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ENERGY EFFICIENCY IN A PUBLIC BUILDING: AN ANALYSIS OF THE POSSIBILITIES

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ABSTRACT

The recent water crisis with severe impacts on hydroelectric generation - the main source of the national energy matrix - and the worsening economic crisis require efficient solutions to reduce public expenditures with electricity consumption. This article addresses this issue with the general objective of identifying the opportunities for increasing energy efficiency (EE) in a public building, with specific objectives: to map present energy losses; to point out the potentialities of energy improvement, taking into account the lower cost-benefits in implementing the necessary actions; and to evaluate the institutional difficulties to execute the public policies destined to this end. The case study was developed in a public institution, through an applied research that used a quanti-qualitative approach, and the instruments used were: tools for measurement of electrical parameters, documentary analysis, structured interview and direct observation. The results of the study indicate that lighting and air conditioning systems are the major energy consuming sources in the building and point out the potential possibilities for reducing energy consumption in the building case.

Keywords: Energy Efficiency; Energy Losses; Public Buildings.

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1. INTRODUCTION

According to the National Energy Balance (Energy research company, 2015), hydroelectric plants currently account for 65.2% of electricity generation within the Brazilian energy matrix, and yet represent only a third of the available national hydraulic potential.

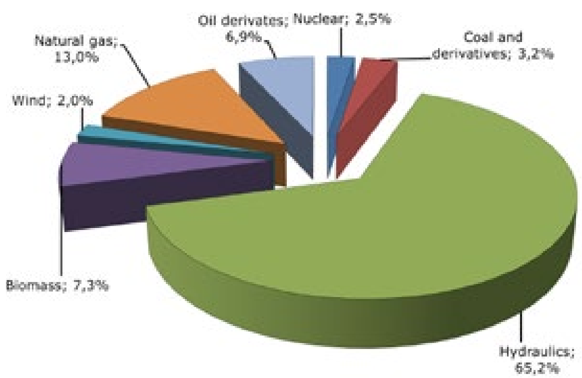

Figure 1. Domestic supply of electricity by source in Brazil
Source: National Energy Balance - BEN (2015, base year 2014)

Cirilo (2015) points out that in 2011 the most severe drought period of the last 60 years was possibly initiated, which aggravates the dispute over the use of water resources for human supply, agriculture and electricity generation. The alternative presented by the federal executive branch, in order to guarantee the demand for electricity, has been the activation of expensive and polluting thermoelectric power plants, fueled by fossil fuels.

This fact would be enough to justify efforts to implement solutions capable of increasing energy efficiency (EE) in public buildings in the country. In addition, neglecting the possibility of contributing to the balance of public accounts, through efficient energy consumption, collides head-on with the harsh reality of the national economy, evidenced by the strong contraction of the Gross Domestic Product (GDP) in the biennium 2014-2015 (IBGE, 2016) and the consequent fall in tax collection, which strongly pressured public budgets in the three spheres of power.

The bureaucratic and legal obstacles that appear in the path between intention and action are the main challenges for those who embrace EE's cause within Public Administration. The existence of adequate legal instruments does not guarantee its effective application, although there is no doubt about the importance of the principle of economicity as a pillar of support for an efficient Public Administration. The erroneous and limited interpretation of these instruments has inhibited public actions for more sustainable and efficient constructions.

By efficiently managing energy consumption in public buildings, especially impacted by air conditioning and lighting systems, social responsibility is valued with public spending, reinforcing the influence of the public sector as an opinion maker. In contrast, initiatives in this field are generally not supported by tools used in public management, leading to the discontinuation of any measures implemented.

The production of scientific knowledge about EE in public buildings permeates all the axes of the tripod of organizational sustainability, be it social, economic or environmental. When analyzing the opportunities and barriers to the implementation of EE policies in public buildings, it is necessary to consider, among other aspects, the structural characteristics of buildings and the behavior of their users, including the floating population.

This article approaches the exposed scenario, with the general objective of identifying the opportunities of EE increase in a public building in Paraíba, with specific objectives: to map the present energy losses; to point out the potentialities of energy improvement - taking into account the lower cost-benefits in implementing the necessary actions; and to evaluate the institutional difficulties faced in the execution of the public policies destined to this end.

2. METHODOLOGY

The research was structured based on a literature review on EE, energy losses and EE public policies in its buildings. Afterwards, the characterization of the building object of the research was made, and finally, the identification of the possibilities of improvements in EE under the point of view of the energetic losses in the dimensions of lighting, air conditioning and energy management.

In the elaboration of the study, the methodological procedures adopted regarding nature were those of applied research, with the purpose of generating scientific knowledge for practical application. We opted for a quantitative-qualitative approach in the exploratory modality, through the collection of data on the subject addressed, in order to support further studies in the future. The research proposes to describe facts and phenomena in the search for the establishment of relations between the analyzed variables.

As for the field of research, the study was developed in a public building in the state of Paraíba. The choice of the institution was based on the accessibility available by the institution under study and on the interest of the managers of the public agency in the establishment of the partnership with the university, aiming to allow the professional, cultural and social improvement of the researchers.

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The research instruments used in the study were: direct observation, documentary analysis, electrical parameters measurement tools and structured interview through the application of a questionnaire.

Timely, it should be emphasized that the construction of the text by more than one author proves to be advantageous, insofar as it aggregates perceptions of professionals of different technical backgrounds and different experiences.

3. ENERGY EFFICIENCY (EE)

The EE concept is associated with understanding the definitions of primary and secondary energy sources, energy losses and useful energy.

For Goldemberg *et al*. (2000), the primary sources of energy represent the set of energy sources made available directly by nature, covering the strength of water, wind, sun, sugarcane bagasse and even garbage, besides the chemical combustion of certain elements present in nature, such as oil, coal, uranium ore and natural gas, to cite the most widely used. Secondary sources are the result of some process of transformation of the primary sources, which convert them into a more appropriate form for consumption.

However, part of the energy is lost during the transformation process due to the inadequate consumption of the secondary sources by the productive systems, either in the supply of some product or in the provision of some service. The resulting difference between the amount of energy delivered by the secondary source and the losses is called the useful energy of the energy use chain. Therefore, It is evident that absolute EE is unattainable, for it would be necessary that all useful energy be exactly equal to primary energy, but in any and every productive process some loss is present. Figure 2 shows the path traveled between primary energy sources and the provision of energy services.

One of the ways to increase EE is by reducing technical inefficiencies throughout the process of transforming primary sources into secondary sources, which reduces the economic impact of any production system, but can also result in a better organization, conservation and energy management of the entities that make up this chain. Other forms are reflected in the reduction of losses in the use of energy by equipment and appliances, as well as waste containment, through the change of attitude of users of energy services.

4. ENERGY EFFICIENCY IN PUBLIC BUILDINGS

One of the ways in which public management is able to demonstrate conformity between the discourse of administrative efficiency - the Constitutional Principle of Public Administration (CF/88, article 38) - and the concrete action is through the permanent search for EE in its buildings.

Several countries adopted EE programs in public buildings, as exemplified in Table 1, because of the important strategic role played by public management in a globalized and increasingly competitive market.

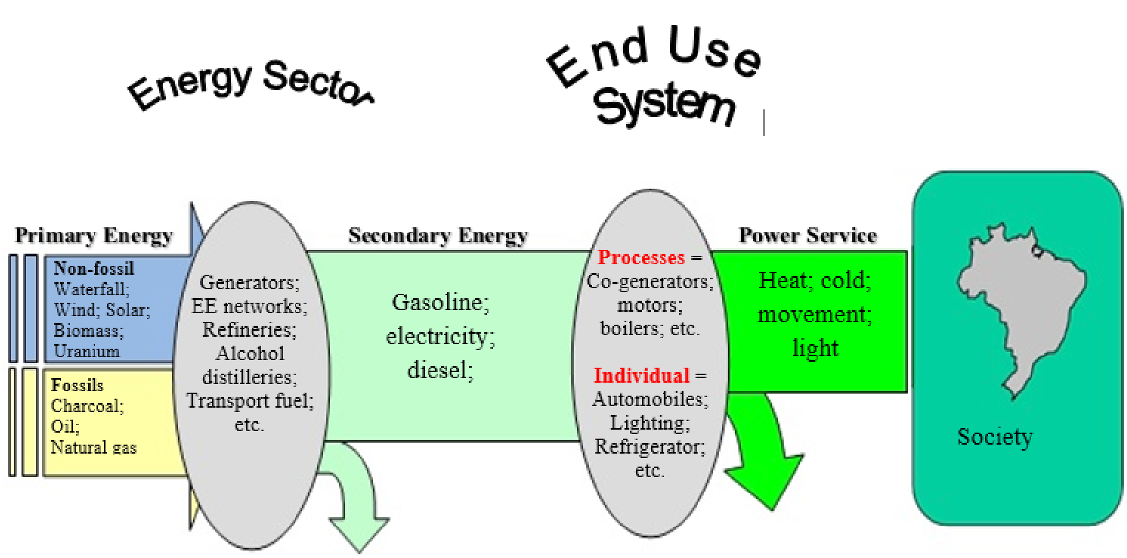

Figure 2. Energy use chain
Source: INEE (2001)

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Table 1. Energy Efficiency Programs adopted in other countries

Country	Program
United Kingdom	Independent, paid certification recognizing the reduction of energy use in public and private sector organizations (Energy Efficiency Accreditation Scheme (EEAS)
France	Directorate-General for Energy and Raw Materials (Direction Generale de l´Energie et des Matieres Premieres - DGEMP), responsible for defining energy policies, as well as guaranteeing the supply of mineral resources
Germany	German Energy Agency (Deutsche Energie Agentur - DENA), responsible for the “Energy Performance of Buildings Program”
United States	Energy Services Performance Contracts (ESPC), a program that includes a reduction of energy consumption in public buildings, introduced in the 1970s in the Federal Energy Program (FEP)
Portugal	Program for Energy Efficiency in Buildings (P3E), promoted by the Direção Geral de Energia e Geologia (DGEG - General Directorate of Energy and Geology), with the mission of contributing to the design, promotion and evaluation of policies related to energy and geological resources

Source: Adapted from the National Energy Efficiency Plan (Brazil, 2011)

In Brazil, programs such as the Conservation of Electric Energy (PROCEL), implemented since 1985, seek to work on the demand side of electric energy precisely with a way of meeting the need to increase EE in end uses without, however, compromising the habitability conditions of the building, maintaining adequate levels of provision of public services.

In addition, the Brazilian government enacted Law No. 10,295/2001 (Energy Efficiency Law) and the extension of PROCEL from the creation of the subprogram PROCEL Builds, motivated by the energy supply crisis in 2001. Estimates of this subprogram point to a potential of, approximately, 30% reduction in the energy consumption of lighting and air conditioning systems, as well as possible interventions in the envelope of existing buildings (Brazil, 2011). Considering that there were 69.15 thousand units consuming the public service, according to the *Sistema de Apoio à Decisão* (SAD - Decision Support System) of the *Agência Nacional de Energia Elétrica* (ANEEL - National Electric Energy Agency), with updated data until February 2012, it is observed that there is an extraordinary potential of reduction in the consumption of electric power by the public power (Brazil, 2012).

5. CHARACTERIZATION OF THE PUBLIC INSTITUTION

The case study on EE was carried out in a public building and the research findings can contribute to the definition of practices of sustainability, rationalization and conscious consumption of electric energy, in addition to alignment with the strategy actions to reduce the cost of energy consumption power.

Most work environments have white brick walls and bright light partitions, in addition to keeping windows with closed curtains, to block the direct incidence of the sun’s rays and, consequently, to avoid raising the temperature of the environment.

Thus, it is necessary to use artificial lighting with tubular fluorescent lamp bulbs, as can be seen in figure 3. It is observed that in some sectors the location of the bulbs does not favor the homogeneous distribution of the illumination, due to modifications made in the layout, involving the repositioning of workstations and partitions without, however, the corresponding alteration of the lighting system.

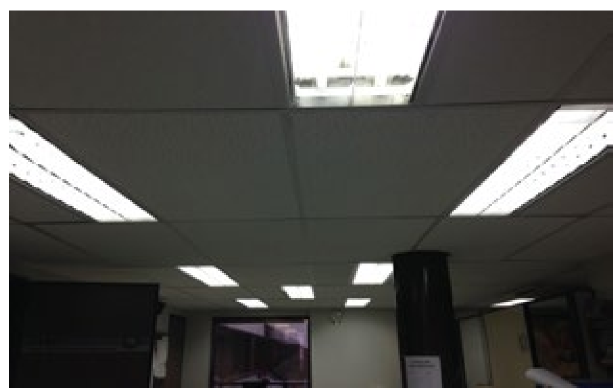

Figure 3. Lighting with fluorescent lamp bulbs
Source: Photographic record held on May 05. 2016

Regarding the air conditioning system, 7,500 BTU/h split air conditioners with PROCEL seal of class A energy efficiency are used in most environments, although split-type equipment with PROCEL seal of class C energy efficiency is still in use or old air conditioning systems of high energy consumption.

Due to the bureaucratic nature of the service performed, users use, throughout their workday, computers composed of a CPU, LCD flat monitors, a keyboard and a mouse, and the use of a stabilizer every two job posts. In contrast to this reality, each unit still has one or two printers.

For vertical displacement inside the building under study, there are four elevators that work throughout the working day.

Faced with a national scenario of energy crisis, in 2010 this institution launched an Energy Saving Program, with the purpose of disciplining the use of electric energy, among other inputs, with the implementation of detailed consumption control and containment measures in the table 2.

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Table 2. Main recommendations of the Energy Saving Program

Aspects of mandatory observation	Items for gradual replacement
Reduction of 50% of the lamps located in areas of circulations and facades	Incandescent and fluorescent light bulbs by LED (light emitting diode)
Shutdown of computer equipment when idle or when the user's absence exceeds one hour, including printers	High energy consumption equipment for low consumption (Category A seal - PROCEL) where possible
Prohibition of the use of adapters ("T" or "benjamin", as referred to in Portuguese), as well as restriction of the use of extensions to avoid the heating of the conductors and, consequently, the increase of the energy consumption or even the risk of accident	
Prohibition of the use of portable appliances, such as sandwiches, toasters, microwave ovens, televisions and coffee makers, except in the central cups, regarding the last item	
Disconnection of minibars, refrigerators, electric drinking fountains and ATMs (banking network) on weekends and holidays	

Source: Energy Saving Program

Although the implementation of the Energy Saving Program within the agency in question was an action of significant importance, there is no record of follow-up as to the quantification, effectiveness and continuity of recommendations and mandates determined by the aforementioned program.

6. ENERGY EFFICIENCY IN PUBLIC BUILDING

6.1. Analysis of the Electric Energy Bill

The analysis of the historical series of electric energy invoices allows us to identify the relationships between habits and consumption, useful for the planning of routines to fight against waste, besides setting the basis for economic evaluation. This critical assessment allows the verification of the need to correct the power factor and the revision of the tariff framework, with consequent determination of the value of the contractual demand.

With a view to a better presentation and analysis of the data of the consumption of electric energy, a graph was drawn showing the energy consumption during the 12 months of 2014 and 2015 and the first quarter of 2016. It is noticed that, although consumption in the year 2015 follows the same tendency of seasonal variation, it grew in every month in relation to 2014. It is recorded that the reduction occurred in the months of February and March of 2016 was mainly due to the change of the building's operating hours.

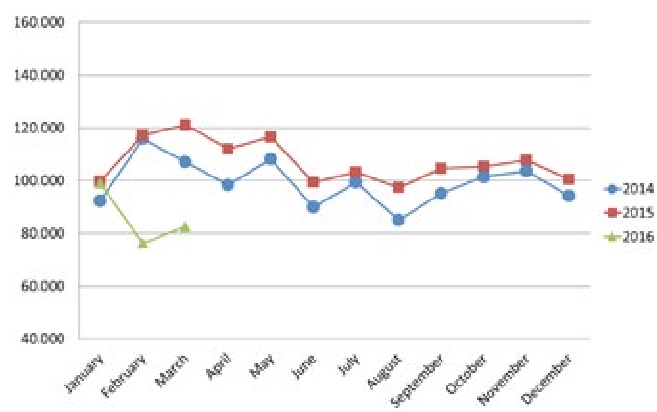

Figure 4. Historical consumption in the period from 2014 to 2016 (kWh)

Source: Electric energy bills issued by the Energisa concessionaire (2014), (2015) and (2016)

The monitoring of the evolution of the consumption in the peak hours, after the change of the working day is essential. From these data it is possible to carry out studies to change the hiring modality, verifying the hypothesis of migration from the hour-seasonal green to hour-seasonal blue mode, which guarantees the inclusion of Peak-Hired Demand. This information provides a basis for changing the tariff system and it should be obtained from the historical series of, at least, six months of consumption, since, after contracting the value of the demand, it can only be changed after twelve months.

In order to analyze the history of consumption, it is essential, however, to understand the causes of variation of consumption in relation to the months of the year, for this purpose one should select some monthly consumption sources such as, for example, the number of users in the performance of their functions, number of working days, number of visitors (floating population) and quantity of new equipment installed.

According to the Energy Pre-Diagnostic Manual (2010), it is necessary to analyze the Load Factor (FC), a non-dimensional index that informs if the company is rationally using the energy it consumes by means of the ratio between active energy consumption and the demand for power in a given period of time, with a variation between 0 (zero) and 1 (one): the closer to the unit the better is the use of the available power. Calculating this index with

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the consumption data of the institution under study, we obtained a mean Load Factor at peak times, in the last 27 months, equal to 0.59, and a Mean Load Factor at off-peak hours, in the last 27 months, equal to 0.37. To improve this index, it is generally suggested to conserve consumption and reduce maximum demand.

Through the analysis of the invoice, it is observed that surplus reactive energy is being collected since November 2014. This expense could be reduced or even eliminated from the correction of the power factor of the installation, a parameter that reflects the relation between the active energy (actual energy producing work) and the total power (or apparent power) of the circuit. According to Resolution 456, of November 29, 2000, of the National Agency of Electric Energy (ANEEL), the electrical installations of the consumers must have a power factor of not less than 0.92 (capacitive or inductive). When the “power factor” is less than 0.92, the use of energy and reactive power demand in the electric energy bill is charged, such as Excessive Reactive Energy Consumption and Excessive Reactive Demand. Unfortunately, the value of the power factor is a data not obtained in this study, because it was not informed in the invoice issued by the local power company.

With regard to the equipment used in the substation, the Energy Pre-Diagnostic Manual (Guilliod *et* Cordeiro, 2010) recommends analyzing the possibility of dividing the installed loads uniformly between the transformers, in order to establish adequate loading levels for both and check whether the installation is operating with a transformer with load above its nominal capacity or near it, and it is advisable to replace it with a larger capacity. Another action indicated to reduce the losses in the windings of a transformer consists in increasing the power factor of the set of loads that it feeds, amortizing the inductive component of the current and reducing the value of the current of the load.

Wang *et al*. (2015) point out the factors that influence energy consumption in public buildings, such as climate, urban microclimate, architectural planning, thermal performance of the building, type of construction and human use, highlighting the factors related to temperature and duration of work, as well as to assess the impact of the variation of the level of energy consumption between weekdays and weekends and the existence of a floating population.

6.2 Lighting System Analysis

According to Silva (2013), the determining factor in the efficiency of the lighting system is the type of lamp chosen to illuminate the environment, although this system is influenced by some external actions, such as: maintenance program of equipment and colors and materials used in the environment. Analysis of the energy consumption of the lamps can be performed by comparing the luminous efficiencies (lm.W) thereof, which comprises the ratio between the luminous flux produced by a source and the power consumed (watts). The calculation of the consumption of the illumination system is obtained by equation (1):

$$CSI=[(P1*n1)+(P2*n2)]*hora/dias*dias\ mês \quad (1)$$

In which,
CSI: consumption of the lighting system
P: Lamp bulb power
n: Number of lamp bulbs

Aghemo *et al*. (2013) state that the goal of the lighting system control strategy is to ensure adequate lighting conditions throughout working hours with reduced energy consumption; however, it must be carried out without impact on the comfort and physical and mental integrity of users. In this context, it is important to emphasize that the choice of the bulb must be made according to the degree of illumination required in NBR 5413 (ABNT, 1992), which requires for office work illuminance (lux), light flux incident on a surface divided by its area, between 500 and 1000 lux.

Robalinho (2014) points out measures for the improvement of lighting systems, among which are: replacing the existing lighting systems with other more efficient and low initial investment; replacing output or emergency LED signaling; ensuring that the switches are easily accessible and identifiable and that they correctly indicate the circuit over which they operate; using programmable timers; reducing lighting in passing areas; using automatic control and command systems in the lighting installations, allowing the level of illumination to be only the necessary for the activity developed, thus reducing energy consumption; installing light and motion sensors to control lighting in warehouses, storage rooms, meeting rooms and other areas with little traffic; and minimizing outdoor lighting.

It should be emphasized that the efficiency of the lighting system and consequent reduction of the thermal load of the environments generated by the heat dissipation of the lighting system results in a reduction in the consumption of electricity in the air conditioning system.

Therefore, it is possible to carry out the inventory of the lighting system in operation, covering information related to the installation site, type of luminaire, type of lamp bulb, type of reactor, number of reactors per luminaire, installed power and luminance produced, in addition to the quantity of bulbs in stock. These data support the analysis of the system efficiency and the economic feasibility of replacing the currently used technology.

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6.3 Analysis of the air conditioning system

The use of the acclimatization system has as conditioning factors the local climatic condition, the way of functioning and the layout of the building in relation to the segregation of the space in rooms with or without windows and incidence of solar rays, collaborating to increase the ambient temperature.

The Energy Pre-Diagnosis Manual (2010) indicates opportunities for improving the efficiency of air conditioning systems: keeping windows and doors closed, avoiding the entrance of external air into the climate-controlled area; limiting the use of the appliance only to occupied premises; avoiding the incidence of solar rays in the air-conditioned environment; cleaning the filter of the appliances periodically; setting the thermostat in summer to a maximum of 23° C; disconnecting the air conditioner in unused or long-term unoccupied environments; turning off air conditioning equipment at predetermined times; not obstructing the air circulation; checking thermostat operation; turning off the air conditioner on cold days and keeping ventilation only; turning the air conditioner on one hour after the start of the work and turning it off one hour before its end; repairing windows and doors that are broken or out of alignment; repairing leaks of air, water and cooling fluids; and verifying that the design of the equipment is in accordance with the thermal load of the environment and, if not, promoting its replacement.

Another possibility is the inventory of the operating air conditioning system, which includes information on the installation place, type of equipment, manufacturer, type of cooling fluid, age and capacity of the equipment, period of use and area served and the existence of equipment in stock. These data may support the analysis of the efficiency of the system and the cost-effectiveness of replacing the currently used technology.

6.4 Analysis of energy consumption management

Gaspar *et al*. (2011) point out as fundamental the issues related to the high cost involved in electric power generation, transmission and distribution and the efficient use of available energy, combined with the efficient management of the network. Moreover, González *et al*. (2011) propose that the adoption of tools for monitoring environmental indicators allows the organization to identify weaknesses and optimization potentials, define measurable environmental goals and objectives, seek continuous improvement and provide visibility and transparency to environmental performance. In this context, it is evident the need to monitor the consumption of electric energy as an environmental and economic indicator.

Liu *et al*. (2012) explain that there is a great emphasis on energy conservation by managers and the issuance of regulations to control energy consumption, contradictory elements regarding the obstacles of the lack of professionals with specialized EE training in public institutions and the lack of appropriate time in their work day to dedicate themselves to EE management. These authors also point out that, in public buildings, the consumption of energy is influenced by the lack of awareness of the users, because there is no relation between public spending and their remuneration/gratification.

Aghemo *et al*. (2013) point out that the provision of consumer information to users aims to achieve greater awareness, actively involving the user community of public spaces. Robalinho (2014) recommends as themes for awareness and training actions: environmental impacts of energy use, benefits of energy savings and individual civic attitude to save energy.

Although there is a monitoring flow to achieve greater efficiency, the Energy Management System (SGE) should be treated as part of the strategic planning of the institution and should be implemented based on the PDCA cycle, ensuring the search for continuous improvement and its constant reassessment. It is extremely important to carry out the usual survey and monitoring of the information in order to enable the knowledge of the opportunities for improvements in energy performance. In several institutions, this monitoring takes place through software purchased specifically for this purpose; however, in the case of the institution in question, while not acquired software or developed by the internal computer team, some data can be accessed on the platform provided by the local power utility itself.

The analysis of the data provides support for the planning and execution of strategic actions in the management of the consumption of electric energy, such as the elaboration of internal energy policy, the revision of contracts and tariff systems, the cost-benefit analysis of the implantation of energy efficient technologies , the alignment of partnerships with universities for studies, procurement in conjunction with other public agencies, availability of EE indicators to all users of the institution and awareness raising through education and training measures.

6.5 Office Equipment Consumption Analysis

Considering that the work environments of the institution under analysis are mostly offices and that activities are usually developed in computer equipment, attention should be paid to measures of economy, such as the activation of energy saving modes in computers, the use of stand-by mode in printers or photocopiers and the selection of energy-efficient office equipment in new acquisitions.

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In this context, the importance of adopting good practices in the use of equipment that, while not requiring investments, requires changes in user habits.

Table 3. Summary table of possibilities for reducing energy consumption

POSSIBILITIES FRAMEWORK	DIMENSION
Analysis of the history of the power factor and renegotiation of the supply contract with the electric power concessionaire	Energy Management
Modification of the hiring modality, verifying the hypothesis of migration from the horo-seasonal modality green to horo-sazonal blue	Energy Management
Inventory of the lighting system in operation, including information regarding the installation place, type of lamp, type of lamp bulb, type of reactor, quantity of reactors per lamp, installed power and illuminance produced and number of lamps in stock	Lighting
Inventory of the operating air conditioning system, covering information related to the installation site, type of equipment, manufacturer, type of coolant, age and capacity of the equipment, period of use and area serviced and equipment in stock	Air Conditioning
Replacement of obsolete equipment of high consumption and equipment with seal PROCEL of energy efficiency class C	Air Conditioning
Encouragement of preferential use of ladders over the use of lifts; permanent orientation as to the elimination of the habit of unnecessarily triggering two elevators at the same time	Energy Management
In sectors where there was a change in the layout, redistribution of lighting rails, positioning them on the workstations and elimination of surpluses; implantation of presence sensors in lavatories and in other environments of transient occupation	Lighting
Technical evaluation on the possibility of shutting down one of the three 300 kVA transformers	Energy Management

Source: The authors

7. CONCLUSIONS

According to the proposed objectives and based on the situations observed in the case building, in the structured interview applied to the team responsible for the maintenance and management of the electricity supply contract and the measurements of the consumer loads, it is possible to affirm that there is a potential of reduction in the electricity consumption of the analyzed building, without compromising the environmental comfort or undermine the provision of services.

In this sense, a possible way to make the initiatives feasible would be through the creation of an Energy Efficiency Management Committee, sponsored and supported by senior management, responsible for initially implementing the actions envisaged in the Energy Economy Program, monitoring the effectiveness of the results and, in particular, to regularly disseminate the results achieved, as a means of sensitizing and involving the users of the building in relation to: (a) the stimulus for preferential use of stairs in detriment to the use of elevators; (b) the preparation and dissemination of a booklet on the use of lifts, when it is not possible to use ladders; (c) permanent orientation regarding the elimination of the habit of activating, unnecessarily, two elevators at the same time, among others.

Some actions of low cost and rapid implantation can contribute to the reduction of the consumption of energy of the building, such as: (a) redistribution of the lanes of illumination, positioning them on the workstations and eliminated the surpluses in the sectors where there was alteration of the layout ; (b) implantation of presence sensors in lavatories and other transient occupancy environments; (c) analysis of the history of the power factor and renegotiation of the supply contract with the electric power concessionaire; (d) technical evaluation of the possibility of shutting down one of the three 300 kVA transformers, considering that the measured current of the building is 48.5 A.

Even though there is legislation on energy efficiency in public buildings, namely Law No. 10,295 of October 17, 2001, which deals with the National Policy for the Conservation and Rational Use of Energy, it is of fundamental importance to implement a model of energy management, with permanent dissemination of actions and monitoring the results achieved, as a way of systematizing the necessary discipline to obtain energy efficiency.

In order to do so, it is essential to have strong political will regarding the implementation of EE practices, translated into technical and organizational skills and with the maximum involvement of human resources.

The result of the study identified that the search for energy efficiency in public buildings is fundamental to the sustainability management, considering the influence of the public sector as an opinion maker in the society, besides its economic representativeness within the public budget, impacting their behavior and its socio-environmental responsibility as a public institution.

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