside. The building skin provides little thermal inertia, this is made from a single perforated brick, air chamber with a thin insulation panel and a panelling with two prefabricated plasterboards (Pladur type).

Similarly if the thermal transmittance of walls and overtures were lower, with better insulation and sealing, these fluctuations would also be lower.

The outdoor humidity varies following a pattern very defined and constant throughout the days, with minimums values around 5 pm and maximum at 7am. The other hand the apartments maintain a relatively constant humidity, between 50 and 60%, and the correlation is not as pronounced as with temperature.

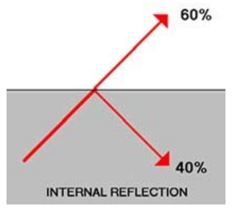
Certainly, the temperature and outside humidity are closely intertwined, when the temperature is maximum the humidity is minimal, and vice versa.

5.2 Infrared camera. FLIR InfraCAM-SD ®

(Ownership: Acoustic and energy saving laboratory. Applied Physics Department. EPSEB)

One of the key components of an effective building energy audit is the infrared camera. The camera detects differences in heat and reveals spots where the house is wasting energy & money, it gives a clear direction for fixing the problems.

Every building component absorbs, transfers or emits thermal radiation. However, the intensity of this radiation varies considerably depending on the materials used. Thermo graphic image shows variations in temperatures using a color scale, the red color corresponds to the warmer areas.



This is due to a characteristic of an object, its emissivity (e). The amount of energy radiated by an object depends on its temperature and its emissivity. An object that emits the maximum possible energy at its temperature is known as a black body (e=1). In practice there is no perfect emitters and surfaces typically emit less energy than a black body (e<1).

The emissivity of an object is the ratio between the energy emitted in respect of the emitted of a black body. Emissivity is therefore an expression of the ability of an object to emit infrared energy.

The application fields are very large and go beyond the mere measurement of temperatures. In buildings can have application in the following fields:

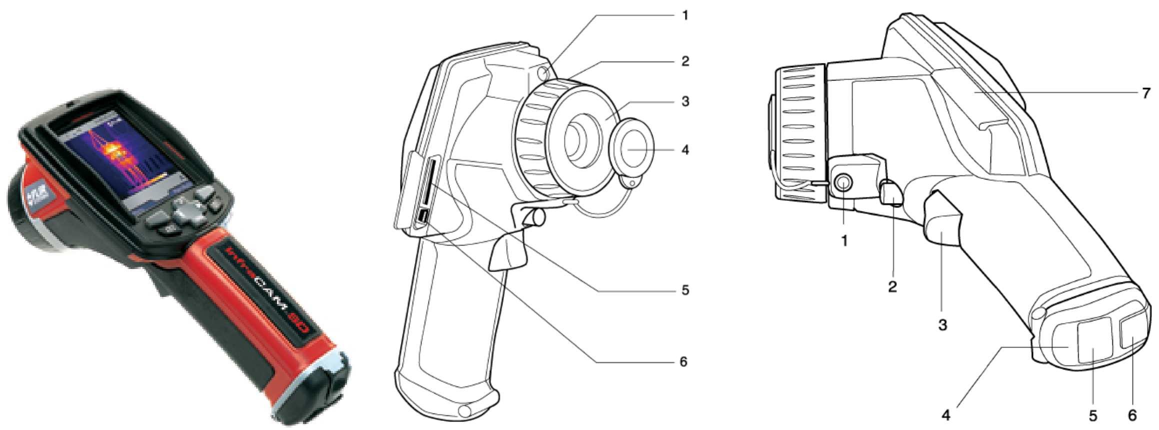
- *Construction*
- *Renewable energies*
- *R & D*
- *Maintenance*
- *Automation and Monitoring*
- *Energy efficiency*
- *Non destructive testing*
- *Detecting defective insulation and thermal bridges*
- *Detect diverse electrical problems*

It has used a FLIR InfraCAM-SD camera to do this project.

It has the following technical characteristics:

Imaging performance	Spectral range	7.5–13 µm
	Detector type	Focal Plane Array (FPA), uncooled microbolometer 120 × 120 pixels
	Image frequency	9 Hz
	Accuracy	± 2.0°C (± 3.6°F) or ± 2% of reading
	Thermal sensitivity	▪ InfraCAM: 0.20°C (0.36°F) ▪ InfraCAM SD: 0.10°C (0.18°F)
Image presentation	Screen	89 mm (3.5 in.) color LCD, 18-bit colors
	Interpolation	Detector image interpolated to 240 × 240 pixels
Object temperature ranges	Object temperature ranges	−10 to +350°C (+14 to +662°F)

Table 5.6. Infrared camera, FLIR InfraCAM-SD technical specifications.



1 Laser pointer with lens cap
2 Focus ring
3 Infrared lenses
4 Lens cap for infrared lens.
5 Slots for SD Memory Card
6 USB mini-B connector

1 Tripod mount 1/4"-20
2 Top trigger to operate the laser pointer
3 Bottom trigger to save an image
4 Battery compartment lid
5 Rubber lid for power connector
6 Locking mechanism for battery compartment lid
7 Camera serial number behind rubber lid

Datasheets have been designed to analyze the thermography pictures, these reflect the conditions under which each of the images was taken. These datasheets, combined with previous planning of visits, help the later review.

The data are grouped into four sections. The first one "**Location and date**" contains the address of the building, if it is inside or outside, the orientation of the facade, and the date of the start and end of the inspection. To facilitate the location it has left a space to insert a sketch or plot of the area photographed.

A second section "**Climatic Data**" contains meteorological information such as outdoor and indoor temperatures and humidity, atmospheric pressure, speed and wind direction or if it is raining.

The next one "**Technical camera specification**s" gives the most significance information about the camera model and its settings, like emissivity, distance to object and reflected temperature.

And finally "**Notes**" with those conclusions can be extracted from the adjusted pictures with the software that accompanies the thermography camera. The "FLIR QuickReport" software, for free download from the website of the manufacturer company, lets you manage thermography images to get surface temperatures on specific points or maximum and minimum values belonging to lines or rectangles. The aim is to locate the most important thermal bridges that correspond with areas where there will be higher energy thermal losses in the envelope.

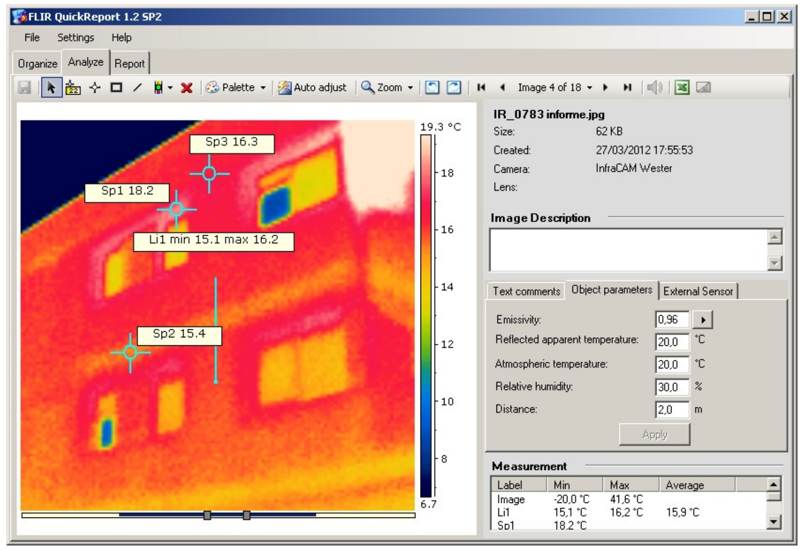


Figure 5.7. Screenshot thermography FLIR QuickReport ® software.

With the analysis of available original project documentation as well as the information from resident surveys, it was considered appropriate to take photographs of those points more likely to suffer thermal bridges. Permission was asked of the 2.8^{th} neighbour, from the north facade, to take images inside his dwelling to detect the causes of surface condensation close to the windows and the difficulty of obtaining a good comfortable temperature in winter time despite the high heating, particularly in the dwellings facing the north façade and under the roof.

We also asked him to turn on the heating a few hours before the performing of images in order to obtain a thermal leap of at least 8 degrees between the inner and outer surfaces of the building envelope.

Forty images were taken on the last days of March and it has chosen six of them to analyze the building. Three of these datasheets are outside and the others are inside the 2.8th dwelling. The corresponding datasheets are attached below.

These datasheets show the different kinds of thermal bridges, like the encounter of concrete slabs and columns with the facade, drawings of blinds and frames of windows. But thermography is not only useful to find insulation problems, it also lets you find out the different materials that are hidden by finishing coats.

One example of this is the 6th datasheet of the south facade that shows the bricks and mortar under the external thin layer of plaster mortar.

THERMOGRAPHY	DataSheet	Nº: 01

Location and date

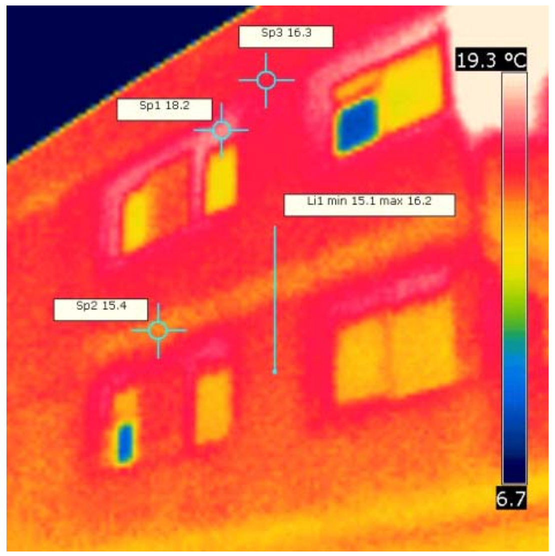
Building:	Pg. Pujoló, 3-5. Taradell	Location:	Outside	Facade:	North
Date:	27/03/2012	Start time:	17:54	End time:	18:00

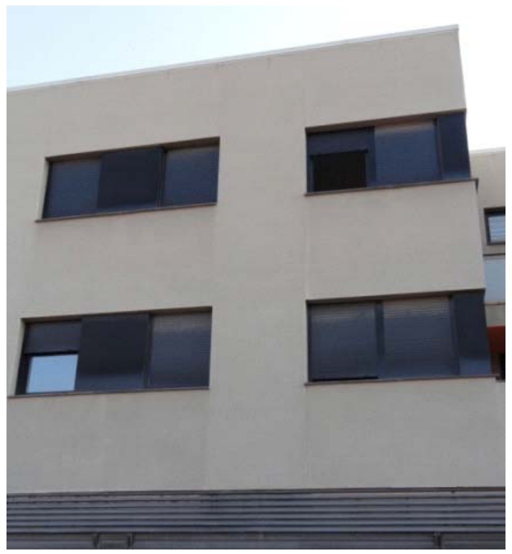
Meteorological data

Outdoor Temperature:	17,8°C	Indoor Temp.:		Outside T. 24h.before:	16,7°C
Outdoor Humidity:	34 %	Indoor Humidity:		Precipitation:	No
Atmospheric pressure:	949 hPa	Wind:	1,1 km/h	Direction:	102 °

Technical camera specifications

Model:	InfraCAM Wester	Image name:	IR_0783.jpg
Emissivity:	0,96	Reflected Temp.:	20,0°C
Distance to object:	9,0 m.		





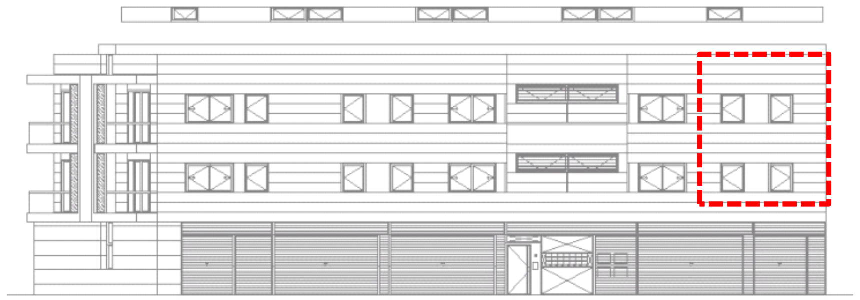
Notes

The north facade made up of brick has a higher superficial temperature than the encounter with the concrete slab which doesn't have good insulation. The structural concrete elements have upper thermal inertia and therefore they need more time in order to increase the temperature.

THERMOGRAPHY	DataSheet	Nº: 02

Location and date

Building:	Pg. Pujoló, 3-5. Taradell	Location:	Outside	Facade:	North
Date:	27/03/2012	Start time:	19:30	End time:	19:35

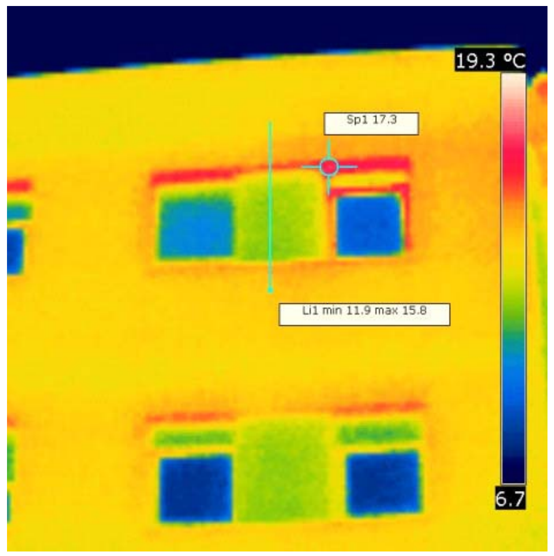


Meteorological data

Outdoor Temperature:	16,4°C	Indoor Temp.:		Outside T. 24h.before:	15,0°C
Outdoor Humidity:	37 %	Indoor Humidity:		Precipitation:	No
Atmospheric pressure:	949 hPa	Wind:	1,3 km/h	Direction:	126 °

Technical camera specifications

Model:	InfraCAM Wester	Image name:	IR_0779.jpg
Emissivity:	0,96	Reflected Temp.:	20,0°C
Distance to object:	8,0 m.		



Notes

The drawing of blind is 5 degrees warmer than the wall located between the windows, this shows large heat losses from inside the dwelling and a waste of money on heating.
The glass has a very low temperature due to reflected sky.

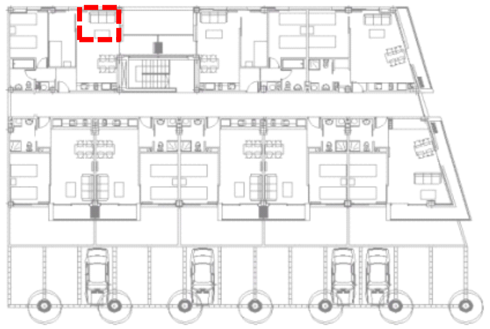
THERMOGRAPHY	DataSheet	Nº: 03

Location and date

Building:	Pg. Pujoló, 3-5. Taradell	Location:	Indoor 2.8	Facade:	North
Date:	27/03/2012	Start time:	19:50	End time:	19:55

Living room

20,08 m2

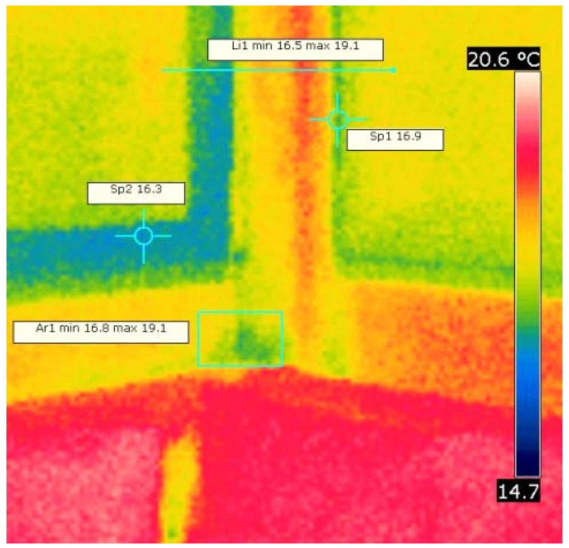


Meteorological data

Outdoor Temperature:	15,9°C	Indoor Temp.:	-	Outside T. 24h.before:	14,5°C
Outdoor Humidity:	41 %	Indoor Humidity:	-	Precipitation:	No
Atmospheric pressure:	949 hPa	Wind:	0,1 km/h	Direction:	252 °

Technical camera specifications

Model:	InfraCAM Wester	Image name:	IR_0800.jpg
Emissivity:	0,96	Reflected Temp.:	20,0°C
Distance to object:	2,2 m.		



Notes

The aluminum carpentry are designed without thermal bridge and also many of them have a bad performance and weak sealing. This has caused problems of moisture condensation in plasterboard with his encounter with the lower frames of the windows.

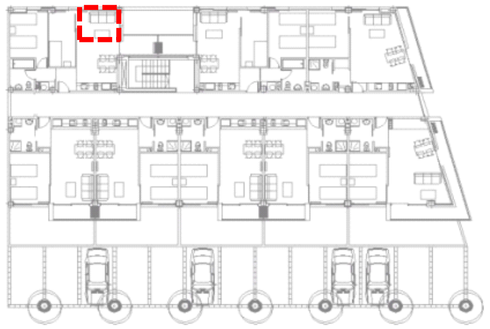
THERMOGRAPHY	DataSheet	Nº: 04

Location and date

Building:	Pg. Pujoló, 3-5. Taradell	Location:	Indoor 2.8	Facade:	North
Date:	27/03/2012	Start time:	19:50	End time:	19:55

Living room

20,08 m2

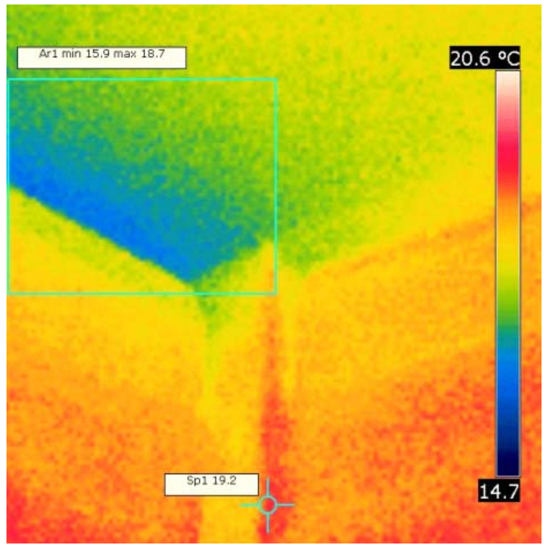


Meteorological data

Outdoor Temperature:	15,9°C	Indoor Temp.:	-	Outside T. 24h.before:	14,5°C
Outdoor Humidity:	41 %	Indoor Humidity:	-	Precipitation:	No
Atmospheric pressure:	949 hPa	Wind:	0,1 km/h	Direction:	252 °

Technical camera specifications

Model:	InfraCAM Wester	Image name:	IR_0803.jpg
Emissivity:	0,96	Reflected Temp.:	20,0°C
Distance to object:	2,5 m.		



Notes

The encounter of the ceiling with the window has a much lower surface temperature due to the lack of insulation on concrete slab and scarce 2 cm. expanded polystyrene inside the drawing of blind. This problem causes an increase of consumption heating in winter.

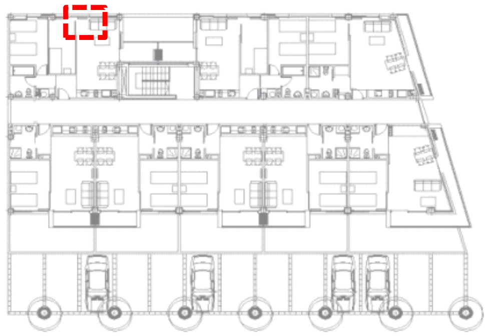
THERMOGRAPHY	DataSheet	Nº: 05

Location and date

Building:	Pg. Pujoló, 3-5. Taradell	Location:	Indoor 2.8	Facade:	North
Date:	27/03/2012	Start time:	19:55	End time:	20:00

Bedroom 2nd

7,98 m2

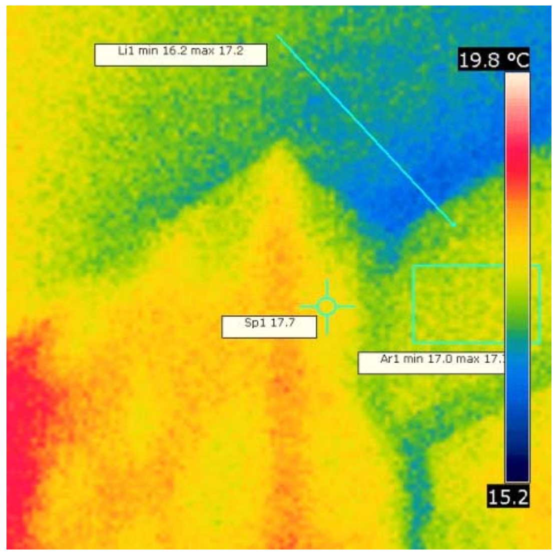


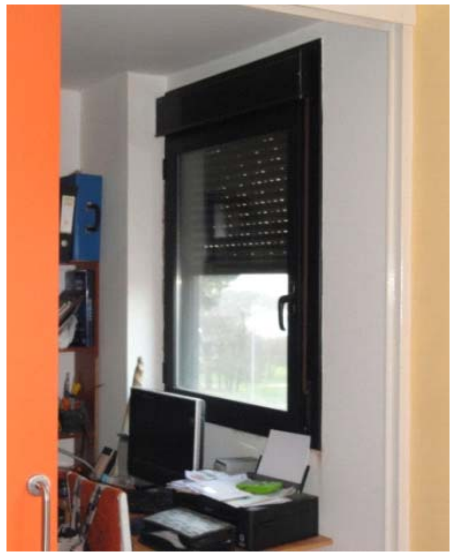
Meteorological data

Outdoor Temperature:	15,6°C	Indoor Temp.:	-	Outside T. 24h.before:	14,4°C
Outdoor Humidity:	42 %	Indoor Humidity:	-	Precipitation:	No
Atmospheric pressure:	949 hPa	Wind:	0,1 km/h	Direction:	228 °

Technical camera specifications

Model:	InfraCAM Wester	Image name:	IR_0806.jpg
Emissivity:	0,96	Reflected Temp.:	20,0°C
Distance to object:	3,7 m.		





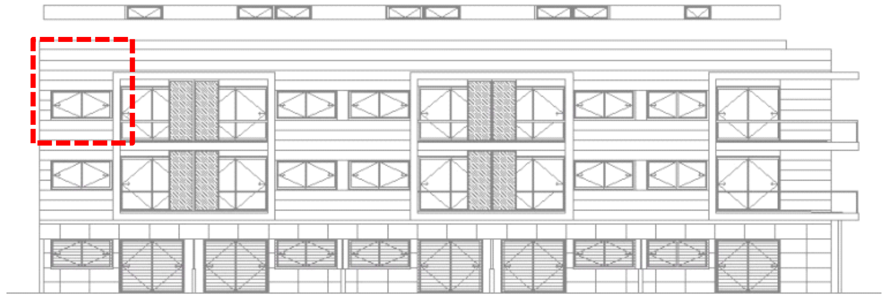
Notes

This thermography was taken from the single room without heating on, but also shows the same problem of thermal bridges to the previous datasheets. The columns don't have remarkable losses of temperature.

THERMOGRAPHY	DataSheet	Nº: 06

Location and date

Building:	Pg. Pujoló, 3-5. Taradell	Location:	Outside	Facade:	South
Date:	27/03/2012	Start time:	19:30	End time:	19:35

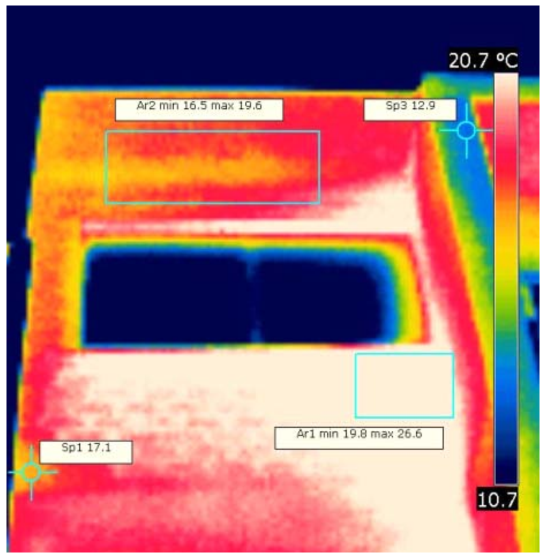


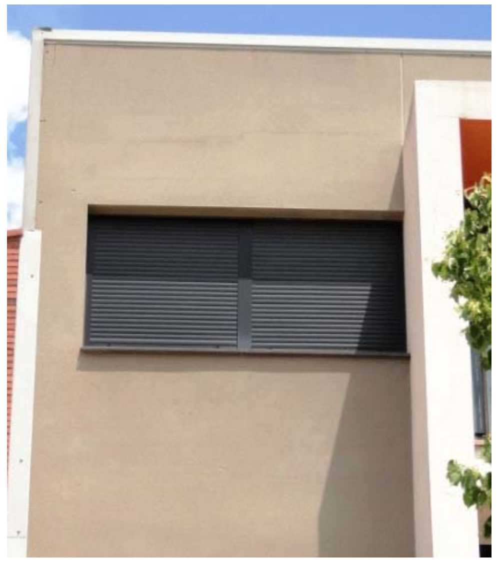
Meteorological data

Outdoor Temperature:	16,4°C	Indoor Temp.:		Outside T. 24h.before:	14,8°C
Outdoor Humidity:	37 %	Indoor Humidity:		Precipitation:	No
Atmospheric pressure:	949 hPa	Wind:	1,3 km/h	Direction:	126 °

Technical camera specifications

Model:	InfraCAM Wester	Image name:	IR_0816.jpg
Emissivity:	0,96	Reflected Temp.:	20,0°C
Distance to object:	8,5 m.		





Notes

This outdoor thermography made in the south facade was taking in the evening in a day with a high solar radiation. The image reveals the dimensions of the bricks and the mortar joints. On top we can see the encounter of concrete slab and the facade with more than 3 degrees of difference.

5.3 Electric consumption

5.3.1 Efergy e2 classic 2.0 ®

(Ownership: AHC). Estimated price: 64,90€.

Is a portable compact display that allows knowing in real time the energy consumption (cost, CO2 and kWh). Historical daily, weekly or monthly data could be analyzed with Elink 2.0 ® software by USB port.

This energy monitor included a wireless energy monitor, a transmitter and a mini CT sensor that it's necessary clip around the live feed cable of the breaker panel.

TECHNICAL INFORMATION

Model Name	**e2 classic**
Model Number	E2-UK
Frequency	433.5MHz
Transmission Time	6, 12 or 18 Sec
Transmission Range	40 - 70m
Sensor Voltage Range	110 - 600V
Measuring Current	50mA - 90A
Accuracy	> 90%

The Elink software lets see informative graphs, print or safe reports as PDF files. Data may also be viewed using Excel.

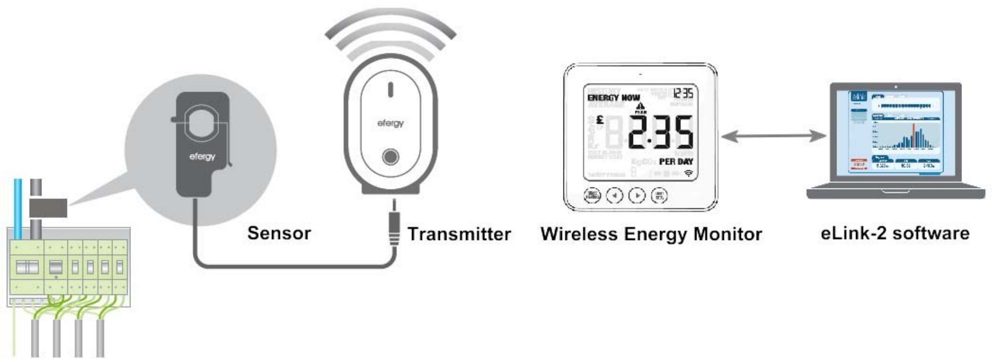


Figure 5.8. Efergy e2 energy monitor, installation scheme.

With permission of the neighbors it could be installed in 1.1st and 2.8th apartments, south and north façade respectively.

Setting-up in 1.1st apartment breaker panel (from 30-04-2012 to 24-04-2012).

5.3.2 VoltCraft ® Energy Monitor 3000 LCD

(Ownership: Acoustic and energy saving laboratory. Applied Physics Department. EPSEB

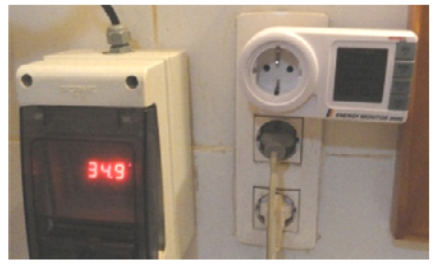
Estimated price: 42,95€.

It's an energy cost meter consumption that besides the usual information (effective power in W and energy consumption in kWh), the 3-digit display also shows the effective Cos-Phi power factor, load type (inductive or capacitive) and power frequency. Its integrated backup battery lets set and read off the stored values even when the device is switched off, and calculate the accumulated power costs over one week, one month, or a full year.

Another interesting feature is that it allows knowing the exact power consumption of equipment with a low effective power factor, such as electronic devices with simple power adapters.

Technical information:

- *Operating voltage:* 230 V/AC
- *Display type:* LCD
- *MID approval:* No
- *Max. recording time:* 2376 h
- *Type (manufacturer type):* Energy Monitor 3000
- *Accuracy class:* ± (1% + 1 W)
- *Frequency:* 50 Hz
- *Weight:* 200 g
- *Display range:* 0.001 kWh - 15000 kWh
- *Specification:* For Mains
- *Dimensions:* (W x H x D) 135x82x70 mm
- *Effective power range:* 1.5 - 3000 W
- *Own consumption:* 1.8 W



It has been used to metering and monitoring the power consumption of heater water tank with solar thermal support of the 1.1st dwelling.

5.3.3 Efergy's Esocket ®

(Ownership: AHC). Estimated price: 35,00€.

Efergy's Esocket is similar to the VoltCraft, it's a plug-in energy monitor to measure how much electricity different appliances and gadgets use. It's ideal for identifying how efficient is an appliance.

The energy monitoring Esocket measures the kilowatts used by appliances and calculate how much that device has cost for the time it is plugged in, whether it is in use or not. This allows understanding the energy usage by the hour, day, week, month or even year.

The Esocket displays voltage (V), current (A), frequency (Hz), current power consumption (W), highest power consumption (Hi W), lowest power consumption (Lo W), unit price of electricity (£/kWh), and records the total energy (kWh) and cost over time.

Technical Specifications:

- *Working voltage: AC90 – 250V/50-60Hz*
- *Power: 0.2 – 3120W*
- *Voltage range: 90 – 250V*
- *Electricity display: 0.001 – 9999kWh*
- *Unit price of electricity: 0.00 – 99.99£/kWh*
- *Current range: 0 – 13A*
- *Frequency range 10 – 99Hz*

It has also been placed in the hot water tank of the 2.4th and 2.8th dwellings to know the power consumption and the contribution of solar thermal installation.

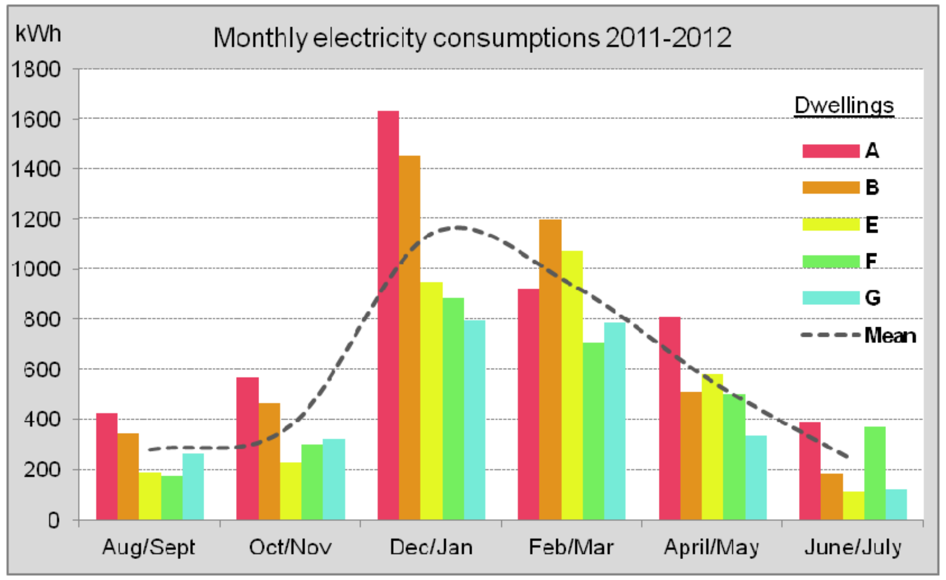
Conclusions

Below there is a summary of the power consumption of the eight dwellings currently occupied, including the metering of general services, shared areas lighting, lift and solar thermal systems. They are displayed graphically and numerically.

This data was obtained from the electrical bills which were facilitated by the neighbors, and from direct readings of meters carried out on each visit to Taradell. For households C, D, H and general services I have had to extrapolate the available data in order to complete the information.

All households have 5.75 kW of power contracted and 2.0A TUR tariff with the distribution company Estabanell Energia.S.A.

CONSUMPTIONS		
Dwel.	KWh/day	KWh/year
A	12,98	4738
B	11,39	4157
C*	10,70	3906
D*	9,98	3643
E	8,58	3131
F	8,04	2933
G	7,20	2627
H*	7,19	2624
Mean	9,51	3470
G.S.*	7,22	2635



We can observe bimonthly the evolution of consumptions. Higher values occur, as expected, in winter, from December to April when there is more heating demand.

	ELECTRICAL CONSUMPTIONS - DWELLINGS AND GENERAL SERVICES									
	A	B	C*	D*	E	F	G	H*	Mean	G.S.*
Aug/Sept	427	343			189	172	263		279	
Oct/Nov	566	462			227	300	323		376	
Dec/Jan	1629	1456			949	883	795		1142	
Feb/Mar	921	1198			1073	704	787		937	
April/May	810	513			581	504	337		549	
June/July	385	186			112	370	122		235	
kWh/year	4738	4157	3906	3643	3131	2933	2627	2624	3470	2635
kWh/day	12,98	11,39	10,70	9,98	8,58	8,04	7,20	7,19	9,51	7,22

*The Tadarell dwellings have a mean of **3470 kWh/year**, close to the 4,000 kWh/year[4] mean of our country Mediterranean houses. But they have also an approximate area of 40 m2 and according to this they would need a lower consumption, we must keep in mind that the heating installations, stoves and ovens operate exclusively with electricity and that the final result is compensated.*

If a typical house of 80m2 where all their energy was electric this would use about 8,000 kWh per year.

For homes with mixed energy (fuels and electricity) average electricity consumption would amount to about 3,000 kWh per year.

5.4 Surveys

The surveys have been designed by the participants of RELS project. In order to fill in these we asked the 8 householders of each dwelling that were inhabited at the time of realization of this work, these lasted about one hour approximately.

During the visit to the different residential dwellings we asked permission to take pictures of their electrical equipment (washing machines, refrigerators, cookers, ovens, heaters, televisions, small appliances, lamps, etc), to take thermography pictures, to install monitoring instruments and to consult the latest electricity and water bills.

Questions are organized into four major sections:

A. ***Structure and family incomes**. Number and characteristics of the occupants of the house (age, studies, income, etc).*

   Conclusions: The total number of building occupants is 17 people, according to the following family structure:

   - *Single (1x3): 3*
   - *Adult + 1 child (2x1): 2*
   - *Childless couple (2x2): 4*
   - *Couple + 1 child (3x1): 3*
   - *Couple + 2 children + adult (5x1): 5*

   The profile of the neighbor is a young person, single or as a couple, with basic education or a professional worker. In the building there are only 5 children of school age or preschool.

   Regarding the incomes we can see many people are unemployed or working with low wages.

B. ***Characteristics of the neighborhood**. Type of neighborhood, access to public transportation and other equipment.*

   Conclusions: The Taradell neighbors have nearby access to public health care, pharmacy, library, school, and large green areas. All their journeys can be done on foot but the nearest hospital is located in Vic, about 9 kilometers away and therefore the journey has to be made by private car or by public bus.

C. ***Electricity demand**. This section is the most extensive survey that includes questions about the number and type of appliances (size, power, energetic class, number of uses daily or weekly, etc.), estimation of hours of lighting and type of lamps (low power consumption, incandescent bulbs, fluorescent, halogen, LED...), etc.. We tried to find out the different uses depending on summer or winter time.*

[4] *IDAE, "Proyecto SECH-SPAHOUSE, análisis del consumo energético del sector residencial en España". 2011.*

Conclusions: Most of the dwellings have a low electrification degree below the average, it should be remembered that they have a small living area and the average income of residents is rather low.

The residents have made efforts to reduce spending on electricity, reducing the number of light bulbs or replacing incandescent lights by other low-power consumption or LED.

D. ***Transport***. *Type of transport (public or private) for the obligatory displacements type (job) or not obligatory (shopping, recreation, vacations, etc.). It allows us to know distances, frequencies of use, and emission levels and energy associated, etc.*

Conclusions: most of the families do a little use of private car and they rarely use the public transport of Taradell (bus service to Vic). Daily shopping is done in Taradell town (on foot or by car) however the weekly or monthly ones are done in Vic or in nearby malls.

Holiday trips are rather nearby and of short duration, except for foreign residents who travel to their countries during the summer time. However, because of the economic crisis and the difficulty of making ends meet, there has been a drop of expenditure on non mandatory displacements.

E. ***Consumptions and energy savings***. *We have tried to find out what is the neighbors perception about the energy costs that they have in their homes, if it is high or low, and if they have taken measures to reduce these costs.*

Conclusions:

The neighbors are conscious that their power bills are very high and that these represent a very high percentage of their incomes, sometimes it is even higher than 50%. The need to save money on heating has reduced the degree of comfort, even getting cold in winter.

We also used the visits to ask residents about any other remarkable event, such as possible problems of humidity or condensation, noises, incidents involving the solar thermal installation, power bills, etc.

Most of that information was collected exclusively for the RELS project.