Energy use and energy efficiency, the way to reduce energy consumption in university buildings.

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Abstract:

The Technical University of Catalonia (UPC) has been developing since 1996 a number of actions and strategies to reduce the energy consumption of its 96 buildings. From the collaboration agreement signed in 2006 with the Catalan Institute of Energy (ICAEN), UPC has agreed to develop measures to encourage energy savings and enhance energy efficiency on its own buildings, distributed over ten campuses.

One of the first actions carried out was the implementation of the Resource Consumption Efficiency Plan (PECR), which culminated in 29 energy audits carried out on different types of buildings: schools, sports facilities, libraries and administration buildings and services. These were performed by Technical Architecture and Building Engineering students as a Final Degree Project.

While carrying out the energy audits, it was recognised four possible lines of action:

- Intervention on the building envelope to reduce energy demand.
- Review the services systems to improve their performance.
- Educate users to behave in a sustainable manner.
- Communicate the results to the school management and training those involved in the use and management of the buildings, to implement possible improvements in resource consumption efficiency.

Taking into account the results obtained and aiming to reduce energy building consumption as a strategic objective, the UPC identified the need to develop a tool that allowed the knowledge of the dynamic data of the buildings (gas, electricity and water consumption and the occupancy and activities carried out within them) and the static data (architectural features, building types, energy systems and equipment) in order to compare historical data, consumption trends and environmental indicators (eg kWh/m2, kWh / user, kWh / ECTS, kWh / type of use).
The SIRENA project (Information System of Energy and Water Consumption), which is an online tool, has allowed comparing different rates of consumption for each building and generating consumption charts showing their evolution over the years (from 2006 to present).

The General Plan proposed by the Technical University of Catalonia began in 2003 with the implementation of methodologies for evaluation and energy assessments of some buildings. Since then the Plan has been implemented since 2008 with new tools and specific actions that concluded in significant savings on resources consumption, such as electrical or gas, which means a reduction in CO_2 emissions, and water use.

The object of this communication it to present the achievements accomplished by the UPC during these years in terms of; reducing energy consumption, the involvement of all the stakeholders in the commitment to sustainability and the need to work on encouraging energy efficiency as institution strategy.

Keywords

- On-line information;
- Energy management;
- Energy efficiency;
- Existing buildings;

1. Introduction

The Technical University of Catalonia (UPC) has been developing since 2003, several actions and strategies to reduce the energy consumption of its 96 buildings and, consequently reducing greenhouse gas emissions.

In late December 2006 the UPC signed a collaboration agreement with the Catalan Institute of Energy (ICAEN). The UPC agreed to develop measures to encourage energy saving and enhance energy efficiency in UPC buildings spread over ten campuses throughout the territory of Catalonia.

One of the first actions carried out was the implementation of the Resource Consumption Efficiency Plan (PECR). The Plan consisted on undertaking an energy building assessment of several buildings with different configurations, uses and construction types, in order to make a first estimate in terms of energy demand, system efficiency and patterns of use and management of the schools.

The PECR concluded with 29 energy audits performed by Final Degree Project students from Technical Architecture and Building Engineering Schools, tutored by the faculty staff members during the years 2004/2006. The methodology used in this work was published in book form (1) and in a published paper (2).

In parallel, using this methodology, the UPC developed the SIRENA project (Information System of Energy and Water Consumption) (3), which is an online tool that provides dynamic information on electricity and water consumption, as well as static occupation and activities that are carrier out in their buildings. This tool has allowed comparing different consumption rates for each building (kWh/m^2, kWh/user, kWh/credit teaching, kWh/per use, etc.), and generating usage charts showing their progression from November 2006 until May 2007(4).

Finally, the UPC presented in 2011 **The Energy Saving Plan (ESP)**, which includes several policies as: general measures for efficient communication between the stakeholders involved in the process of management and with responsibility in energy consumes for all buildings in the UPC; management investments and improvement of facilities and adequate distributions of spaces; monitoring and management of energy information, with a gradual extension of the network monitoring and visibility of building consumption data through the SIRENA system; and optimizing Systems with the installation of the software Granola PC UPC.

The ESP has set a target for reduction by 2014 of 25% of total energy consumption (gas and electricity) compared to 2010 (see Fig. 1) and, to reach it, the ESP works in different projects:
• Energy Optimization Projects (Projectes d'Optimització Energètica POE), which are instruments that encourage responsibility in the consumption of resources through a cooperative work in 13th teams, that corresponds to a team per schools, in order to improve the energy efficiency in the UPC campus.

• The Energy Efficiency Working Group, which has played a decisive role to convey information and experiences.

• Guide 2.0 for energy savings, which promotes a culture of saving among people in the university

• Training plans on collaborative tools applied to energy savings and addressed to the Administration and Services staff.

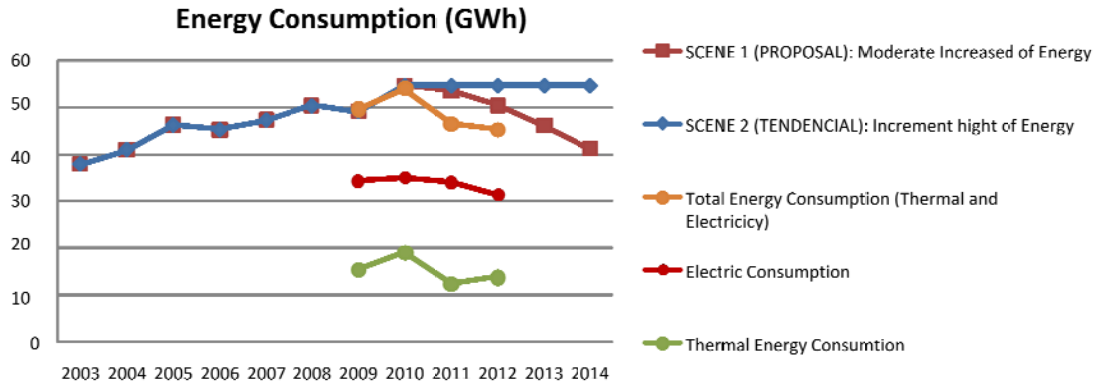

Fig.1 Evolution and Future Scenes of Energy Consumption from 2003 to 2014

2. Methodology

The development of the first projects was planned for a twelve months period, which involved 21 Technical Architecture and Building Engineering students from the Building School of Barcelona (EPSEB), two lecturers and various staff members from the Environmental and Maintenance Offices and other units. Within the project was included a weekly seminar in order to discuss its progress and any arising issues, and also to share information and experiences. In conclusion, it was an enriching experience for the students. Each student was expected to do her/his own work, but they were also encouraged to collaborate and share their experiences, aiming for a high and consistent quality of work done.

Once the program was established, the students were provided with tools and standardised forms in order to adapt to the different assessment projects to the program framework (Fig. 2) established in advance, consisting on:

- Summary of general characteristics and survey data using specification data sheets gathering architectural information, building envelope type, internal layout, structure and building construction type;
- Study of energy resources: electricity, gas, water, and other fuels;

- Analysis of services facilities: lighting, air conditioning, energy and outfitting, and water pipes, providing plans and sets of data sheets compiling all the information;
- Energy consumption monitoring;
- Data analysis and assessment of the energy efficiency of the building;
- Proposals for actions to be taken.

The data gathering, the working methodology and the analysis of the data obtained were carried out in accordance with the models and the experiences provided by the tutors and other experts consulted during the development of the activities. Finally, there were summary sheets providing all the values obtained and these were drawn up on plans for each building studied. After verification of the proposed energy indicators, it was set out a series of actions and strategies for each building in order to comply with energy efficiency policies from UPC General Plan.

A total of 29 energy audits were carried out on different types of buildings: schools, sports facilities, libraries and administration buildings and services.

While carrying out the energy audits, it was recognised four possible lines of action:

- Intervention on the building envelope to reduce energy demand.
- Review the services systems to improve their performance.
- Educate users to behave in a sustainable manner.
- Communicate the results to the school management and training those involved in the use and management of the buildings, to implement possible improvements in resource consumption efficiency.

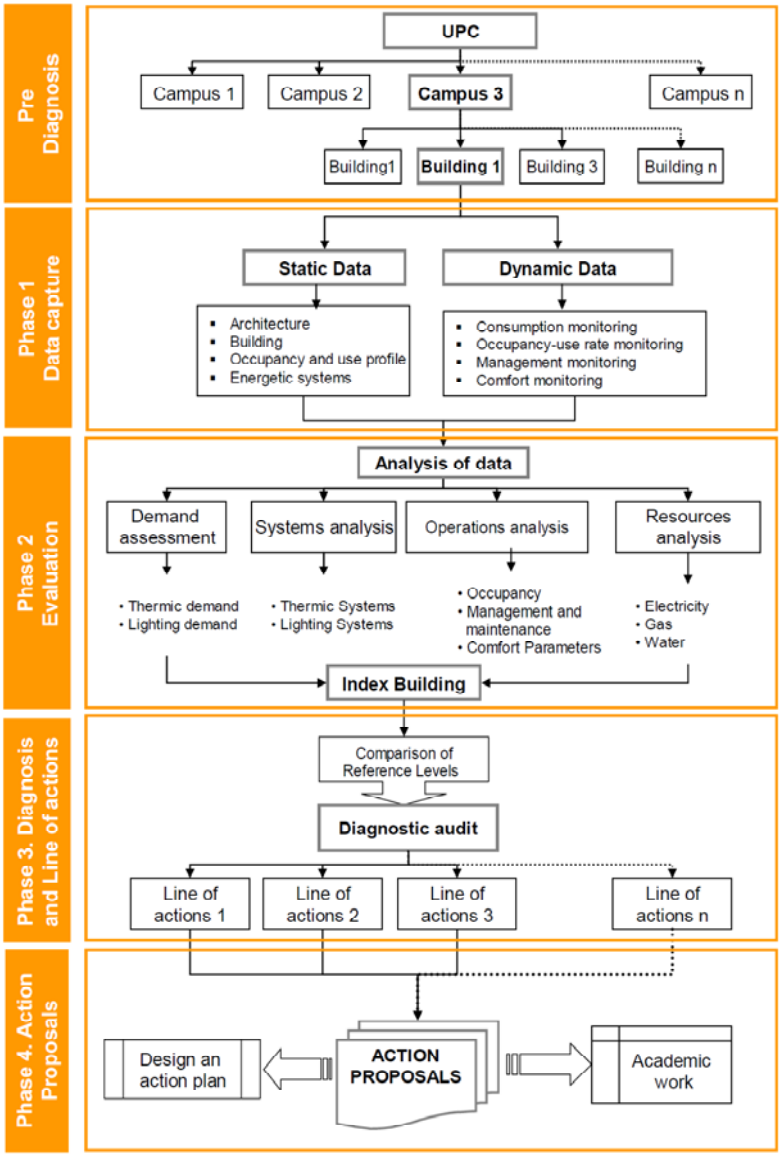

Fig 2 Methodology diagram for energy building assessment

In this regard, as an example, it was found that most buildings suffered from significant heat loss due to the lack of insulation in the opaque parts of the envelope and through the obsolete joinery. The proposal for intervention was to insulate floor slabs in contact with external temperatures (lecture halls over porches), change glass panes and window frames, and fix air drafts produced by different defects on the building envelope.

On regards the services, it was frequent the use of artificial lighting in unoccupied spaces or with natural light (toilets, classrooms, corridors). Sometimes the lights were switched on even when they were not necessary. In addition was noticed that the classrooms had oversized lighting (1000 lux on work surface when the Código Técnico de la Edificación (5) CTE indicates 500 lux).

It was found in several areas that internal temperatures were higher than standard temperatures of comfort, producing an unnecessary overuse of the heating. Therefore, it was recommended lowering the set point temperature or otherwise using control valves on the radiators. It was noticed the use of electric heating systems that could be replaced by others systems with higher performance.

One of the incidents commonly detected was that the heating was turned on throughout the day (7:00 to 21:00 when comfort temperature could be guaranteed with a burning time of 7:00 to 19:00 h). It should be noted that changing patterns of use could affect the consumption savings in some cases, from 25% in February to 40% in November. It was also suggested turning off the heating during the afternoon or setting up a new set point temperature of 20°C instead of 22°C as established till then. All these measures taken together could produce savings of up to 70% with an intervention cost of 0 €.

Another widespread problem was the so called "ghost consumption", which is the background consumption that occurs when buildings are unoccupied (during the night and on holidays). In some cases was up to 30% of peak consumption. It was identified the causes of this use, related on one hand with server rooms that need to be permanently air conditioned but on the other hand it was often caused by the lack of awareness of energy users.

Finally, It was evident the need for building maintenance manager training as well as providing consistent information on the services consumption taking place at all times to improve management of the resources on place.

Taking into account the results obtained and aiming to reduce energy building consumption as a strategic objective, the UPC identified the need to develop a tool that allowed the knowledge of the dynamic data of the buildings (gas, electricity and water consumption and the occupancy and activities carried out within them) and the static data (architectural features, building types, energy systems and equipment) in order to compare historical data, consumption trends and environmental indicators (eg kWh/m^2, kWh / user, kWh / ECTS, kWh / type of use) (6).

This led to the development of the tool called SIRENA, which allow us to know through a monitoring network system the energy consumption of most buildings that the University uses and manages (86 of 96 building that owns and comprising 93% of the total area). It is possible to consult the historical consumption of those buildings with systems and facilities monitored. With this tool it is possible to check the consumption taking place at all times but most of all, the overall

saving results achieved from the interventions targeting energy efficiency carried out in several buildings throughout the years.

The current Energy Saving Plan works on various projects to improve innovation and energy management in different UPC's buildings by an open network that involves an efficiency and energy savings workgroup. This group meets every 2/3 months, looks to the monitoring energy of the buildings, shares information and works within their own data.

The POE has allowed rationalize the energy consumption of buildings, change habits and routines and create a culture of savings and use of resources. The system allows economic incentives consisting in returns the 25% of the savings to the building managers to achieve paybacks in new reducing consumption measures. These economic returns must be invested in new actions in terms of energy savings with the clear objective of optimizing the buildings (Fig.3).

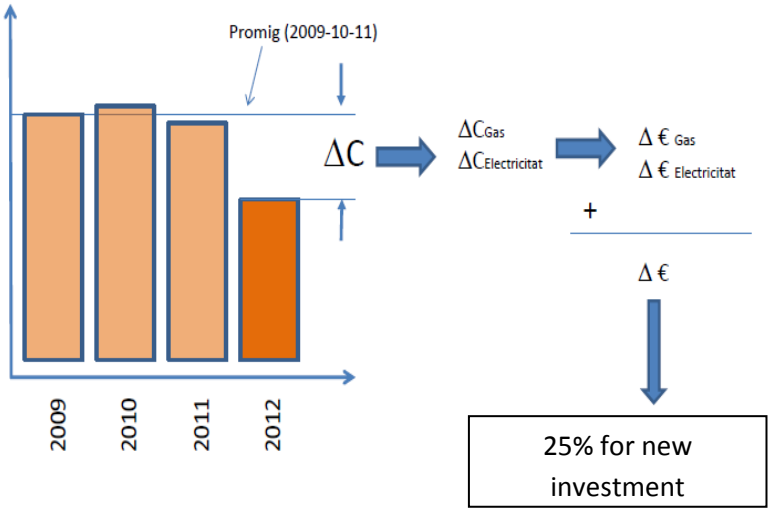

Fig 3. Payback of the Savings on Energy Consumption

3. Results

From the results documented in the Final Degree Project "Intervention strategies comparison for energy savings on existing buildings" (7), data extracted from SIRENA Reports 2009 (8), 2010 (9), and the Energy Saving Plan 2011 (10), it has been chosen three buildings as examples to expose the achieved results.

3.1 Sports Facilities Building at Campus Nord

An energy assessment was undertaken on 2004 (11). In this building the use of hot water was the parameter that bore the highest energy consumption. During 2009 and 2010 there were taken actions to reduce consumption related to air conditioning, which consisted basically on:

- The substitution of the pressure transducer, which reduced the hours of operation of the system and pressure pump starts-up system;
- The drop in working pressure set to try to reduce hours and water consumption with no impact on the user;
- For health and safety reasons, the existing system was replaced by two 35kW boilers freeing each recovery unit, which has meant a reduction of approximately 1486m^3 of gas / per week;
- It was found that the start-up of the boiler was not linked to the schedule, so the boiler was turned on all night. The programing was changed; thereby the consumption was reduced about 6,122 kWh per week. As shown in Figure 4, the energy building performance was reduced considerable in the last year.

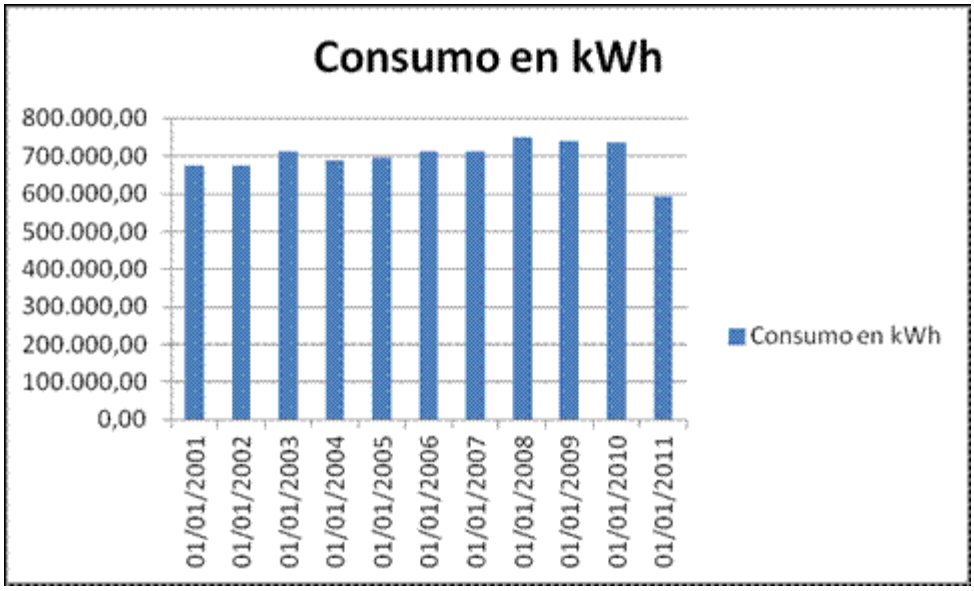

Fig 4. Electric usage diagrame of Sports Intalation Building

3.2 Rector Gabriel Ferrater Library

An energy building assessment was carried out on 2006 (12). This library was on fourth position on energy consumtion of all UPC buildings, so it was also studied for the period of a year by a group of university students in the project *Consumint Barcelona*.

Within this work the following conclusions were drawn:

• Due to the architectural characteristics of the building with a glazed facade facing south-east and little sun protection, it was very difficult to maintain comfortable temperature conditions inside the building, to the point that some areas were not allowed for general use because the high temperatures recorded;

• During the summer months, despite the significant decrease of users, there was a management of spaces to be used, so the library was kept air conditioned throughout;

• It was detected an excessive use of artificial lighting;

• Approximately 50% of the total building consumption energy was used to air conditioning (which runs fully on electricity). Still, the degree of thermal discomfort was high, indicating that saving measures could also mean improved thermal conditions;

• There was little relationship between outdoor and indoor temperatures.

The energy saving measures were implemented by:

• Management of the spaces by occupation rates, reducing spaces open to the public in off-peak times;

• Reducing energy usage adjusting air conditioning temperature setpoint depending on the time of year and areas of the building, and producing a timetable schedule by day and floor as needed, and a manual of use for air conditioners systems.

• Installing solar film on the glazed façade that was most exposed to the sunlight and planting evergreens trees as permanent protection from excessive solar radiation throughout the year;

• With regards to lighting facilities it was proposed to develop a timetable for switching on and off the lights and adjust it to the lighting requirements for each day and for each floor; replace fixtures switched on permanently with LEDs; install systems with motion detectors in areas of restricted access; use of natural light controlled manually by the library staff and the installation of light sensors.

The results obtained after the commissioning of these measures can be checked in Figure 5

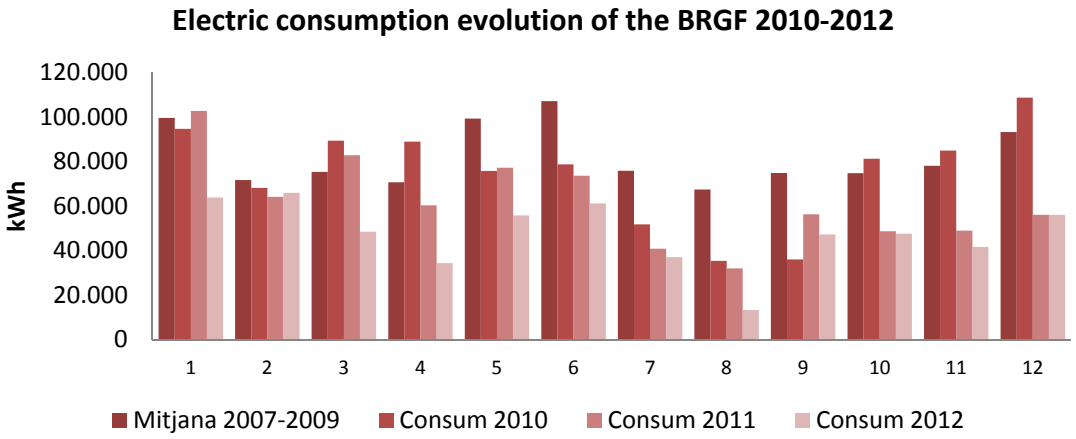

Fig 5 Electric usage diagram of BRGF

3.3 Vertex Building

The Vertex building was subjected to an energy assessment in 2005 (13). This building is used by the General Services offices of the University, is therefore considered a building for administrative use. The conditions of comfort measured in different areas, indicated a high degree of discomfort, with spaces at 25 °C of temperature even when air conditioned. This situation was due to inappropriate use of air conditioning systems by users, the architectural characteristics of the building and the various changes of use over time.

On 2009 a set of measures were carried out to reduce energy consumption, focusing on the creation of a network of stakeholders to articulate a process to review its uses and building management. Together with several actions carried out regarding waste reduction and improving the selective waste collection, it was found the following lines of action regarding energy efficiency:

• The shading of the facades was originally designed regardless of the direct sunlight they received, with shutters blocking the entry of natural light and curtains that only served as a control for reducing natural lighting and direct thermal radiation to the occupants;

Some of the proposals carried out were:

• Promote night ventilation aiming to reduce thermal load and slow down the warming up of the spaces the next day, thereby reducing the need for artificial air conditioning;

• Optimize the management tool of the air conditioning system adapting the actual needs to the current uses of the building and the real occupation rate;

• It was proposed to use lighting systems based on the actual lighting needs, taking advantage of zoning, installation of photo-sensors, and reviewing lighting timetables for switching on/off within the building;

• From the monitoring of the building with the tool SIRENA, there was detected a high energy usage during unoccupied periods. Managers and maintenance technicians were involved together to reduce this energy consumption and it was carried out a campaign to increase awareness within users identifying and quantifying energy usage corresponding to each user. The desirable reduction in energy consumption during unoccupied periods was not achieved; however it was reduced to half (from 90kWh to 47kWh).

Implementing these measures (among others of lesser importance) has incurred on significant savings on energy consumption in this building, as shown in Fig 6.

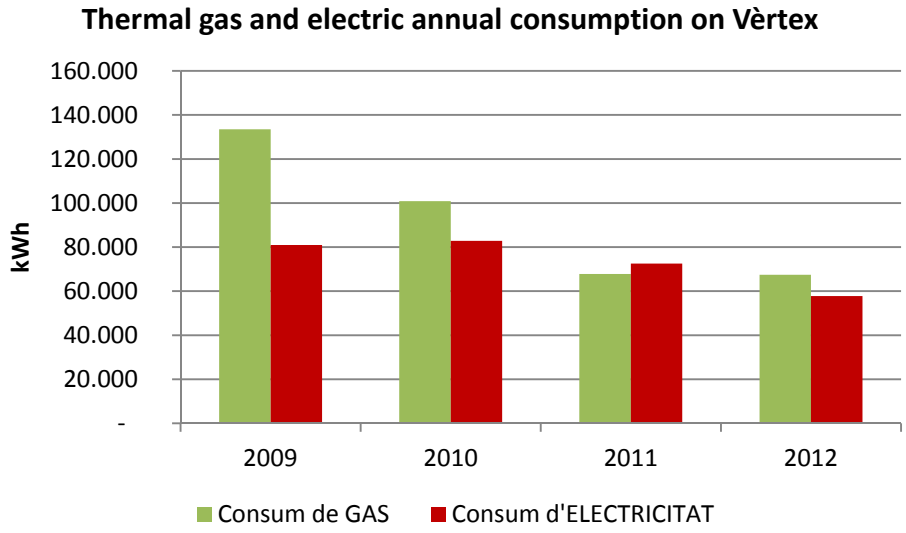

Fig 6 Electric usage evolution at Vertex building

4. Conclusions

The institutions must establish strategies for reducing energy consumption within public buildings as a compromise to involve the whole community (14) . In particular the universities and education centres seek to educate the students in good skills for life in earth (15), (sustainability 2012), (16)

The General Plan proposed by the Technical University of Catalonia began in 2003 with the implementation of energy assessments of some buildings. Since then the Plan has been implemented with new tools and specific actions that concluded in significant savings on resources consumption, such as electrical or gas, which means a reduction in CO_2 emissions, and water use.

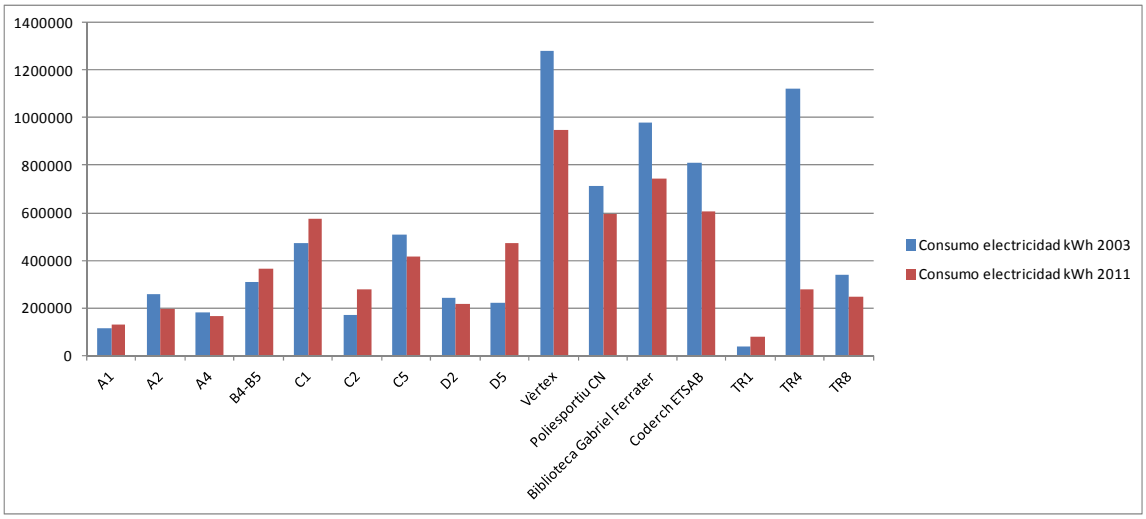

Fig. 7 Energy consumption evolution (2003-2011) for some UPC Buildings

The involvement of all stakeholders that make up the university community, from management, teaching staff, administration, to services and students, has shown excellent results (17). Among all of them it is noticeable the increase of awareness on sustainable manners within users and also the training of future professionals who produced their Final Degree Projects using real examples that result in remarkable improvements.

Acknowledgments

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