Energy Efficiency and Luminotechnique Analysis in a Higher Education Unit in Manaus - Amazonas

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Abstract

This paper presents an energy efficiency analysis at a unit of a private higher education institution in the city of Manaus. In this case study, we sought to analyze the lighting system of the educational institution, promoting a simple and effective way to contribute to the improvement of energy efficiency in the institution that is the replacement of fluorescent lamps with LED lamps (Ligth Emitting Diode). In addition to increasing efficiency, LEDs bring significant benefits to the power grid, such as improved installation power factor and power quality, and reduced maintenance due to their longer service life. This case study presents a case study to be implemented in a higher education institution. The benefits that the use of LED brings in various aspects will be analyzed in detail.

Keywords: *Energy efficiency*; *Lighting system; Ligth Emitting Diode.*

1. Introduction

Much of the electricity produced in Brazil comes from hydroelectric plants, even if considered as renewable energy sources, hydroelectric plants have a large environmental impact in the region where they are installed [20]. After years of uncontrolled energy consumption, disregard for environmental problems, the scarcity of natural resources, the overconsumption of consumerism by a large portion of society, humanity faces a major hindrance: saving, recycling, sustainability and using it wisely. efficiency of natural resources [22].

Humanity today faces several problems when it comes to conscious use of energy, since to produce more energy is necessary to extract it from some source of energy and thus it is necessary to build generating sources. Energy production through hydroelectric dams does not pollute the air, but causes huge environmental impacts due to the large amount of water that will be dammed. The generation of thermoelectric energy emits gases that can contribute to the aggravation of the greenhouse effect. Solar energy needs large areas for the installation of photovoltaic panels. Wind energy from the displacement of air masses generates many noises and can interfere with the migratory behavior of birds [15].

In 2001, Brazil experienced several frequent outages or outages, such as long-term blackouts due to low levels of hydroelectric reservoirs due to the long drought and a lack of planning in the sector and lack of investment in power generation and distribution [5].

The search for greater efficiency in consuming energy is not only due to environmental factors, such concern is also due to the current economic situation in Brazil, which has been formally in recession since the second quarter of 2014, Brazilian per capita output fell by 9%. % between 2014 and 2016, with the economy recovering and inflation rising, the price of energy rose almost exponentially [10].

One way to have more energy for consumption without increasing electricity production or expanding the energy matrix would be to invest in energy efficiency, i.e. to develop equipment that consumes less and less energy in the execution of electricity. a particular process [21].

With the increasing difficulty of many countries in meeting the growing demand for energy, it also provides energy resources to meet their economic growth. It is the responsibility of the public authorities to know the behavior of its population that demands energy so that mechanisms can be developed that promote the rational use of energy in the most diverse sectors [3].

In Brazil, several public policy programs were adopted to encourage energy efficiency, which began since 1981 with CONSERVE, where the purpose of this program was to promote energy conservation in industry, the development of efficient products and the substitution of imported energy sources by national sources. . The following year the Energy Mobilization Program (SME) was launched in which its main features consisted of a set of actions aimed at encouraging the use of energy conservation measures and especially replacing petroleum products with renewable energy sources [17].

In 1985 the National Program for the Conservation of Electric Energy (PROCEL) was created, its main mission was to promote the rational use of electricity throughout the country and among its initiatives is the creation of the Brazilian Labeling Program [18]. The National Program for the Rationalization of the Use of Oil and Natural Gas Derivatives (CONPET) was established, whose purpose was to stimulate the rational use of energy resources in the country, but focused on renewable energy sources [17].

The National Energy Policy (PEN) program was created by Law No. 9,478, and the principles of the PEN in relation to the rational use of energy sources were determined, aiming at energy conservation and environmental preservation [3].

At the beginning of the 21st century, in the 2000s, the main legal framework in the area of energy efficiency in the country was published, Law No. 10.295 / 2001, which launched the National Policy for Conservation and Rational Use of Energy, with the purpose of to establish that the executive branch be responsible for developing mechanisms that promote efficiency in machines and equipment produced and sold, and in buildings built in the country [3].

About 5% of world electricity consumption could be saved annually by implementing more efficient lighting, reflecting an annual savings of more than US $ 110 billion, where Brazil, when adopting this strategy saves more than US $ 3 billion / year. and would reduce more than 5% of its consumption [15].

With all measures and incentives made to increase equipment efficiency, between 2001 and 2010 the first results of this investment were obtained where the efficiency of the installed lighting system increased from 45 to 58 lm / W, a significant increase of 28.8%. due to the replacement of the incandescent lamp for the compact fluorescent lamp [20].

Incandescent lamps until mid 2007 were common in many locations due to the low initial cost. Its simple operation produces light by raising the temperature of a filament, commonly tungsten, when subjected to electric current. Several factors contributed to the replacement of this technology, among them the short life span of about 1,000 h and its energy loss by Joule effect where about 90% of the energy is lost and only 10% is transformed into light [13].].

Low-pressure discharge fluorescent lamps [2] were created by Nikola Tesla, introduced in the market in 1938. Their operation consists of discharging mercury vapors composed of a filament, a cylindrical glass tube filled with a noble gas (argon is usually used) and the inner part covered with fluorescent powder which is phosphorus [9]. There are several advantages to its use, given its low energy consumption, of approximately 80% less compared to ordinary incandescent lamps, high performance in turning electric energy into light than in heat and its durability is far superior to incandescent ones. Fluorescent lamps have an average lifespan of 6,000 to 9,000 h [11].

Contrary to what is thought of light emitting diode (LED) lamps, it is not such a recent discovery. LED has been around since 1962 and was initially used only for signaling because of its low luminous flux (light emission), narrow color gamut and low wattage. In 1990, with investments in technology, Dr. Shuji Nakamura of Nichia Chemical Corporation invented the high luminous blue LED, which together with a Phosphorus layer emits white light [6].

The LED lamp has superiority to other lamps in the market because it has higher luminous efficiency, that is, it uses less energy to generate the same illumination [12]. By definition LED is a semiconductor electronic component, with technology similar to that used in computer chips, which has the function of turning electricity into light. No metal filaments are used, do not emit ultraviolet radiation or gas discharge. All electricity consumed is transformed into light, without considerable loss [19].

It is remarkable the superiority of LED lamps over the others, with a service life ranging from 15,000 to 50,000 h, their disposal is also a factor that proves their sustainability as it has no heavy metals in its composition and disposal in the environment. it does not need any special treatment before recycling [14].

The human being is influenced by visual stimuli and has optical information for most of his daily actions. The luminotechnical study is of utmost importance so that the lighting efficiency is as high as possible without affecting the human health [8].

In an environment it is essential that lighting values are in accordance with the standard, as poor sizing can influence worker performance or a student's ability to learn and discomfort can cause visual fatigue [7].

For each task to be performed there is an adequate luminance level and for the present study the luminance levels for classrooms will be used. It is established for classrooms with a minimum luminance of 500 lux [4].

The present study seeks to analyze the luminotechnical and economic benefits of led lamps, compared to conventional ones, with the aid of luxmeter aiming to verify the lighting levels in the higher education unit in Manaus-AM. In case of non-compliance with NBR-8995, carry out a new lighting project to comply with the standard if necessary, simulate the impact on electricity consumption with possible substitution, assess what capital needs to be invested.

2. Material and Method

The study was conducted in a unit of a private Higher Education Institution (HEI), located in the Chapada neighborhood, Manaus / AM.

The analysis of energy and lighting efficiency was due to the large amount of luminaires containing fluorescent lamps and four types of rooms that will be named as: STANDARD 1, STANDARD 2, STANDARD 3, STANDARD 4, such separation of room types occurred. by Layout having different dimensions, with patterns that repeat on all six floors, with nine classrooms (Figure 1).

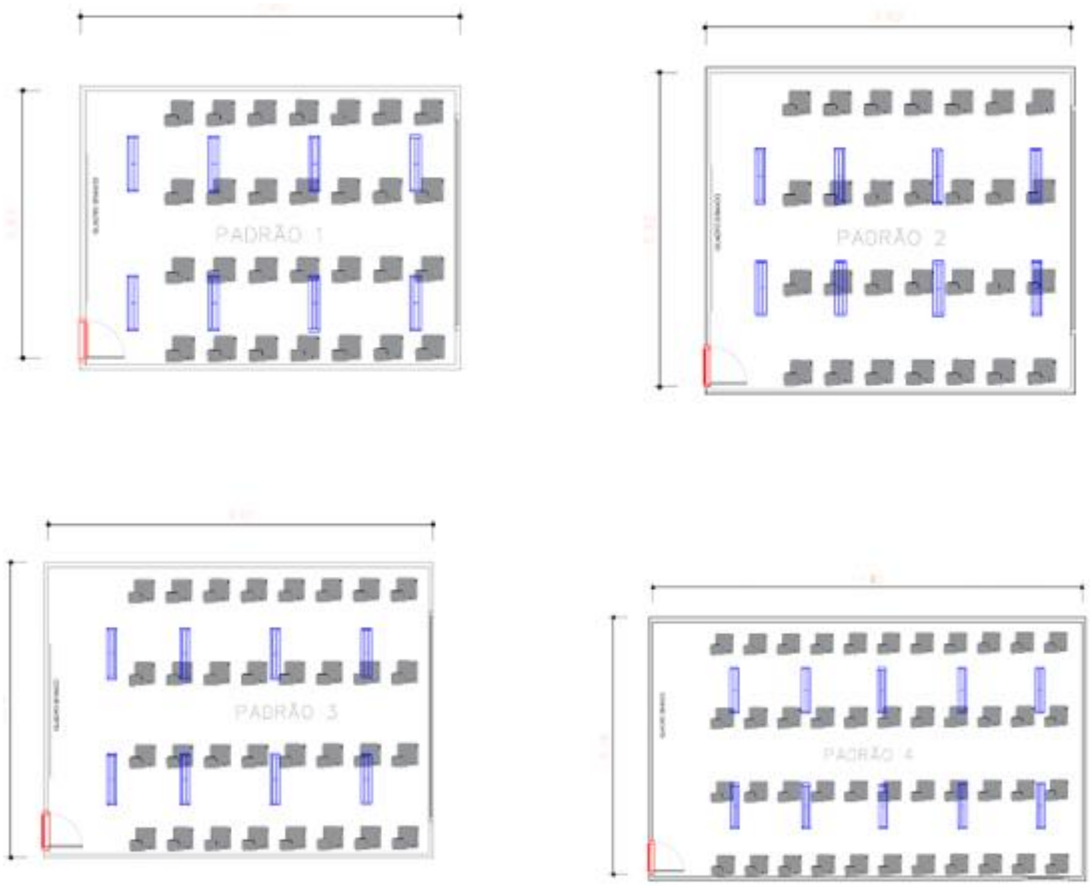

Figure 1. Layout of the four room patterns in a teaching unit.
Source: Own authorship, 2019.

a) Survey of characteristic site data

The unit has 54 rooms, with four different standards, considering size (area - m2): STANDARD 1 - 46.4 m²; STANDARD 2 - 54.80 m2; STANDARD 3 - 61.1 m2; STANDARD 4 - 77.3 m2. The rooms have a ceiling height of 2.55 m. The distribution of luminaires for each room pattern was as follows: eight luminaires for standard 1, 2 and 3 and 10 luminaires in rooms with standard 4. Adding the number of luminaires from all rooms gives an amount of 444 luminaires, each luminaire with two 36W fluorescent lamps. Each floor has two rooms similar to Standard 1, two rooms similar to Standard 2, four rooms similar to Standard 3, and only one room has Standard 4.

b) Standardization of Project Items

Given the variation in the brand of lamp manufacturers, a standard was adopted for each one, using the largest quantity present in the rooms. Thus, the manufacturer used will be Philips Lighting, model TL - D 36W / 54-765 1SL / 25, with characteristics: luminous flux 2500lm; service life 13000h; lumen maintenance 10000h - 75%; lumen maintenance 2000h - 90%; lumen maintenance 5000h - 80%; color temperature - 6200 K; color rendering index - 72%; power36W; power consumption kWh / 1000h– 43kWh; length - 120cm [16] .The luminaire to be adopted is made by Abalux, model - A 60; yield - 86%; length - 123 cm; ip - 20 [1].

For the new project, the Philips Lighting TMS022 2xTL-D18W HFS + GMS022 R LED luminaire will be adopted, with total luminous flux of 2400lm, with the power of each 18W LED bulb. The equipment to be adopted has the following technical information: base - G13; luminous flux - 2100 lm; useful life - 25000 h; color temperature - 6200 K; color rendering index - 82; power - 18 W; power consumption kWh / 1000h - 19.5kWh; length 120 cm [16]. To obtain parameters of the lighting design the Dialuxevo 8.2 software was used.

c) Current demand for lighting in the analyzed rooms.

The demand for an electrical installation is the amount of power required by all equipment to be energized demonstrated by equation 1.

$$D = Pn * QE \qquad \text{(Eq. 1)}$$

Where:

D - demand

Pn - nominal wattage of the lamps;

QE - amount of existing equipment;

For the survey of the consumption of IES, it was established characteristics of the equipment, while: the full use of its useful life, 100% luminous flux and no system failure. For monthly consumption for calculation purposes we have:

$$C = \frac{(Pn * Nh * QE)}{1000} \qquad \text{(Eq. 2)}$$

Where:

Pn - nominal wattage of the lamps;

Nh - number of hours the lamps are on;

QE - amount of existing equipment;

The unit has six floors, with nine rooms per floor reaching 444 lamps and 888 lamps in general. The academic calendar is available for the annual consumption calculation (Table 1).

Table 1- Average data of current lighting system

Academic Calendar			
School days	1st semester	2st semester	Horas
	127	104	2772
Total			2772

Source: Own authorship, 2019.

d) Initial Luminotechnical Diagnosis

The on-site collection, used to reach the luminotechnical data due to the lack of electrical and luminous design of the IES, used the base project to perform the energy efficiency study considering all the characteristics present in the current layout, where to perform the analysis all steps in NBR - 8995, to better portray a study environment (Table 2).

Table 2- Average data of current lighting system.

Environment	Medium Brightness	Lowest brightness value	Uniformity Factor
Pattern 1	492 lux	243 lux	0,49
Pattern 2	430 lux	177 lux	0,41
Pattern 3	240 lux	97 lux	0,40
Pattern 4	306 lux	136 lux	0,44

Source: Own authorship, 2019.

The definition of the use plan considered for all rooms was 0.73m, with a ceiling height of 2.55m. For classrooms using NBR-9995 500 lux illuminance and uniformity factor of ≥ 0.70.

e) New project: Retrofit

The new project aimed to adjust the illuminance values (NBR-8995), where table 3 shows the values of average illuminance and uniformity factor.

Table 3- Average data of the new lighting system.

Environment	Medium Brightness	Lowest brightness value	Uniformity Factor
Pattern 1	516 lux	349 lux	0,67
Pattern 2	666 lux	460 lux	0,69
Pattern 3	609 lux	438 lux	0,71
Pattern 4	631 lux	430 lux	0,68

Source: Own Authorship, 2019.

Isometric lines

In a lighting system the isometric lines show how the entire luminous flux in a room is distributed, indicating which area needs more lighting. Thus, it is possible to obtain through simulations how the new project will behave in the real environment.

3. Results and Discussion

The teaching unit where the study was carried out has 100% of its illumination composed by fluorescent tube lamps, where summed up the demands of each classroom it was possible to obtain for the lighting system the total demand of 31,968 kW, which corresponds to approximately 4% of the contracted demand of the teaching unit. Considering the teaching days of the teaching unit and the demand obtained, the annual consumption value is 92.06784kWh / year.

Evaluating the current situation of the lighting system, it was observed that the standards of the rooms do not meet the minimum illuminance requirements of 500lux, being 26.6% below the ideal required by the standard. It was found that the average uniformity factor is 62.14% below the ideal, which may lead students to visual fatigue [8] and decreased academic performance, thus justifying the elaboration of a new lighting project for the institution. .

The elaboration of the new project with the aid of Dialux software kept the same right foot and the same height of the work plan, below it is possible to verify the isometric lines of the new project (Figure 2).

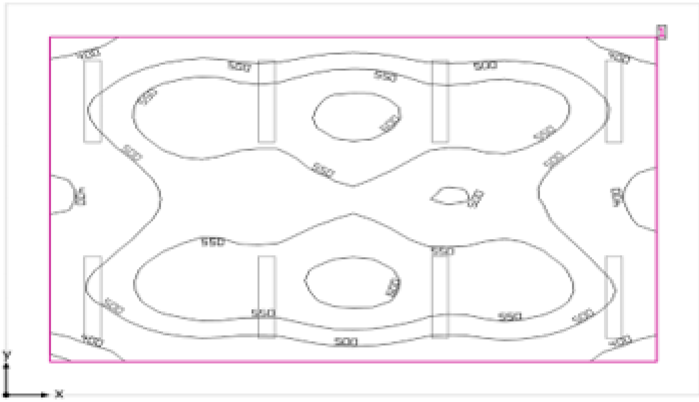

Figure 2. Isometric Lines Retrofit Pattern 1.

Source: Own authorship, 2019.

Light has a measurable neuroendocrine and neurobehavioral effect on the human body. By investigating the effects of light on human health, [8] indicates that the evidence shows direct relationships between light exposure and health and productivity, further complements that light ensures a healthy sleep / wake cycle and acts to maintain the health. activity / rest cycle.

Retroft fits NBR - 89951, maintaining average illuminance of 516lux. The adequacy of the rooms with standard 1 kept the same amount of light fixtures and lamps present, with a reduction of 50% of the demand due to the replacement of fluorescent lamps with LED lamps (Figure 3).

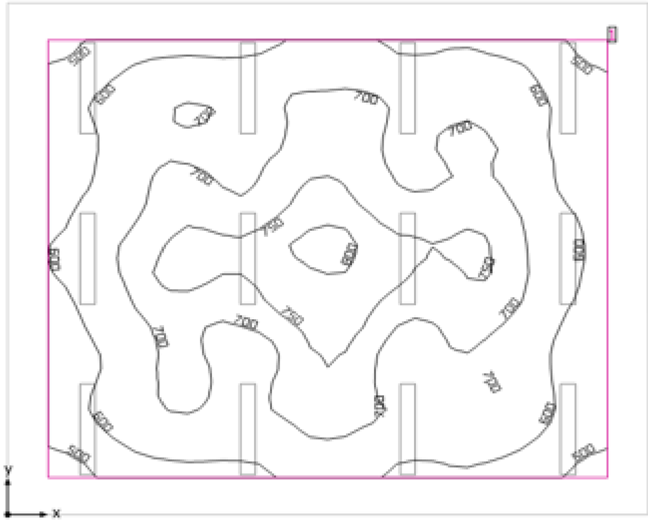

Figure 3. Isometric Lines Standard Retrofit 2
Source: Own Authorship, 2019.

The retrofit of the standard 2 rooms met the illuminance standards established by the standard, and the illuminance obtained was 666 lux. There was an increase of four new luminaires because the room area is larger than standard 1. The new demand is 25% less than the old design and the uniformity factor meets the minimum parameters (Figure 4). .

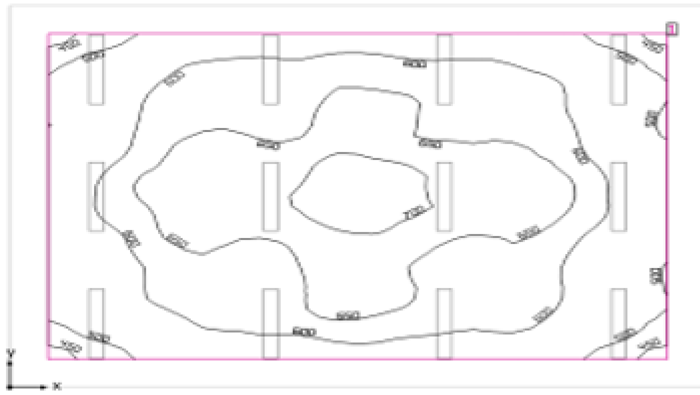

Figure 4. Isometric Lines Retrofit Pattern 3
Source: Own Authorship, 2019.

According to [20] the lamps purchased are based on characteristics such as their power consumption (in Watts), without considering the illumination level (lux), considering lumens information, as measured by the amount of light. or total number of lines of light flux emitted from the light source; efficiency, measured by how many lumens are emitted for a given input power (lumens per Watt - lm.W 1); and illumination, measured in a given area of the brightness level.

Standard 3 showed an increase of four luminaires compared to the old design and savings of 25% compared to the system already installed in the teaching unit. The project met the norm, in which the retrofit had an average illuminance of 609 lux (Figure 5).

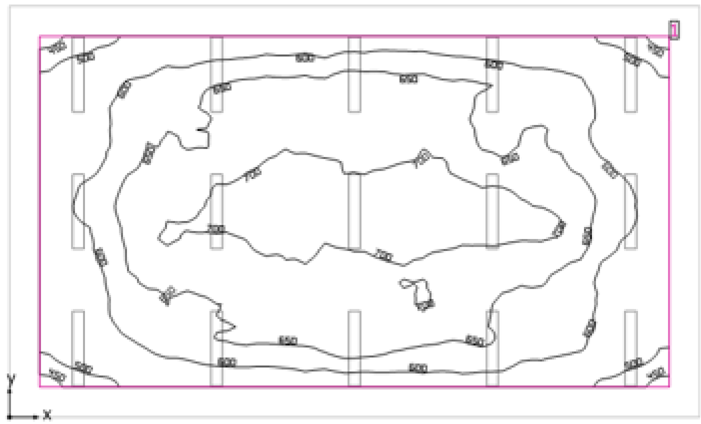

Figure 5. Isometric Lines Standard Retrofit 4
Source: Own Authorship, 2019.

For an autonomous potential for energy efficiency (range between 4.4% and 8.7%), [3] effective planning is required for the rational use of energy inputs by different economic sectors and also by the population. It is indicated that they are autonomous potentials, that is, those expected in the evolution of the market, and that the technical potential is much higher and usable if implemented by strong incentive policies for energy conservation.

The retrofit of the rooms with standard 4 simulated average illumination of 631 lux, which is the standard with the largest area (77.3 m2), with an increase of five new luminaires compared to the original installation, with the change of lamps. fluorescent lamps for led lamps an increase in savings of 25% over the previous system. The retrofit of pattern 4 observed in isometric lines presents better luminous flux distribution and fits NBR8995-1.

The new project called retrofit has 457 luminaires and 914 18W led lamps, where applying equation 1 it is possible to obtain the demand of 16.452 kW which represents 48.53% savings compared to the current lighting system. Using equation 2 it is observed that the annual energy consumption is 47.38kWh / year.

4. Conclusion

After the data collection stage, concomitantly with the elaboration of the project and analysis of the obtained results, it is verified that the lighting system of the teaching unit's rooms when compared to the energy efficiency actions described in this work can be considered inefficient. .

With the new project, the room lighting system will represent approximately 1.79% of the total contracted demand, which is 920 kW. The saved energy can be redirected to other tasks. It is known that the trend is to adopt LED lamps in lighting systems, where it has been proven in simulation a decrease of 48.5% of the concomitant demand with consumption.

Energy savings may be greater as the impact of harmonic distortions caused by fluorescent lamp reactors is not being analyzed. The design becomes viable due to the suggested lamp life for use in the new design and the low lamp maintenance and replacement factor.

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