ENGINNEERING BUILDING
FINAL PROJET DEGREE

ENERGÈTIC EVALUATION AND ACTUATION PROPOSAL OF THE GERIATRIC CENTER IN EL PRAT DE LLOBREGAT
DOCUMENT 4. MEMORY - TRANSLATED DOCUMENTS

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Convocatory: June / July 2014
Auditoria energètica d'una residencia per a gent gran al Prat de Llobregat

SUMMARY
This current Project of Final Degree consist in the energetic evaluation of the Retirement Home for elderly people called Residencia Ribera Baixa and located in Avenue Once de Setembre number 81-83, El Prat de Llobregat.

The building lies in an assisted residence for the elderly with 90 beds and a service of the daytime care centre which accept 24 people. The building has got one ground floor and three similar upper floors. It is need to say that the building has been designed to meet the needing of the final user.

The building takes part in the Governmental Plan CAT 21 within the context of the program GTI 2002, who has the aim of increase the sustainability in building process and its subsequent use.

GTI project wants to analyze and apply the introduction of environmental rules in the buildings managed by la Generalitat. The main objective is to reduce the set of impacts associated with the extraction, manufacture and reintegration of the materials that make up the building, and achieve a series of parameters to make the energy consumption and waste generation during the lifetime of the building as low as possible. During the design phase some different solutions were adopted that fact makes the building energetically sustainable, between them we can find a radiant ceiling, a ventilated façade, cross-ventilation, dry-construction, hot water system generated by solar energy, green roof with native plants, grey-water system which will be connected to the new creation grey-water system network in El Prat de Llobregat, energy efficient light bulb controlled by light sensors and finally there are installed dual flush toilet.

The purpose of this project is the realization of an energy audit after eight years of use of the building. We pretend to evaluate the behavior and suitability of construction systems, materials used and the performance of installations systems, the maintenance management and the consumption of resources. we will compare the results with a building of the same use to check if the established energetic improvements really work.

The methodology for this evaluation project was developed by the teachers Bosch González and Rodríguez Cantalapiedra and the UPC, after a long experience analyzing buildings.

The documents that make are part of this PFD are structured in these parts:

DOCUMENT 1 _ ENERGETIC EVALUATION
DOCUMENT 2 _ GRAFIC DOCUMENTS
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2. INTRODUCTION
The building Ribera Baixa of the Prat de Llobregat is the main focus of this Project of Final Degree, is a building of new construction who is included in GTI 2002 program, that is why from the design phase, through the building phase and its service life some saving measures were taken into account.

In the planning stage were taken into account aspects such as the location and orientation of the building or the choice of materials that make up the building considering energy consumption and CO2 emissions in the manufacture of them, The durability of the material and maintenance requirements, the incorporation of recycled materials and the possibility of recycling them after its useful life are other items that were taken into account.

In the construction stage was attempted to minimize the waste generated and control the consumption of energy and water. All the wasted generated were managed in the best possible way to avoid the environmental pollution, by means of the segregation and subsequent deposition in authorized waste collection center.

But certainly the stage that we are most interested in is analyzing the life of the building, as this is the longest and the stage with more consumption of resources. As mentioned before the building study was designed to achieve minimum sustainable criteria, so the objectives of this audit are:

• Evaluation of the performance and suitability of building systems and materials used.
• Evaluation of the facilities installed and the resource consumption of the building
• Take better advantage of existing facilities and systems
• Evaluate and assess whether there is any other possibility for energy savings.

Based on this audit we will be able to detect deficiencies of the solutions adopted a redefine course of action to improve the use, efficiency and savings in resource consumption.

Following the experience of EPSEB and UPC, the basic scheme of the energy evaluation in this project has been organized into five different phases:

• Phase 1: Pre-diagnosis
• Phase 2: Data survey
• Phase 3: Evaluation
• Phase 4: Diagnosis
• Phase 5: Proposed intervention
7. DIAGNOSIS AND ACTION LINES
7. DIAGNOSIS AND ACTUATION LINES

7.1 Diagnosis

The diagnosis is the last stage in the process of energy assessment. At this point we are going to try to summarize the work done throughout the evaluation process.

We are going to do methodical and systematic assessment of the different aspect that influence the efficiency and the resource consumption of the building. In this way we identify the opportunities of improvement.

We are going to evaluate independently the following points:
- Diagnosis of the envelope of the building.
- Diagnosis of the facilities.
- Diagnosis on the management of energy resources.
- Diagnosis on consumption of resources.
- Diagnosis of comfort conditions.

Envelope’s Diagnosis

We have made the valuation of the exterior of the building with the program LIDER. Regarding to the conformance with the current legislation, the building does not achieve the minimum requirements for CTE as we can see in the following figure 7.1.1.

2. CONFORMIDAD CON LA REGLAMENTACIÓN

El edificio descrito en este informe NO CUMPLE con la reglamentación establecida por el código técnico de la edificación, en su documento básico HET.

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<thead>
<tr>
<th>Calorifacción</th>
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<tr>
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</table>

Figure 7.1.1 LIDER evaluation

For further information check:
- Section 5.2. Static data construction.

Those point that do not accomplish with the rules are the decks, the windows and the first flooring.

We have done different evaluations with the informatics programs in order to reduce the energetic demand and to adapt the building to the current normative.

In the next section we are going to develop those technical improvements that we can summarize in:
- As the first floor is easily accessible we can install thermal isolation in order to reduce the U from 2.09 W/m²K to an U lower than 0.63 W/m²K, demanded by law.
- Replace the windows in order to reduce their actual U from 4.00 W/m²K till U 3.00 W/m²K.
- Remove the vegetal soil from the green roof and add a layer of isolation and an anti-root lamina to protect the isolation in order to reduce its actual U from 0.52 W/m²K till U 0.41 W/m²K.
- Replace the pieces of Losa Filtron from the roof made of 40mm of extruded polystyrene isolation and 35mm of concrete in order to reduce its actual U from 0.52 W/m²K till U 0.41 W/m²K.

We have made those changes and then recalculated the building with the informatics program LIDER, now we can see as the building is adapted with the current legislation. (Figure 7.1.2)

2. CONFORMIDAD CON LA REGLAMENTACIÓN

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<tr>
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<td>Proporción relativa calorifacción/refrigeración</td>
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</table>

Figure 7.1.2 LIDER evaluation

For further information check:
- DOCUMENT 3. Attached document 5 Calener Lider
Diagnosis on the systems

Air conditioning

Originally the building was designed to be heated with a radiant ceiling system that it would be used for both heating and cooling. The set of two boilers has enough power to serve requirements of the building. And the two machines also have a cooling capacity sufficient to meet the demand.

As we have said with more detail earlier in this moment the building uses the air conduct system to acclimatize, to get this it only uses one of the two cooling units, the two boiling and 4 air-conditioning machines.

This causes significant thermal amplitude during the day and the consequent discomfort to users.

This radiant ceiling system represented an investment of 526,722.77 plus IVA. And now, for different reasons, it is completely useless.

In the next section we are going to analyze the cost of reconditioning the system to re-launch it again and an approximation to know the consumption it might have, this information would be useful to calculate the amortization. But in the state in which it is now, we believe that the whole system should be completely replace, so the necessary investment would be exaggerated.

The system currently used to condition the building was designed as radiant ceiling support system and now it is used as the main system.

The cooling production is coming from a cold condensed air chiller plant with heat recovery which has two scroll compressors and two refrigerating circuits. The cooler fluid is R410a, and it has axial fans. This plant is intended to produce the air-conditioner’s cooler power with thermal differential of 5 °C (from 7 to 12 °C).

The heating production comes from two overpressure and low-temperature boilers. The fuel is natural gas and the burner is modular.

The air-conditioning have a free-cooling system and are L built, with constant caudal, and cold battery, heat battery, and heat-recovery battery. The valves are three-way action proportional. A heat-recovery battery is installed (who comes from the cooler plant air-condensed and from heat-recovery system), as it is required to send the air with a low amount of humidity to avoid the condensation in radiant ceiling.

In theory, the system is efficient, but in practice, the use of air conditioning in the building is completely out of proportion.

On one hand the clearest conclusion to be drawn is that the selected temperature is too high, it is need to remember that in November, when the termhygrometers were placed the temperature ranged between 23 and 35°C with a humidity of between 20 and 48%. The range of temperatures recommended for an elderly people home is about 23-24°C.

So, our first recommendation is to regulate the set point temperature between 23 or 24°C in order to bring down the excessive consumption and increase the comfort.

On the other hand it would be convenient to recalculate the whole installation by a specialized company. It would be necessary to check if the dimensions of the conducts, the air supply grilles and the propelled caudal in each room are appropriated.

It is possible to install inverters to adapt the yield curve to the needs of the building and regulate the use of the cooling plant

Another improvement would be to install electromechanical gates to control the air intake in the different rooms.
Diagnosis on the management of energetic resources

This center has some systems to take advantage of the natural resources and a computerized software control of its facilities.

The drawback is that the systems installed and the control program must be handled by a highly qualified.

Now the building has 2 storage accumulators for sanitary hot water production, although one of these accumulators is out of service.

The person currently in charge of daily maintenance doesn’t have specific knowledge about the computer control system works. An external company with trained workers is responsible of centralize and control the maintenance on a telematic way by the management program.

It would be necessary that a qualified technician realize a complete maintenance program, that involves all the implicated parts as management, users and responsible of maintenance.

Diagnosis on the resources consumption

According to the assessment of LIDER program the building consumes 28% more energy from it should. But if we compare the consumption with other buildings like we did in point 6.5, we see that the consumption is three times higher.

This consumption is particularly important as the air conditioning is done with natural gas and electricity and this has an important impact on CO2 emissions.

With water consumption there isn’t much difference, but the consumption is twice higher compared to the building Viladecavalls.

We must make a special impact on the climate control to reduce those data, in the Lighting system and laundry.

To rationalize the consumption of water it is necessary to be careful when watering, install aerators on taps or modifying the toilets flushing.

Diagnosis on comfort conditions

One of the virtues of radiant ceiling system is that the heat transmission is made by radiation, this implies that it isn’t necessary the circulation of air to acclimatize and the consequent comfort to the users.

In this case, this system is useless and the building is acclimatized by air conditioned. Some of the users of the building explain to us that in some moments of the day they feel a lot of hot and other moments they feel cold. If we check the results that the thermhygrometers recorded, we noticed those sensations. The temperature reaches a maximum of 35 ºC during the early morning hours and a minimum of 22 ºC between 1 and 3 am. That information was recorded during the first week of November.
7.2 Actuation lines

From diagnosis and once identified the deficiencies and opportunities of improvement of the building, we can begin to ask specific actuations to reduce the energy demand. The proposals would be grouped into the following areas:

- **AL 1. Actuations related with the building skin**, in order to influence the thermal demand of the building to reduce it, acting on the architectural features and construction of the building to improve the quality of its skin.
- **AL 2. Actuations related with the systems and facilities**, with the aim of improving the overall performance of the facilities acting on low performance devices, in the distribution system, on the emissions, etc., and also on the control system of the comfort parameters and operating conditions of the building.
- **AL 3. Actuations on the resource management**, acting on the improvement of the management profile of the building to fit the demand identified, controlling the parameters of comfort and operating on the conditions of the building, acting simultaneously on the preventive and corrective maintenance of the building and its facilities.

Taking advantage that the center has a full-time maintenance staff and a company that manages the facility through the computer program telemetrically, as we study the economic proposals, we consider the possibility that some of these parts can make modifications to it to avoid having to go to an external company.

When we do the repayment calculation we don't took into account any subsidies, grants or support programs that the company who manage the building may have access to.

The proposals that we have been evaluating take as its starting point the current state of the building. The investment cost, the energy saving and the emissions associated or depreciation of the investment would vary throughout the time as the proposals are applied.

For further information check:

- **DOCUMENT 3.** Attached documents 5. CALENER REPORT and attached document 6. CE3X REPORT

**AL 1. Improvement of first slab’s insulation**

At this time the separation of the building and the land is solved by a non-insulated floor slab.

Now the first slab is formed by unidirectional and freestanding beams with concrete caissons + 5cm mortar layer + slope's layer formation + ceramic tile placed with cement adhesive. It has an $U=2.09\text{ m}^2\text{K}$, CTE restricts it to 0.63 W/m²°K, so in this case it **DOESN'T COMPLY**.

As the floor slab is accessible from several points the proposal to improve the system and accomplish with the parameters that mark the CTE is adding insulation to the bottom in order to reduce the U to 0.63 W/m²°K.

We have evaluated placing 5 cm of rock wool across the surface on the bottom of the first slab. With a $\lambda = 0.05 \text{ W / mK}$.

It takes into account a cost of € 65.05/m² and an area of 1526.06 m².

**AL 1.2 Improvement on the aluminum exterior carpentry**

Currently the windows are made of aluminum with a thermal breaking system and glasses 4/8/3 on the windows and 3+3+4/3+3 on the sliding door. The U of the group is 4.00 W/m²°K and it should be of 3.00 W/m²°K. The building has 69 openings and changes all of them to accomplish the CTE’s requirements as the cost is too expensive and the return of the inversion is completely unworkable.

### SUMMARY OF ACTUATION DONE BY A SPECIALIZED COMPANY

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<thead>
<tr>
<th>Action scope</th>
<th>Summary of Actuation</th>
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<td>29,025,40</td>
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<tr>
<td>Economic saving potential in the consumption</td>
<td>29,025,40 kWh/year</td>
<td>29,025,40</td>
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<tr>
<td>Emission saving potential in the consumption</td>
<td>5,923,55 kg of CO2</td>
<td>5,923,55</td>
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<tr>
<td>Economic cost return of the investment</td>
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</tr>
<tr>
<td>Return of emissions related to the investment</td>
<td>22,44</td>
<td>22,44</td>
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</tbody>
</table>
AL 1.3 Improvement on the deck insulation.

The building has two types of cover, a green one that covers part of the ground floor and a Losa Filtron that covers the third floor. Both of them has a current $U=0.52 \text{ W/m}^2\text{K}$.

The proposed actuation is to achieve a lower $U=0.41 \text{ W/m}^2\text{K}$, which is what the regulation says, acting differently in each one.

The green roof it is necessary to remove the topsoil and add a layer of insulation and sheet anti-roots to protect the insulation, it would reduce its current $U$ from 0.52 to 0.41 W/m2 K.

On the third roof it is need to replace the current Losa Filtron with 4cm of insulation and 3.5cm of concrete, to 5cm of extruded polystyrene to reduce its current $U$ from 0.52W/m2ºK to under 0.41 W/m2ºK.

<table>
<thead>
<tr>
<th>AL 1.3 Improvement on the deck insulation</th>
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<tr>
<td>Action</td>
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<tr>
<td>1,026.06</td>
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AL 2. Actuations related with the systems and facilities

The main systems which are needed to make adjustments in our building are air conditioning system, water and lighting consumption.

Regarding water consumption we can see that it follows the trend of the rest and it is excessive. We consider small changes in the facilities as flow reducers on taps and showers, toilet with dual flush device and regulate the uptime controls type Presto.

But we have to make special emphasis on the regulation of water for irrigation. When the city hall would built the network that provides grey water from the treatment plant it will be the primary to realize the connection. There isn’t any date for this project so we evaluate the installation of a tank filled with rainwater or non-potable water suitable for irrigation but from industrial processes.

We divide the air conditioning system in heating and cooling, although the conduct systems are the same for both.

In the lighting system we noticed something missing by excess that is easily solve by changing the type of bulbs for another with a higher efficiency, and compartmentalized zones of lighting.

AL 2.1 Installation of a tank to collect the rainwater

As the building has a garden that needs watering, we have evaluated the installation of a rainwater collection tank that could be refilled with water suitable for irrigation but not for drinking, when there isn’t enough rain water.

We have confirmed the historical data of rainfall on the nearest weather station which is located at the airport of El Prat de Llobregat.

This station has registered an average annual rainfall of 700.2 l/m2. As the roof of our building has an area of 1.526.06 m2. We could get 1,068.5 m3 of rainwater to allocate it to irrigation.

<table>
<thead>
<tr>
<th>AL 2.1 Installation of a tank to collect the rainwater</th>
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<tbody>
<tr>
<td>Action</td>
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<tr>
<td>Scope</td>
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</table>

AL 2.2 Installation of flow reducers on taps.

In the building there isn’t any tap aerators to reduce water consumption, those elements can reduce water consumption of devices between 35 and 50%.

<table>
<thead>
<tr>
<th>AL 2.2 Installation of flow reducers on taps</th>
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<tbody>
<tr>
<td>Action</td>
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<tr>
<td>Scope</td>
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</table>

AL 2.3 Reduction of the volume of water flushing on the toilet

As the toilets of the building have a single download tank, we propose the installation of a volume reducer device, which is some kind of plastic bag which is placed inside the water tank. This simple system allows savings of about 2 liters each time it is used, more over it would be useful to install dual flush mechanisms.

WC cisterns of the building have a capacity about 10 liters, applying this system achieves a saving of 20% of the water.

<table>
<thead>
<tr>
<th>AL 2.3 Reduction of the volume of water flushing on the toilet</th>
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<tr>
<td>Action</td>
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<tr>
<td>Action</td>
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<td>Scope</td>
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</table>
AL 2.4 Regulation of uptime pushbutton type PRESTO

The mechanisms PRESTO types which are installed on the toilets allow the regulation of the operation time, the maintenance operator can adjust this time to suit the needing of each room.

AL 2.5 Installation of changers of frequency devices on the compressors of refrigeration.

On the air conditioning section, the installation of changer of frequency devices on the refrigeration system would allow to adapt the yield curve and the real needing of the building in each moment, a lower deviation of temperature, less amount of starts and stops of compressor, more stability and lower consumption.

AL 2.6 Installation electromechanical grilles on impulsion grates

As there are spaces where the temperature gets to too high for the time of year there is a way to regulate the air flow that enter in the rooms which is placing electromechanical grilles on conducts or on impulsion grates. These gates would be connected to the temperature sensor on the room and to the control of opening.

AL 2.7 Change to a biomass boiler

We have assessed the installation of two biomass boilers; the advantage of this system lies in CO2 emissions equal to 0, but against it has a high cost and it need so much space to store raw materials.

This building has heating and hot water consumption of 691,953 kWh / year, the pellets have a calorific value 10% lower than the gas, so the consumption would be 761,114,830 kWh. The pellet has a calorific value of 5kWh so the building would use 152,229 kg of pellets per year. At a price of € 0.21 / kg it represents an annual cost of 31,968€ when gas represents 32,897€

AL 2.8 Replace the lightening

There are two types of lights that don’t accomplish of excess with the values of VEEI:
- Luminary type recessed downlight with reflector, individual safety transformer and lamp w qr,cbc-51/50 there are 193 units
- Decorative Luminary type downlight with lamp q3 24 G, 2 horizontal fluorescent 26 W; there are 169 units

A total of 531 bulbs can be changed by a LED technology. We counted a cost of € 10 per bulb.
AL 2.9 Modify the double ignition and creating new ones.

There are lines that serve more than one room, so it is necessary to made new division of electrical lines in order to suit the needs of each room.

AL 2.10 Presence detectors.

Although the building has presence detectors, it would be convenient to install a few more in some places to control and adapt to the specific needing. It has been taken into account placed a detector in the office corridor, in the staff corridor on ground floor and in each room’s bathroom.

AL 3. Actions on resources management.

Some of the actions that could be considered for managing the resources we have included in section AL2. Actions related systems and facilities. We think that at first it is necessary to make an investment to improve or modify existing systems. In this section we will study how to manage these systems more efficiently.

As the control system and the facilities of the building are difficult to control we propose to train the staff in this software in addition to the actions already undertaken.

AL 3.1 Staff training.

Due to the complication of systems and control program is a priority to train the maintenance staff.

AL 3.2 Maintenance project and annual monitoring with the facilities.

In order to adapt the system to the needing of the building and achieve the maximum level of efficiency it is necessary that the maintenance keeps over the time. It is necessary to make a good planning. This recalculation and adjustment of the system should be done by a specialized company. To assess the possibility of new fixes or new proposals.
7.3 Priority chart

The study so far has considered two main factors, economic and environmentally friendly, the first factor is divided in:

- The cost of the actuation
- The potential cost savings and
- The return of the investment

And the second one is:

- The energy cost of the actuation
- Emissions associated with the actuation
- The potential savings in emissions
- The return on investment and energy cost
- The return on investment associated emissions.

When we try the actuation we prioritize the recovery of the investment and its initial cost, but we don’t forget the environmental impact.

We have made an economic study in 10 years, but we discard the actuations on the building skin and the biomass boiler because its investment return period is too long.

This study has increased the annual cost of the investment and savings by 5%.

We analyze the last box:

In 2015 there is a 20.178€ of investment, in actuations like regulation on PRESTO devices, the installation of the frequencies changers, the staff formation and the maintenance and improvement of the facilities. At the end of the year, with the consumption reduction of the first improven, we have a deficit of 16.010€. In 2016 it wouldn’t be any actuation, still keeping the maintenance cost of facilities and monitoring consumer, at the end of the year the deficit would be reduce to 14.783€.

Between 2017 and 2021 the rest of the proposed improvements would be done and at the end of the year there would be a deficit of 10.754€.

In 2022, the total of the investment would be recovered with a final profit at the end of the year of 6.252€, in 10 years it would be a profit of 42.878€. From here it can be consider the possibility of investing in other improvements that had been discarded in this study or maybe further improvements will surely be applied.

This is a draft table of priorities, but there are many alternatives. And priorities are subject to change during the period and the needs of the building.
Based on the economic study calculates energy savings in kWh:

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<td>A1</td>
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<td>Improvement of the heating system</td>
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<td>Improvement of the ventilation system</td>
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</table>

Energy savings: 1,368,604 kWh

Based on the economic analysis calculates the associated CO2 emissions in Kg:

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<th>Action</th>
<th>CO2 Emissions at the beginning of the year (Kg)</th>
<th>CO2 Savings at the end of the year (Kg)</th>
<th>CO2 Emissions at the end of the year (Kg)</th>
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<tbody>
<tr>
<td>A1</td>
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<tr>
<td>A2</td>
<td>6.306</td>
<td>4.345</td>
<td>15.56</td>
</tr>
<tr>
<td>A3</td>
<td>6.072</td>
<td>4.062</td>
<td>15.22</td>
</tr>
<tr>
<td>A4</td>
<td>5.894</td>
<td>3.914</td>
<td>14.90</td>
</tr>
</tbody>
</table>

With the actions taken, in 10 years the CO2 emissions would be reduced by 563,492 tons.
8. CONCLUSIONS
At first we decided to make this energy audit because the project of this building was part of a governmental program that had as an objective to get a better sustainability during the building process and in its subsequent use.

To accomplish the premises of low energetic consumption and low generation of waste, some constructive solutions were used as: air conditioning system by radiant ceiling, ventilated façade, crossed ventilation, dry-construction system of all interior distributions, hot water generated by solar system, green roof with native plants, grey-water system connected to El Prat de Llobregat’s new grey-water supply and low consumption lights.

What we have discovered as we were compiling the building data is that the most of the used systems are disuse. Air-conditioning system by radiant ceiling is totally useless, the windows aren’t opened to take advantage of the crossed ventilation, green roof hasn’t got any plants, the grey-water system isn’t connected because the net it isn’t constructed yet and in many rooms the artificial lights are oversized.

We are also surprised to discover that this building triplicates the electricity, gas and water consumption compared with another retirement home that was built thirty years ago.

We believe that it is a general problem the increase of complexity in the facilities systems and the lack of qualified staff to make a correct and efficient use of them. That’s why a governmental program which tries to reduce CO2 emissions and reduce the consumption, it obtain just the opposite that was expected, a part from the huge initial investment necessary to install those systems.

Once the construction time was ended the management of the building including its maintenance was transferred to a company that hadn’t got enough capacity to assume this task, and that causes the wastefulness of some systems.

On the other hand in this particular case, the management of service facilities has been awarded to the company for a delimitated time, that fact makes difficult to make investments with a long payback period. Those kinds of investments are completely unworkable.

Luckily the current management team is fully aware about the reducing energy consumption is not only a general benefit but also it has a direct economical profit on monthly billing. Following this criteria they have been applying some improvements in the management from the different data between the first year of management and the second one.

However we thought in those kinds of buildings is extremely important to have a team of skilled technicians to manage, control and assure that the economical and human investments has the maximum performance.

In our opinion we think that all of the chain actors who are involved in the design, construction and management of the building must have the same level of commitment and expertise. The break in the chain causes the opposite effect.