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Energy Efficiency in a Municipal Building
Case Study: "Casa da Cultura de Coimbra"

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Abstract. The aim of this paper is to present the main results of an energy audit that has been conducted in a Portuguese municipal building during 2009. The adopted methodology for analysis the energy flow in the building for energy saving and rational use of energy in municipal buildings can be applied to all municipal buildings. Besides the main results of energy analysis, the paper presents the identified energy efficient measures to reduce energy consumption (with positive impact on the energy bill and greenhouse gas emissions), while maintaining or improving human comfort, health and security. The evaluation of measure's impact is also presented.

Key words

Energy audit, Energy efficiency, Energy management, Municipal Buildings.

1. Introduction

The increase of the earth's surface temperature has been a great concern both nationally and internationally over the last few years. During the last century human activity has caused an increase in the concentration of greenhouse gases, which has resulted in a significant increase in the average global temperature. This, in turn, causes melting of the polar ice caps, which results in rising sea levels and possible flooding in low areas.

With the signing of the Kyoto Protocol, Portugal agreed to limit the growth of greenhouse gas emissions by 27% between the period of 2008 and 2012, relative to the values from 1990.

Being that carbon dioxide (CO_2) is one of the most common greenhouse gases and results primarily from the burning of fossil fuels for the production of electricity, the Kyoto Protocol agreement stated that certain criteria were to be met in energy efficiency. Included was a reduction in the consumption of energy, which would contribute to the reduction of greenhouse gases.

In Portugal the public buildings sector is responsible for almost 17% of the total consumption of final energy (from a total of 30% of buildings in general) and for 33% of the consumption of electricity (from a total of 62% of buildings in general) [1].

In public buildings, the implementation of energy efficient measures can significantly reduce energy consumption, the energy bill and greenhouse gas emissions, while maintaining or improving human comfort, health and security. For the identification of energy efficient measures its necessary to analyse the energy flow in the building, one of the main objectives of the energy audit.

In this paper we present the main results of an energy audit that has been conducted during 2009 in a Portuguese municipal building, "Casa Municipal da Cultura de Coimbra" (Municipal Cultural Centre), the energy efficient measures identified and the evaluation of measure's impact.

2. Energy Audit – main results

An energy audit can be simply defined as a process to evaluate where a building or plant uses energy, and identify opportunities to reduce consumption [2].

As in similar studies [3]-[5], and according to some guidelines referred in [6], the adopted methodology for the energy audit involves: analysis the energy flow in the building; identification of energy saving opportunities; evaluation of measure's impact and, when possible, establish a plan for implementing energy saving projects.

This section is divided in three parts. In the first one it is described the Coimbra Municipal Cultural Centre

location, purpose and utilization. In the second part is presented some results related with the building energy use and part three presents the energy efficient measures identified and the evaluation of measure's impact.

A. Municipal Cultural Centre

The Municipal Cultural Centre is located in Coimbra, a medium sized Portuguese city and is mainly dedicated to local public providing access to a library, cultural events, arts and entertainment.

The building has 7 floors occupying a total area of 9800 square meters. Figure 1 presents a general view of the Coimbra Municipal Cultural Centre.

In this building 80 employees work daily and the number of visitors per year are about 17 500. The building's timetable is from 9:00 AM to 19:30 PM, except Sunday and public holidays. On Saturday the building opens at 14:00 AM and closes at 19.30 PM.

Fig. 1. General view of the Coimbra Municipal Cultural Centre.

B. Building energy use

The figures presented in this section refer to the main results carried out during the energy audit conduction.

Electricity is the only used energy source in the building. This is a very comfortable energy source to use and has been also a cheap one. The building is supplied at medium voltage (15 kV) and the transformation to low voltage is made in a private transformer station located in the basement. The transformer is oil cooled and has an apparent power of 630 kVA. The building has a General Low Voltage Framework and 21 Low Voltage Switchboards.

The Coimbra Municipal Cultural Centre had in 2008 an annual electricity consumption of 642 157 kWh, which correspond to approximately 186.2 toe (tones of oil equivalent). Some energy indicators have been calculated, namely annual energy consumption per square meter (0.01378 toe/m².year) and annual energy consumption per *capita* (0.0078 toe/*capita* year).

Figure 2 depicts monthly electricity consumption values per tariff period and monthly peak power. According to Portuguese electricity tariffs, tariff periods considered are: peak period (Wp); full period (Wc), off-peak period (Wv) and special off-peak period.

As expected, the most electricity consumption occurs during full tariff period (63 %). Since the building is closed during off-peak periods, the electricity consumption is lower at this time.

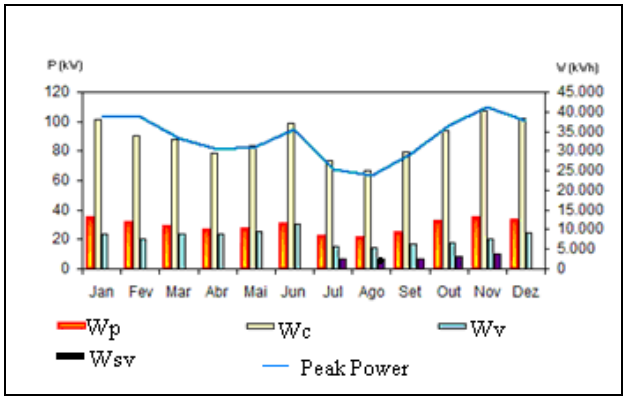

Fig. 2. Monthly electricity consumption values per tariff period and monthly peak power.

The relative importance of the different service's electricity consumption it is shown in figure 3. The sectors considered are: lighting, restaurant, computers, heating and air-conditioning systems (AVAC) and other equipments. It can be seen from figure 3 that lighting represents the greater fraction of global electricity consumption.

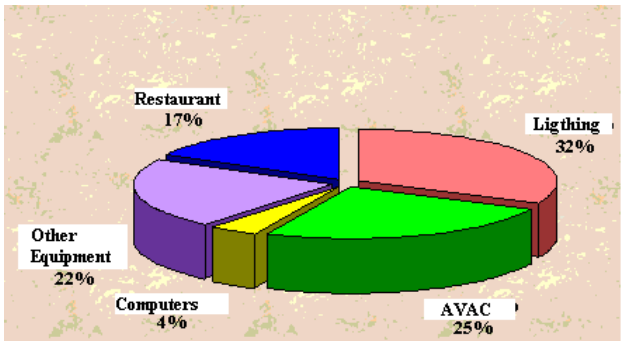

Fig. 3. Relative importance of the different service's electricity consumption.

With the power quality analyzer that can be seen in the figure 4, consumption data have been collected to obtain electric load diagrams of the building. Load patterns contain valuable information that the simple accumulated values of energy consumption are unable to provide. Among other things, with the help of load diagrams it is possible to establish average patterns of load demand, to identify maximum demand values and their time of occurrence, to assess the effectiveness of the use given to the capacity resources available and to better identify efficient energy measures.

In figure 5 are represented the global load diagram. Data have been collected during five days (from 18 to 22 of June), including Saturday and Sunday.

Fig. 4. Collecting data with power analyser.

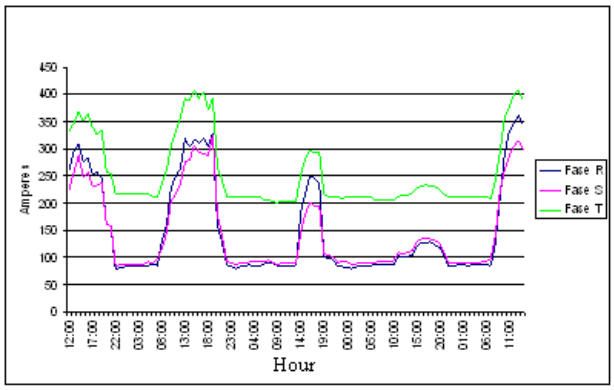

Fig. 5 Global load diagram.

From the load diagrams it is possible to obtain some global characterization indices. In figure 6, load factor and installed power utilisation are presented.

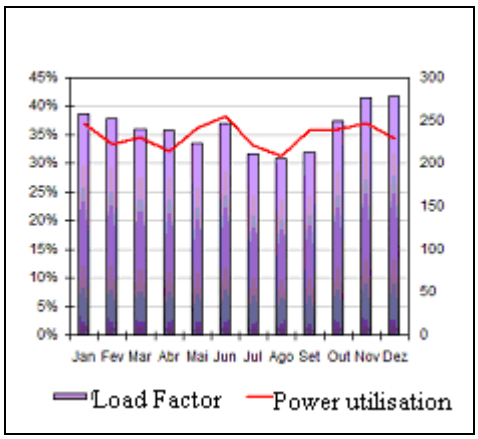

Fig. 6 Numerical indices obtained from the load diagram.

As verified from figure 2, where we can see the distribution of monthly electricity consumption per tariff period, the major electricity consumption occurs during full tariff period and it is lower during off-peak periods. However, the electricity consumption during this period, corresponding to the building's closure, presents unexpected significant values. The present situation clearly suggests that measures should be taken in order to identify consumers during off-peak periods.

Load factor never exceeded 42 % and the annual average is 36 %. These values are appreciably low, rising the possibility of a good potential for load shape alterations in order to improve the rational use of available resources.

Lighting typically accounts for a significant portion of electrical energy consumed in municipal buildings. Energy is saved and electric demand is reduced by reducing illumination levels, improving lighting system efficiency, curtailing operating hours, and using day lighting.

Reduction on lighting levels without danger to visual comfort and worker performance would save energy directly and by reducing air-conditioning loads. For this purpose, data referred to lighting technologies and illumination index have been collected.

Fluorescent lamps are the most common lighting technology used for interior lighting in this public building, with the exception of sanitary facilities and some rooms with double right foot, where lighting is provided by incandescent lamps and halogen lamps, respectively.

Figure 7 depicts the variation of illumination index for the library for three different days: on March 21, June 21 and December 21. The library is located on the ground floor and has an area of about 380 square meters with a double right foot of 5.80 meters. The room has 10 rows with 17 sets of simple luminaries equipped with 58 W tubular fluorescent lamps and electromagnetic ballasts, in a total of 170 units, without any lighting control equipment.

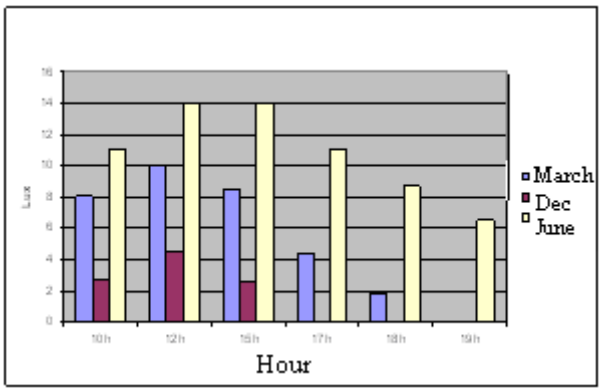

Fig. 7 Illumination index for the library.

C. *Energy Efficiency Measures*

A list of recommended energy saving measures is provided, aiming at increasing the energy efficiency of the building as a whole and reducing the energy costs.

The measures recommended for implementation were categorized in terms of ease and cost of implementation and included the following:

- Optimization of the contracts with electricity supplier;
- Replacement of low efficiency with high efficiency lighting (compact fluorescent lamps, electronic ballasts, lighting control equipment) for different spaces;
- Different thermal regulation for different space utilization;
- Use of motion detectors.

The cost reduction associated with the optimization of the contracts with electricity supplier is about 1700 €/year and has no investment costs. However, this measure does not correspond to any energy save.

Some measures of technology replacement for interior lighting will concern:

- the replacement of TL-D Standard lamps by TL-DECO, in different rooms;
- the replacement of incandescent lamps by compact fluorescent lamps;
- the replacement of electromagnetic ballasts by electronic ballasts;
- the installation of lighting control equipment.

The total of measures identified for interior lighting correspond to an investment cost of 23 648 € and to a reduction of electricity consumption of about 60 000 kWh/year.

For outdoor lighting we propose the replacement of 100 W incandescent lamps by 20 W compact fluorescent lamps, in a total of 29 units. The total implement cost of this measure is 203 € and the expected annual energy reduction is about 8500 kWh.

From the evaluation of measure's impact, namely in terms of cost and consumption reduction, the implementation of all the measures evaluated will resulted in a reduction of electricity consumption in the building of about 68000 kWh and a total annual cost saving of around 8 700 €.

3. Conclusion

From the results presented in the previous sections we can conclude that, in fact, Energy Audits, identifying potential measures to save energy and to "pay back" the short and medium term, with analysis as simple as checking the best tariff options and/or analysis of the powers engaged, which can result in significant annual cost to the energy, without any investment.

Lighting is another of the aspects that deserve a thorough investigation because in fact there are now on the market more efficient technologies that allow us to keep the same levels of illumination, but with significant reductions in consumption.

The transfer of consumption to time schedules more economically advantageous. Transfer of consumption in Air-conditioning, does not only reduce the direct costs of energy, but also reduce the cost of peak performance, which is currently significantly penalized at the level of tariffs.

The implementation of the measures identified, will produce an annual reduction in consumption of about 68 000 kWh, which environmentally is to reduce annual carbon emissions of about 32 ton CO_2 eq. With the implementation of the measures presented will be an annual saving of around 8700 €.

Acknowledgement

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