Energy Characterization, Methodology and Results for a University Public Building

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***Abstract*—this paper presents the methodology and results for the energy characterization at an educational public building located at Bogota. This building belongs to the tertiary sector, it mainly has offices and classrooms and the scope of the paper shows the methodology and results of its energy characterization from the view of Energy Efficiency. It presents its current energy situation, identify areas of opportunity and give the main energy saving goals, as well energy indicators are shown for comparison and monitoring of building energy efficiency.**

***Index Terms*—Energy efficiency, public building, energy characterization, saving opportunities.**

I. Introduction

Climate change is a main problem currently in the world; it is directly associated to environmental pollution due to the emission of greenhouse gases resulting in a large proportion from the use of fossil fuels [1]. Increasing energy costs is also a good reason to give importance to the research on sustainable living and renewable energy issues [2].

The great potential of energy efficiency improvements in all stages of production and use of energy is widely recognized, but reaching that potential remains a challenge almost worldwide. For that reason, numerous energy efficiency action plans are under implementation at different levels. The tertiary sector is one of the largest electricity consumers with 25 % of total consumption of electrical energy for the year 2009 in Colombia [3], that is why is to ensure a higher energy and environmental efficiencies [4].

Investments in the educational sector are often scare and the budgets of public educational institutions are tight [5], therefore energy efficiency could play an important role in saving operational costs for those institutions and also as tool to become more efficient in the use of their resources, developing demonstrative initiatives and given students education with real life cases [6].

II. Energy Efficiency

Energy production and consumption have shown and increasing rate of growth during the last decades and this tendency is expected to continue. All forms of energy consumption have impacts on the environment and health as well as in the different processes and their performance. Energy efficiency is important to society, both industrialized and developing countries have plans to decrease the consumption maintaining the same services and performance in the buildings, without a negative impact on the quality of life [7], and also protecting the environment, due to CO_2 emission decrease and sustainable use of natural resources.

Energy efficiency is also a tool for becoming more competitive, and in the case of the public sector were the profit is not the main goal it could represent lower operational costs, and therefore available budget for other investments [8].

The electric projects developed in existing buildings should consider energy technologies to renew the equipment with energy efficiency concepts such: energy management, maintenance of energy consuming equipment, the implementation of energy saving measures and use of renewable energy [9]. With the existing technologies, it is possible to obtain significant efficiency improvements in buildings without decrease the levels of safety and comfort. With this purpose it is necessary to identify the final uses that the energy have in the building as well as the equipment using this energy in order to determine whether they are adequate or efficient [10]. Because there is equipment for lighting, air conditioning, refrigeration and computing that can achieve very high efficiency with the appropriate selection [11], it is important not only to take into consideration the fact that efficient equipment that currently exist in the market can appear to be costly due to the initial investment but also to evaluate the options with a financial analysis.

Energy efficiency has alternatives for comfort, economic and energy savings. Some energy efficiency solutions are the automation processes, technological changes, energy management, user awareness of end-use equipment and detailed architectural design for sustainability [12].

Building automation is a key part of energy efficiency, for example a building could have electrical energy savings between 10-40% in the commercial sector, by closely monitoring and supervising the use of energy and electrical parameters [13], Automated processes provide low power consumption, maximum user comfort, energy and cost savings at the same time [14].

III. Methodology

The present work consists essentiality in the evaluation of the energy situation of one of the buildings of the 'Universidad Distrital Francisco José de Caldas', located at Bogotá - Colombia. The study of educational buildings has a great importance, not only because the large number of buildings in Bogota and in the country, but also due to their high-energy consumption, often with low efficiency. Educational sector presents an interesting opportunity to increase public awareness regarding energy efficiency and environmental conservation since its "users" are generally young population, in the process of academic training and are therefore more aware of these issues. The building under study serves currently to about 3000 students and it is an old building with more than 50 years of construction. Besides classrooms, it has offices for research and administrative purposes and service areas such as halls and restrooms.

Public buildings have different energy requirements to those used in the residential or industrial sectors, for that reason it is important to have some considerations in the energy characterization, some differences are: load profiles, consumption value, people habits, final energy uses and equipment used.

Some public sub-sectors are:

- Health
- Administration
- Education

To determine the energy characterization of this educational building it was necessary to follow some steps, first to establish the characterization by means of identifying the main consuming equipment and the historical energy consumption, then to build and analyze some indicators and finally to propose some recommendations to improve the current energy situation of the building. To perform the characterization it was necessary to have different information as: lighting measurements, electricity bills, inventory of different installed loads, habits of consumption, etc.

Energy management is an important tool to achieve high energy efficiency for this purpose it is necessary to build energy indicators, which in this case were constructed based on the current state of energy consumption, installed power and the time of use for each load. This construction of indicators was the second step and finally recommendations were given.

A. Energy Characterization

The information of energy consumption was taken from the electricity bills during the period July 2010-December 2012. In this period there were changes in the value of the energy consumed; due mainly to the holiday periods and installation of new equipment, the consumption is shown in figure 1.

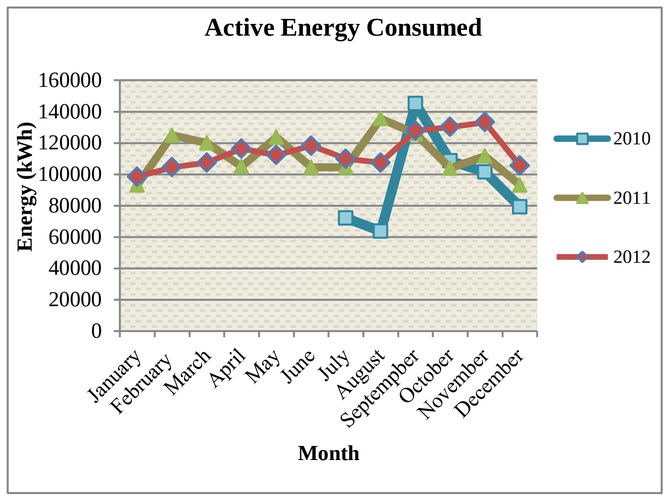

Fig. 1 Energy consumption July 2010 - December 2012

In the period of time analyzed the average monthly consumption was 109540 kWh, the minimum monthly consumption was 63600 kWh, happening in August 2010 and the maximum monthly consumption was 145200 kWh which occurred in September 2010.

The total cost of energy during the analyzed period was COP$ 912,527,037.

Considering an emission factor of 120 g CO_2 / kWh due to energy consumption as indirect emissions given for the electricity sector [15], the average monthly emissions were 11.4 tons of CO_2, in 2011 reached 13.45 tons of CO_2, both values lower than in than in 2012 when monthly emissions accounted for 13.71 tons of CO_2. Throughout the period emissions were 394.3 tons of CO_2,

Thereafter the consumption curve and the statistical analysis was done, then the installed power was calculated for each type of equipment; the methodology used to know the installed power was the inventory of all building loads, the results are shown in the figure 2.

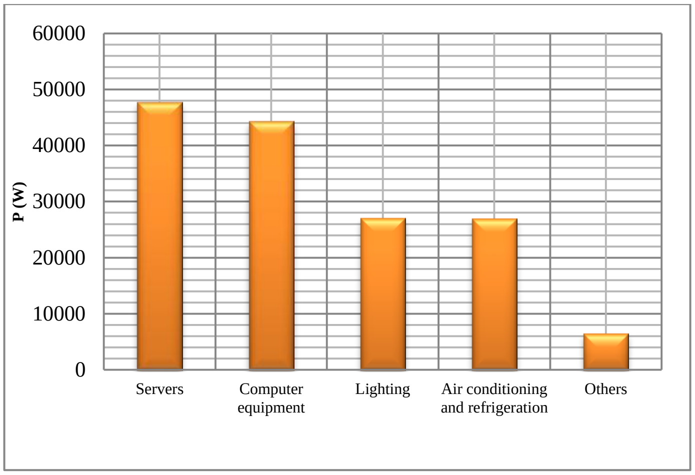

Fig. 2 Installed power

The building has installed different equipment in classrooms, offices and rooms, these spaces have a power consumption for specific uses such as: lighting, computer equipment, data centers, air conditioning (AC) and cooling; besides there are other important energy equipment as water pumps, televisions and ovens, the consumption distribution is shown in the figure 3, taking into account the time of use for each load.

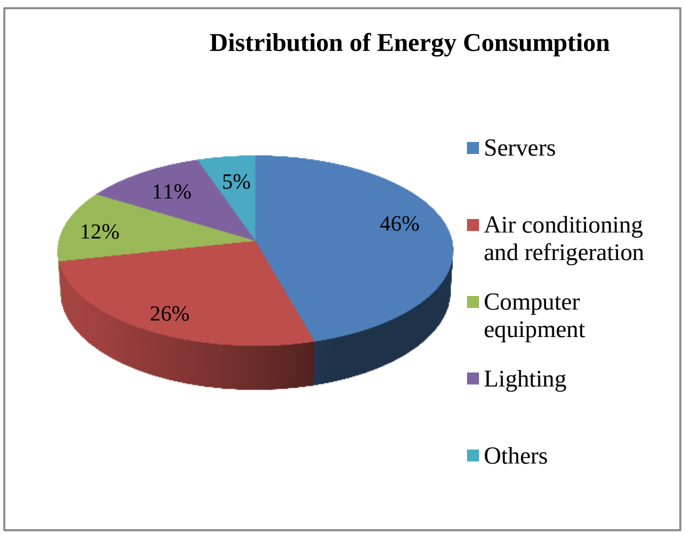

Fig. 3 Distribution of energy consumption

The maximum percentage of consumption is for servers, which consume 46 % of total building´s energy and most air conditioning equipment is used in the servers, but both servers and air conditioning of data center are not potential for savings because they have high efficiency with smart power consumption technology. Computer equipment and lighting together account for 23% of total energy consumption and their installed equipment have low energy efficiency, currently there are better technologies to reduce energy consumption and improve their energy use.

B. Indicators

After the energy analysis and the characterization were done, the next step was to define and analyze some indicators; this was done focused on identifying energy savings. Indicators are a tool to identify opportunities and monitor results of future implementations, since they gave the base line to evaluate future improvements and to reduce energy consumption mainly due to technological and culture changes.

It is necessary to select suitable indicators to be compared with the efficient case obtained of simulations and projections, some indicators could be related with lighting efficiency and quality, installed power, energy consumed per person and per m^2, occupancy per room, CO_2 emission per month and others. In order to keep control of the indicators and monitoring installed power and energy consumption they were classified in different levels according with their relevance, this criteria was chosen taking into consideration those parameters that present more importance in the energy efficiency context such as energy consumption (level 1) while those that are complementary such as emissions (level 4) the classifications shown in table I.

TABLE I
ENERGY INDICATORS

Indicator	Unit	Value
Level 1		
Energy consumption index per floor	kWh/mes-m²	
Floor 1	kWh/mes-m²	60.39
Floor 2	kWh/mes-m²	4.81
Floor 3	kWh/mes-m²	7.54
Installed power index per floor	W/m²	
Floor 1	W/m²	116.64
Floor 2	W/m²	25.73
Floor 3	W/m²	30.11
Level 2		
Energy consumption index per application	kWh/mes-m²	
Servers	kWh/mes-m²	11.47
Computer equipment	kWh/mes-m²	3.05
Lighting	kWh/mes-m²	2.76
Air conditioning and refrigeration	kWh/mes-m²	6.52
Others	kWh/mes-m²	1.33

Installed power index per application	W/m²	
Servers	W/m²	15.93
Computer equipment	W/m²	14.05
Lighting	W/m²	10.71
Air conditioning and refrigeration	W/m²	10.92
Others	W/m²	7.34
Level 3		
Energy consumption index by total area	kWh/mes-m²	25.13
Installed power index by total area	W/m²	58.94
Level 4		
Index of CO_2 emissions by total area	kg CO_2/mes-m²	3.02

The above indicators allow comparing the technological level of the building, which is based on equipment type used and the efficient equipment commercially available. All of these indicators are related to power consumption, also consumer habits and schedule regimen involving the energy indicators, in order to manage these indicators it is needed to have meters strategically located in the areas and identified processes that involve each indicators proposed in table 1.

The constructions of these indicators not only allow comparing internally the level of efficiency and improvements that are made, moreover it allows making comparison with other buildings whose activities are related to education and have similar construction features.

All the indicators of level 2 have relatively high values taking into account that there is more efficient equipment available in the market, so the value of the proposed indicators can be reduced by implementing saving measures and energy efficiency in equipment and also improving consumer habits.

C. Recommendations

Finally, after the analysis of the characterization and the indicators some recommendations were given, in order to improve the energy use in the building, reduce the electricity bill, demonstrate possible energy efficiency actions in public buildings and increase public awareness. Following are shown a list of potential economic and energetic savings.

1) Electric System

   Replacing pumps: The pumps that are being used are obsolete.

   Installing a KNX: Standard for centralized control of all equipment in a building.

2) Computer Equipment

   Change CRT monitors to LED Monitors: There are still offices with CRT monitors, these devices have higher energy consumption than LED monitors.

3) Lighting

   Replace fluorescent lamps for higher efficiency lamps: Almost all areas of the building have low-efficiency lamps and when they require replacement it is done with devices of the same efficiency characteristics.

   Install dimmer light: The building has classrooms and offices with natural lighting; for that reason it is recommended to install an automatic control of luminous flux.

   Install timers: Currently in the building manual switches are used in bathrooms.

4) Consumer habits

   Training on energy saving: Organize courses to teach about energy savings and energy efficiency.

   Awareness program: Perform an energetic culture campaign with people working and using the building.

Some recommendations listed above have return periods of over five years as replacement of fluorescent lamps for higher efficiency lamps, therefore in this case is recommended a gradual replacement when damaged.

With the implementation of the proposed saving measures it can be achieved an energy saving of 75625 kWh per year accounting for an economic savings of $21,822,496.39 COP per year.

IV. Conclusions

Public buildings have great potential for energy efficiency, but it is necessary to carry out studies in order to characterize the consumption identify the indicators and propose feasible recommendations.

There are different solutions for efficient energy management in buildings, some solutions are associated with automation processes, the actions should be oriented to install equipment for real-time monitoring of consumption and comparing energy indicators, since it is one of the steps to implement an energy management system.

In order to improve the energy efficiency it should be considered the monitoring of indicators to follow up on energy consumption; there should be goals in order to lower the value of the measured indicators, these goals could be achieved if the given recommendations are implemented.

The educational building studied has an energy saving potential of 75625 kWh per year equivalent to 9.12 % of its total annual energy consumption; this represents emissions savings of 9.07 tons of CO_2 per year.

Each recommendation should be evaluated in terms of its technical and financial feasibility, in order to develop a road map of energy efficiency actions.

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