

# ENERGY SAVINGS IN SABADELL (SPAIN) SCHOOL FACILITIES

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## ABSTRACT

Improving the energy efficiency standards in schools is a very convenient practice since it not only makes them more sustainable and less pollutant by reducing their energy demands, but also, and most importantly, it can strongly contribute to raising awareness among the children attending those schools, in other words, the citizens of tomorrow's society.

Over the last years, new legal regulations and social awareness obliges to use energy responsibly. Currently, politicians and social agents are growing more involved and committed to the environment.

This work shows the results of the study of energy savings carried out in different CEIP (Primary Education Center) in Sabadell (Barcelona). The project has been developed by different institutions lead by the Technological University of Catalunya (UPC). With the aim to guarantee environmental comfort without the increase of energy expenses, we have detected and characterized different needs and improvement actions in several facilities studied.

The results obtained can help establish future working procedures in order to improve the quality of use of buildings and to design possible energy saving measures. We understand that new buildings should be designed, built, used, and maintained focusing on a rational use of energy. The capability to achieve this goal is in our hands.

With the aim to systematize the information about energy and water consumption, we have developed the following procedures:

1. Establishing criteria for data retrieve.
2. Systematizing data retrieve using a procedure of information management.
3. Creating a data base.
4. Proving staff and facility managers the benefits of using data bases in the maintenance plans.
5. Retrieving suggestions from managers and staff of buildings.
6. Final report.

From the present study, an action plan and improvement proposals seeking the definition of new policies, objectives, and commitments in energy savings will be established.

## 1.- Background

The city councilors for the Environment and Sustainability along with the Region of the Town Hall of Sabadell have signed an agreement of collaboration with the UPC Interdisciplinary Center for Sustainable Technology, Innovation and Education

(CITIES) to develop an Energy Savings Plan for Municipal Facilities (PE3).

This improvement plan aims to enhance energetic efficiency in different sectors of activity in the city, promoting the use of renewable energy and decreasing the environmental impact of energy consumption. This plan has been categorized into the specific areas of education, sensitization and energetic counseling, and it was developed by the Energy Efficient Buildings group, the City Council of Environment and Sustainability and the Regional City Council of the Town Hall of Sabadell. It was developed in collaboration with the *CITIES* of the *UPC*.

The Plan, initiated in April 2005, is made up of three phases:

Phase 0: Initial diagnosis and definition of lines of action

Phase 1: Development of specific studies (energy auditing in buildings by sectors)

Phase 2: Execution of Plan and prioritization of action

The three Phases have been completed, and we believe that now is the time to spread the word about it and to start the evaluation of the results obtained.

## **2.- Energy Savings Plan for Municipal Facilities (PE3)**

During the development of Phase 2, the following steps were taken:

The standardization of an *ad hoc* energy auditing protocol for the Sabadell Town Hall, based on the auditing methodology developed for UPC buildings [1], and the establishment of a methodology applicable to any short-term auditing of municipal offices or facilities.

A detailed study of preschool, daycare and primary education centers, allowing for the overall characterization of generalized energy savings measures [2][3].

The drafting of a Plan of Action for the development and evaluation of proposals for improvement.

And, the drafting of a General Plan of Action for all municipal facilities (educative, sport, cultural and administrative) starting from the pre-diagnosis of Phase 0, and taking into account the specific steps of Phase 1.

This paper briefly shows the results of the energy savings study in different PECs (Primary Education Centers) in Sabadell. School facilities are an appropriate place to start because a direct and permanent link with the education of tomorrow's citizens is fundamental for improving construction and environmental sensibility.

### **2.1.- Methodology**

The process of establishing energy savings criteria in buildings calls for measures and collaboration at different levels. The participation and involvement of all intervening agents in the process are therefore necessary from the start.

In accordance with the objectives defined in PE3 and after some experiments carried out in municipal buildings in Sabadell, we present here what could be considered a basic work scheme. It is organized into four main differentiated phases in addition to the previous Phase 0 of pre-diagnosis which defines the scenario for initiating work.

- Phase 0: Pre-diagnosis
- Phase 1: Data collection

- Phase 2: Assessment
- Phase 3: Diagnosis and lines of action
- Phase 4: Intervention proposals

### **Phase 0: Pre-diagnosis**

This is the first phase of the entire process and is oriented to discovering energy dysfunctions in a building.

As mentioned, any initiative which aims to define improvement, savings or energy efficiency criteria needs to previously establish the starting scenario with which to evaluate the potential for improvement and the viability of objectives. If the goal is, for instance, reducing a building's consumption by 50%, we need to establish the reference parameters for this percentage: Annual consumption; Total resource consumption; Consumption of specific energetic uses; Consumption per sqm, etc.

These reference parameters require sufficient information in order to identify resource consumption trends, factors which may be conditioning these trends, and, depending on how detailed the available information is, the specific lines of action to be developed.

Since the purpose is to define the starting scenario from existing information, the pre-diagnosis is key as the final diagnosis will be based on the results obtained once the study is finished. It will be carried out with a much more detailed analysis at another level after collecting all of the specific information.

In the case of large-scale work, such as a group of municipal facilities [4], the pre-diagnosis must be carried out prior to the detailed study itself. This could result in the need to carry out a complete energy audit.

### **Phase 1: Data collection**

This is the first part of the complete process, and the good results and reliability derived from the following work phases rely on this phase. Access to the different information sources must therefore be facilitated by the building's managers and users. With this idea in mind, we have established three types of access:

- **Basic level access BL:** for buildings with scarce information or data to be verified.
- **Mid level access ML:** for buildings with partial available data in need of improvement in quantity and quality.
- **Detailed level access DL:** for buildings with great available data of good quality which only needs verification.



Figure 1: Espronceda PEC, Sabadell

The types of collected data must be distinguished into “**static data**” and “**dynamic data**”, according to the modifications registered over time. A building’s architectonic characteristics, which in principle do not vary, are considered “static” (Fig. 1), while a building’s intensity of use or conditions of comfort is considered “dynamic”. We make this distinction because each of these data types requires work from different areas and must be reflected in specific document formats.

### **Phase 2: Assessment**

Once the data collection process is finished, which is the longest part and the most demanding regarding precision in order to produce reliable documents, an assessment is made which will be used for the diagnosis of the building being studied.

The collected data is processed in order to assess the following:

- Resource consumption according to meter monitoring when possible.
- Resource consumption according to computerized meter readings and bill data.
- Characterization of energy consuming systems and devices which cover the demand for air conditioning, heating and lighting.
- And, when possible, operating conditions (occupation, maintenance and management, and comfort parameters).

With this data we can form what we call an index or significant values which allow us to characterize a building.

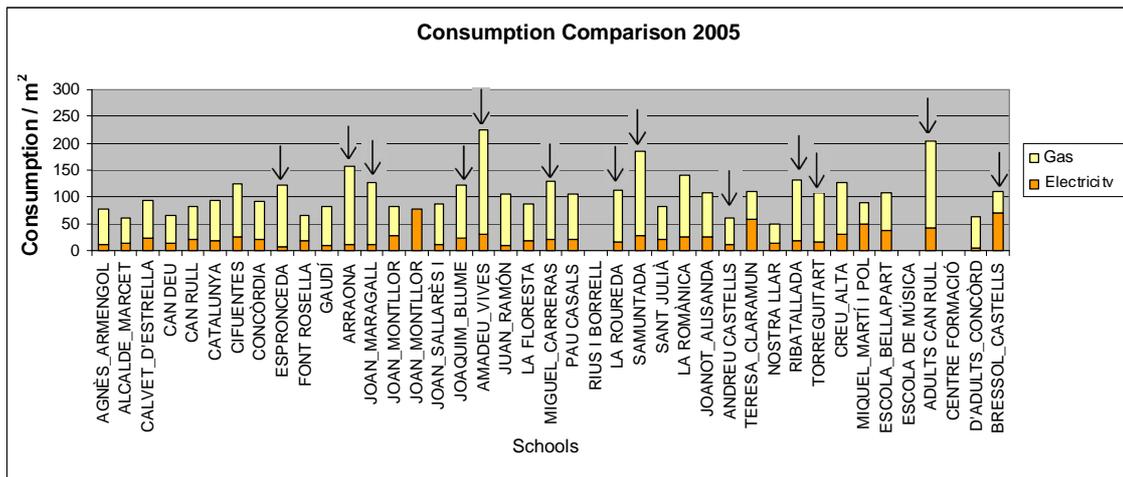


Figure 2: Comparative consumption data between the different PECs of Sabadell

Using the **indexes** or **significant values** we are able to transform the collected data from different units with diverse tools into values which are unified and comparable (kWh/m<sup>2</sup>, lux/space, etc.) to those of similar buildings (Fig. 2). Given that there are many types of indexes that characterize buildings by energy use, the most appropriate one must be selected depending on the objective of the analysis. In our case, we have used the indexes in relation to other buildings with similar characteristics, for example to compare the resource consumption per m<sup>2</sup>/person/year, etc.

At this point the data collection becomes significant, since the mechanical task of collection and registry is transformed into **significant indexes** that allow us to compare a building with the **reference indexes** or **reference parameters**. This allows us to define the starting scenario from which to identify a building's opportunities for improvement.

In this phase the diagnosis can be made after assessing the data and comparing it with the reference values (Fig. 3). From this point on, the lines of action and intervention can be defined.

### **Phase 3: Diagnosis:**

The recognition of a building's energy consumption and its possibilities for improvement is obtained through partial diagnoses in each of the areas analyzed: architectonic structure, energy systems, usage and management. This diagnosis can be a starting point for defining the lines of action to be taken for improving the building's energy efficiency and resource consumption, taking into account its technical, economic and logistic viability.

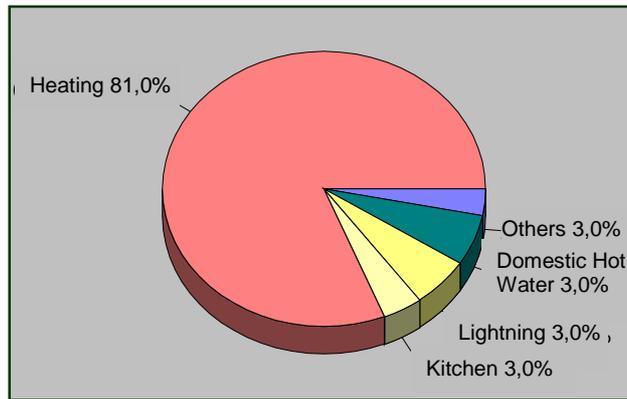


Figure 3: Energy consumption distribution graph in the school sector in Catalonia

With this diagnosis we should be able to detect the different possibilities for improvement in each of the areas mentioned, as well as to evaluate proposals depending on the difficulties involved in their execution. In the case of a building in which lines of improvement are identified in both the structure and in the functioning of air conditioning and heating, and supposing that both would provide similar energy savings, the necessary investment for each one must be determined in terms of costs and logistics before deciding on an intervention proposal.

The adaptation and ascertainment of the diagnosis will therefore depend directly on the quality of the information gathered during the data collection phase, and on the rigor with which the evaluation of the results is carried out.

#### Phase 4: Lines of action

And finally, from the diagnosis we can identify the shortages in a building and consider specific solutions to remedy them. The different proposals are grouped into what we call lines of action, which are determined by the methodology used during the data collection and assessment phases. They are defined as such:

- Lines of action related to the structure: those which have to do with the building's architectonic characteristics and construction and specifically with its physical envelope (roofing, vertical exterior coverings, grounds, etc.)(Fig. 4). This type of action has the objective of reducing energetic demand.

ZONA CLIMÁTICA C2										
Transmitancia límite de muros de fachada y cerramientos en contacto con el terreno					$U_{Mlim}: 0,73 \text{ W/m}^2\text{K}$					
Transmitancia límite de suelos					$U_{Slim}: 0,50 \text{ W/m}^2\text{K}$					
Transmitancia límite de cubiertas					$U_{Clim}: 0,41 \text{ W/m}^2\text{K}$					
Factor solar modificado límite de lucernarios					$F_{Lim}: 0,32$					
% de huecos	Transmitancia límite de huecos <sup>(1)</sup> $U_{Hlim} \text{ W/m}^2\text{K}$				Factor solar modificado límite de huecos $F_{Hlim}$					
	N	E/O	S	SE/SO	Baja carga interna			Alta carga interna		
					E/O	S	SE/SO	E/O	S	SE/SO
de 0 a 10	4,4	4,4	4,4	4,4	-	-	-	-	-	-
de 11 a 20	3,4 (4,2)	3,9 (4,4)	4,4	4,4	-	-	-	-	-	-
de 21 a 30	2,9 (3,3)	3,3 (3,8)	4,3 (4,4)	4,3 (4,4)	-	-	-	0,60	-	-
de 31 a 40	2,6 (2,9)	3,0 (3,3)	3,9 (4,1)	3,9 (4,1)	-	-	-	0,47	-	0,51
de 41 a 50	2,4 (2,6)	2,8 (3,0)	3,6 (3,8)	3,6 (3,8)	0,59	-	-	0,40	0,58	0,43
de 51 a 60	2,2 (2,4)	2,7 (2,8)	3,5 (3,6)	3,5 (3,6)	0,51	-	0,55	0,35	0,52	0,38

<sup>(1)</sup> En los casos en que la transmitancia media de los muros de fachada  $U_{Hlim}$ , definida en el apartado 3.2.2.1, sea inferior a 0,52 se podrá tomar el valor de  $U_{Hlim}$  indicado entre paréntesis para las zonas climáticas C1, C2, C3 y C4.

Table 1. Limit transmittance per climactic zone C2, according to the CTE. [3]



Figure 4: Façade protected with vegetation and unprotected envelope.

- Lines of action related to systems and facilities: covering all interventions which may improve the functioning of equipment and systems that deal with the energetic demand of a building (lighting, air conditioning and heating equipment, flux regulators, etc.).



Figure 5: Conduction with excessive runoff piping on the outside of the building.

Figure 7: Installation of solar plates for sanitary hot water.

- Lines of action related to energy resource management: including those identified with a building's occupation characteristics, uses and functions (schedules, periods, etc.)(Fig. 5).

Questionnaire and assessment of comfort	Yes	No	?	comments
There is a/c and heating in the work area				
There is a thermometer in the work area				
The temperature in summer is 25°C (more or less)				
The temperature in winter is 20°C (more or less)				
In winter the windows must be opened due to excess heat				
There is solar heating				
There is gas heating				
There is electric heating				
The windows are sealed shut				
The window faces south				

The window faces north				
The window faces east				
The window faces west				
The windows have blinds				
The box for the blinds is insulated and stuck				
The blinds can be lowered/raised by the user				
The windows have curtains				
A jacket must be worn in summer				

Table 2: Model of data collection file related to area use.

Each of the identified lines of action must be evaluated in three aspects: the effect on a building's energy demand, overall consumption and the percentage of potential savings and technical and economic viability.

### 3.- Proposal of action

With all of the difficulty involved in defining overall lines of action for all of the educational facilities in the town of Sabadell, and after having carried out the consumption assessment and detailed studies of some PECs with excessive consumption, we believe that certain patterns can be established from which the *Energy Savings Plan for Municipal Facilities* (PE3 and PE4) can be designed.

In drafting these general lines of action, some specific proposals have been included which were extracted from various energy audits carried out in Phase 2 of the Plan: PEC "Miquel Carreras"; the sports facility "Municipal Sports Pavilion Esportiu Can Balsach"; the cultural facility "Vapor Badia Library"; and the administrative facility of the "Can Marcet" building.

We need to make it very clear that an advance toward more efficient and responsible energy consumption does not necessarily mean reducing the parameters of comfort within the buildings. What's more, it specifically means an improvement in environmental quality through a reduction of greenhouse gas emissions, and, in the end, an economic savings from a reduction in consumption. Savings opportunities and a possible reduction in consumption must therefore be discovered for each building.

We've established a Decalogue of possible savings opportunities that we've detected during the drafting of the different work phases of PE3. Granted not all of them will be applicable in all of the buildings, and for each facility a detailed study must be carried out so as to establish what the different lines of action mean in terms of energy savings.

1. Citizen commitment
2. Control of expenses and energetic building management
3. Summer is summer and winter is winter
4. The skin of the building
5. Defining a reform plan in existing buildings
6. System performance
7. Solar ordinance and other renewable energies
8. Reactive energy
9. Light savings

## 10. Light maintenance

### 4.- Conclusions

Energy-conscious design, construction, use and maintenance of school buildings can contribute to significant energy savings and improve the students' learning environment. The purpose of this research is to formulate design recommendations for school buildings in a city near Barcelona and to assess the influence of different design variables on their energy consumption. A high performance design of a school classroom in the hot–humid climate could reduce the annual energy consumption for heating and lighting.

A base-case classroom was constructed by taking commonly used values for each design variable. Using demand simulation techniques, these variables were modified one by one to find the value that minimized energy consumption, while keeping thermal and visual comfort in the room. Based on these tests, the recommended value for each design variable to create a high performance classroom, was determined. Comparative tests were done to determine which variables have the greatest impact on the energy consumption and thermal comfort in the classroom, and how their absolute influence depends on the order of implementation of each improvement. A complex interdependence among the design variables was found, but strong conclusions for energy savings could still be reached.

It is observed that a well-designed classroom uses less artificial lighting and the children can benefit from daylight almost all year round. A reduction in the use of artificial lighting also contributes to a reduction of heat loads and therefore a more comfortable place for children. Moreover, the use of daylight will have a positive influence on the performance of the children in the classroom. The use of a mechanical ventilation system in the improved classroom enhances the performance of it. Since the heat loads are clearly high in the room, the energy needed for heating is reduced if the woodworks are changed in the improved classroom. These conclusions emphasize that implementing these design recommendations in schools in the hot–humid climate will not only obtain a significant reduction in the energy consumption, but will also improve the performance of the classrooms.

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