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The present study has as main objective to verify the reduction of electric energy consumption, allied to the possible economic-financial and environmental benefits that are associated with the use of LED lamps in a commercial building, where it develops office activities covering only part of the building. , which served as the experimental basis for the application of the case study, initiated after a survey of the electrical and constructive characteristics of the luminaires installed on site. In research conducted in the local market specialized in the subject, we selected lamps that are more easily found, analogous to those already installed, manufactured by traditional companies in the field. The monitoring of lighting loads was made by measuring by specific equipment and simulation of energy billing according to the rules of calculations established in rules governed by government agencies and tariff framework in which the building is in both scenarios, before and after lamp replacement. Providing financial technical evaluation through the use of indicators that show the viability of this substitution.

Keywords: energy consumption, benefits, lighting.

1. Introduction

In 1973, the first major oil crisis began, and it was then that there was worldwide mobilization in function of energy saving and the search for other forms of generation through alternative sources[1].

In Brazil, the National Program for the Conservation of Electric Energy - PROCEL was created on December 30, 1985, to promote the efficient use of electricity and to combat its waste [2]. Following the policy of reducing dependence on oil and its derivatives. "CONPET is a Federal Government program, created in 1991, by presidential decree, to promote the development of an anti-waste culture in the use of non-renewable natural resources in Brazil" [3].

On the other hand, the lack of diversification of energy matrices accompanied by the neglect of the rulers and climate change culminated in the first major energy crisis in Brazil in the early 2000s[4]. After a period of electricity rationing, the contribution of "alternative" energy sources has been increasing significantly year after year. This is due to the creation of public policies aimed at the sector. Data show [5] that the origin of the corresponding Brazilian energy matrix today is 61% Hydro, 14.8% Fossil, 8.8% Wind, 8.4% Biomass, 4.6% Imports (Paraguay, Argentina, Venezuela and Uruguay), 1.3% Solar and 1.1% Nuclear.

Brazil experienced an increase of 94.28% in electric power, from 1995 to 2018. Considering the following categories: residential, industrial, commercial and others. A prominent class showed a significant increase in this period, the commercial, surpassing the level of 175% of electricity consumption [6].

A practice adopted by consumers today is the replacement of conventional lamps with lamps that use LED (Light Emitter Dioder) technology. At the end of 2014, LED lamps were included in the Procel Seal award program. With them, the program reached the milestone of 39 categories of equipment with the seal, which, in 2014 alone, provided energy savings of over 10.3 TWh, corresponding to about 2% of national consumption [7].

Based on the above, this study seeks to highlight the economic viability of replacing low-pressure discharge fluorescent tube lamps with LED tube lamps in a commercial building.

2. Theoretical Referential

2.1 Low Pressure Discharge Tubular Fluorescent Lamp and Control Devices

They consist of a cylindrical bulb of glass, having at its ends metal tungsten electrodes (cathodes), through which electric current circulates. Inside is mercury vapor (Hg) or argon at low pressure, and the inner walls of the tube are painted with fluorescent materials, known as phosphor crystals [8].

For their full operation are used devices that assist in startup, are known as reactors. It is a device used to limit and / or control the electric current in the discharge lamps by supplying the necessary voltage for its operation. It is also responsible for providing an adequate luminous flux. Reactors can be conventional (electromagnetic) or electronic [9].

2.2 Power Factor

Power factor and the ratio of active electrical energy (kWh) to the square root of the sum of squares of active (kWh) and reactive (kvarh) electrical energy consumed over the same specified period. "The reference power factor " f_R ", inductive or capacitive, has the minimum limit allowed for the consumer units of group A, the value of 0.92" [10].

2.3 LED

LEDs are optoelectronic mechanisms that convert electrical energy into light. “When a direct voltage is applied through the p-n junction, unbalanced junction, electrons and holes are injected through the depletion region. These excess minority carriers may radically recombine with the majority carriers, giving rise to light emission”[11].

2.4 Led lamp

LED lamps depending on the model can last four times longer than fluorescent lamps, they pose less risk to consumers and the environment because they do not contain mercury in their manufacture, they do not emit ultraviolet and infrared radiation. However, some external factors may affect product durability, such as power line surges, poor contact at the point of installation, unsuitable locations, contrary to manufacturers' recommendations [12].

2.5 Quantities and Lighting Concepts

For the different types of lamps in the market, shapes, colors and shades, numerous applications can be performed, taking into consideration the environment (residential, commercial or industrial), whether they are indoor or outdoor, whether the lighting is decorative or necessary for performing visual activities [13]. So, some luminotechnical concepts we need to know:

Luminous flux (φ): is the total amount of visible light that a light source radiates in various directions, measured in lumens (lm);

Color Reproduction Index (IRC): A measure that corresponds between the actual color of an object and its appearance against a particular light source. Ranges from 0 to 100. The lower the (IRC), the lower the quality of the lamp;

Luminance (L): is the luminous intensity emanating from a surface in a given direction, captured by the retina of the eyes;

Luminous efficiency (η_w): indicates the rate at which the consumed electrical energy is converted to light, the ratio of the luminous flux emitted by a lamp to its electrical power (lm / W);

Color temperature (K): is the classification given to a lamp compared to the color tone of the emitted light given in (Kelvin). It can range from 800 K (red light) known as warm colors to 6500 K (blue light) cold.

2.6 Definitions of the National Electric Energy Agency (Aneel) through Normative Resolution No. 414 of 2010

Contracted demand (kW): demand for active power to be compulsorily and continuously provided by the distributor at the point of delivery, according to the amount and effective period established in the contract;

Measured demand (kW): higher demand for active power, paid at 15 (fifteen) minute intervals during the billing period;

Rush Hour: period consisting of 3 (three) consecutive daily hours defined by the distributor considering the load curve of its electricity system, approved by ANEEL for the entire concession area, except for weekends and national holidays;

Off-peak hours: period composed of the set of consecutive daily hours complementary to those defined in rush hour;

Green hourly rate: applied to group A consumer units characterized by differentiated rates of electricity consumption, a single end-to-end demand tariff; and

Blue hourly rate: applied to group A consumer units characterized by differentiated rates of electricity consumption and power demand, according to the hours of use of the day;

Tariff: monetary amount established by ANEEL, set at R $ (Reais) per unit of active electricity or active power demand, based on the definition of the price to be paid by the consumer and stated in the electricity bill, as follows:

a) energy tariff - TE: unit monetary value determined by ANEEL, in R $ / MWh, used to make monthly invoicing related to energy consumption; and

b) distribution system usage fee - TUSD: unit monetary value determined by ANEEL, in R $ / MWh or R $ / kW, used to bill monthly users of the electricity distribution system by using the system;

Primary Voltage: consumer units supplied with supply voltage equal to or greater than 2.3 kilovolts (kV) that are part of group A;

Binomial tariff: consists of the active electricity consumption (kWh) and the power demand (kW) applied to the group A consumer units.

2.7 Tariff Structure

The amounts charged (tariff) for electricity consumed in Brazil, vary in various regions of the country. In this study, we will emphasize the consumer unit belonging to group A and we will use as model (energy bill) Amazonas Energia (AME). “The tariff represents the sum of all components of the industrial process of generation, transportation (transmission and distribution) and commercialization of electricity. In addition, the charges for the cost of applying public policies are added ”[14].

2.8 Tariff Modality - Group A

In tariff modalities, differentiated energy tariffs are applied for electricity consumption (kWh) and power demand (kW), according to the hours of use of the day, in order to rationalize the consumption of electricity. For hours of use of the day, two different tariff stations are established (peak and off-peak hours), and may opt for the blue or green tariff [15]. Amazon rush hour: 8:00 pm to 10:00 pm [16].

2.9 Electrical Power Invoice Calculation Components - Group A

ANEEL publishes, by resolution, the value of the electricity tariff, without taxes by consumption class (residential, commercial and industrial). Based on these amounts, the energy distributors include taxes (PIS, COFINS, ICMS and COSIP) and issue the energy bill that consumers pay [17]. There is an adjustment of the electricity tariffs (TE) and the distribution system usage tariffs (TUSD) annually. The AME in 2019 follows the tariff values (table 1) determined by means of Homologation Resolution No. 2,478 of October 30, 2018.

Table 1 - Application rates without taxes, Group A (subgroup A4), AME

SUBGROUP	MODE	POST	APPLICATION RATE		
			TUSD		TE
			R$/kW	R$/kWh	R$/kWh
A4(2,3 a 25kV)	Blue	Tip	34,43	0,13584	0,45538
		Out Tip	16,6	0,13584	0,27643
	Green	Tip	16,6	0,96534	0,45538
		Out Tip		0,13584	0,27643

Source: Adapted from Homologation Resolution 2,478, ANEEL, 2018.

2.10 Consumption Value

The consumption value to be paid by the group A consumer, among the charges embedded in the energy bill value, are the peak and off peak energy consumption (kWh), demand (kW), surplus reactive energy consumption (“ fine ”charged for low power factor) if any, street lighting (COSIP). For each tariff mode (blue or green), differentiated tariffs for consumption and demand are applied, as well as for the tariff station (rush hour and off peak). [18] the consumption and demand (R $) installments are calculated as follows:

Total Consumption (R$) = {[Consumption Portion (R$ / kWh) + Demand Portion (R$ / kW) + Excessive Reactive Energy (R$ / kWh) + Overload Demand (R$ / kW)) / 1 - (Taxes)] + COSIP}

Rate mode - BLUE:

- Consumption Portion (R$ / kWh) = (TE (Tip Consumption) x Consumption (Measured at Tip)) + (TE (Off Tip Consumption) x kWh (Measured Off Tip));
- Demand Installment (R$ / kW) = (TE (Tip Demand) x kW (Measured Tip)) + (TE (Demand Off Tip) x kW (Measured Off Tip)).

Rate mode - GREEN:

- Consumption Plot = (TE (Tip Consumption) x kWh (Measured at Tip)) + (TE (Off Tip Consumption) x kWh (Measured at Tip));
- Demand Installment = (TE Demand x kW contracted).

Overpass Demand:

- Overrun Demand Value (R$) = (kW_Measurement – kW_Contracted) x 2 x TE (Overrun Demand).

2.11 Economic Feasibility Analysis

The investment and actions employed in an energy efficiency project demand proof of viability, that is, the financial return over a certain period of time, when the designer and / or client deem it satisfactory. For this, it is necessary to calculate some financial indicators through investment analysis techniques (simple payback, discounted payback, net present value, internal rate of return) to prove the benefits of the proposed Project [19].

Simple payback is the recovery period of the invested financial resources, the time required for the return on the initial investment from the revenues resulting from the implementation of the project, the ratio between the initial investment and cash flow. Similar to the simple payback, the discount takes into account the interest rate (currency devaluation) during project implementation, focusing on cash flow values (difference between the reduction of energy consumption and the additional maintenance costs) [19].

Every activity that involves the use of money requires observance of the level to be discounted or applied over time, called interest which may be simple and or compound. [20] Interest is the return on capital applied over a given period of time, and interest rate is the degree arising from the ratio of interest to capital employed. Special Settlement and Custody System (Selic), “It is the main monetary policy instrument used by the Central Bank (BC) to control inflation and influences all interest rates in the country, such as interest rates on loans, financing and financial investments” [21].

3. Methodology

The research approach is comparative because it consists of replacing low pressure fluorescent tube lamps with Led tube lamps. Combining all costs generated to perform the process and the resulting electricity savings.

It is a building, for commercial purposes, where the main activity developed is administrative. Met in primary voltage (13.800 V), three phases, its form of electricity billing is binomial and the tariff mode green. The building has 07 (seven) floors, underground to the 5th floor. The object of study, is located on the first floor, comprising an area of approximately 226.45 m².

The model of the predominant luminaires in the administrative / office areas is built-in. Each luminaire has 04 (four) low pressure discharge fluorescent tubes, each lamp has a nominal power of 16 W, for each pair of lamps an electronic ballast (2x16 W) with power factor 0.98, as indicated by the manufacturer.

The number of luminaires distributed in this sector is 61 (sixty-one), totaling 244 (two hundred and forty-four) fluorescent tubes and 122 (one hundred and twenty-two) reactors, the lighting load is distributed in 04 (four) circuits. three of them belong to the southern light distribution panel (QDL-SOUTH) and one to the general emergency panel (QGE), the mains voltage is 220 V.

The building lighting system is automated, the opening hours for administrative areas during the day are from 6:45 am to 11:30 am in the morning and from 1:00 pm to 7:00 pm in the afternoon. Therefore, the daily working time is 10h45min, 22 (twenty-two) days per month, totaling 236.5 hours / month and in 1 (one) year approximately 2,838 hours. Currently installed lamps have a color temperature of 5000 K (cool white), luminous flux of 1150 lumens, IRC of 85, with efficiency of 72 lm / W.

The LED tube lamp model chosen for retrofitting was the one that had the characteristics similar to those of fluorescent lamps, in terms of size and color temperature, so that the existing luminaire rails could be reused. Therefore, the LED tube lamps chosen have a rated electrical power of 10 W, color temperature 6500 K, luminous flux of 900 lumens, IRC greater than 80 and luminous efficiency of 90 lm / W.

Measurements of lighting loads occurred in two steps, only on business days for 10 (ten) days, in the first step, with the “old” system, using fluorescent lamps and in the second, after replacement by LED tube lamps, resulting in five days for each, one hour in the morning and one hour in the afternoon for each circuit, in order to verify the occurrence of requested power variations (W) of the electric network. The meter used was a wattmeter, model AK353 - True RMS, AKSO manufacturer, calibration certificate no.

130700377. The electrical values noted were: Voltage (V), Current (A), Active Power (kW), Apparent Power (kVA) and power factor.

With the data collection, tables were elaborated, inserted in them, quantity of existing luminaires in the environment (office), hours of operation of the system and estimated consumption in 22 days (kWh / month). Then the consumption in the energy bill was calculated, taking into account, operating hours (top and off), tariffs applied according to tariff mode (green tariff). With the consumption results, the financial technical viability of the energy efficiency project was analyzed through the payback calculation. This includes the initial costs with materials (lamps and cables) and labor in relation to the energy savings generated, allowing to verify the return time of the invested capital.

4. Results and Discussion

In the measurement for the first lighting system (fluorescent lamps), the samples collected showed homogeneity between the readings taken in the morning compared to those taken in the afternoon. Through the arithmetic mean, the data exposed (table 2) represent the estimated system consumption monthly, considering, utilization time, demand (kW), peak and off-peak consumption.

The simulation of the amount (R $) of the energy bill was made using the monthly consumption, without taxes and charges on energy tariffs, to better evaluate the possible benefits generated with the implementation of the project.

Table 2 - Electricity consumed by the lighting system - Tubular Fluorescent Lamp - 16W

Switchboard	Circuits	No. Light Fixtures 4x16 W	Measured Voltage (V)	Measured Current (A)	Power Factor (cos θ)	Measured Demand (kW)	Utilization / month (Hours)	Consumption Outside Tip (kWh)	Consumption (kWh / month)
QDL-SOUTH	S.1	12	212,8	3,56	0,99	0,75	236,5	178,32	178,32
	S.2	18	212,6	5,31	0,99	1,12	236,5	265,83	265,83
	S.3	18	214,0	5,24	0,99	1,12	236,5	262,99	262,99
QGE	SE.1	13	211,7	3,57	0,99	0,75	236,5	177,61	177,61
TOTAL	**-**	**61**				**3,74**		**884,75**	**884,75**

The “monthly consumption” of electricity using fluorescent lamps was 884.75 kWh, the average demand was 3.74 kW. Due to administrative office hours in the building, the lighting system shuts down daily at 7 pm. For this reason, consumption at peak hours is zero.

The green billing energy bill (R $ / month) will be: (R $ 1,42072 / kWh x 0 kWh peak) + (0,41227 R $ / kWh x 884.75 kWh off peak) + (16.6 R $ / kW x 3.74 kW) = **426.86**.

For measurements, after replacement by LED lamps, the data were collected and organized similarly to those presented above, as shown in table 3.

Table 3 - Electricity consumed by the lighting system - LED Tube Light - 10W

Switchboard	Circuits	No. Light Fixtures 4x16 W	Measured Voltage (V)	Measured Current (A)	Power Factor (cos θ)	Measured Demand (kW)	Utilization / month (Hours)	Consumption Outside Tip (kWh)	Consumption (kWh / month)
QDL-SOUTH	S.1	12	211,9	2,30	0,97	0,48	236,5	112,34	112,34
	S.2	18	210,7	3,60	0,97	0,73	236,5	171,94	171,94
	S.3	18	212,1	3,50	0,97	0,72	236,5	170,28	170,28
QGE	SE.1	13	212,0	2,50	0,97	0,51	236,5	120,62	120,62
TOTAL	**-**	**61**				**2,43**		**575,18**	**575,18**

The amount of electricity consumption (R $ / month) will be: (R $ 1,42072 / kWh x 0 kWh peak) + (0,41227 R $ / kWh x 575.18 kWh off peak) + (16, 6 R $ / kW x 2.43 kW) = **277.50**

Average savings per month is R $ 149.36 (one hundred and forty nine reais and thirty six cents) and annually it will be R $ 1,792.32 (one thousand seven hundred and ninety two reais and thirty two cents) representing approximately 35% reduction in electricity bill.

The initial costs and revenues generated with the implementation of the new project, materials and labor, this second, performed by two qualified professionals (electrician and assistant) for 4 (four) days, 8 (eight) hours daily. Follows (table 4) statement below:

Table 4 - Costs of Goods and Services

Material	LED tube light	**R$ 3.513,60**
	Cable 1.0 mm²	**R$ 73,57**
Services	Labor	**R$ 823,10**
INITIAL EXPENDITURE		**R$ 4.410,27**

The time required for the return on invested capital will be counted from the first year after project completion. It has been set by means of discounted payback at a basic interest rate of 6.5% (selic) per year, with a fixed cash flow of R $ 1,500.22 which the difference between the annual savings on the energy bill (R $ 1,792.32) and the maintenance expenses (twice a year) of the system (R $ 292.10) in the lamp life will be 3 years and 4 months, values shown (table 5) below:

Table 5 - Discounted Payback

YEAR	CAPITAL	DISCOUNT CAPITAL	BALANCE
0	-R$ 4.410,27	-	-R$ 4.410,27
1	R$ 1.500,22	R$ 1.408,66	-R$ 3.001,61
2	R$ 1.500,22	R$ 1.322,68	-R$ 1.678,93
3	R$ 1.500,22	R$ 1.241,96	-R$ 436,97
4	R$ 1.500,22	R$ 1.166,16	R$ 729,18
5	R$ 1.500,22	R$ 1.094,98	R$ 1.824,16

The balance will be positive before the middle of the fourth year. The profit after the installation of the "new" lighting system at the end of five years will be R $ 1,824.16 (one thousand eight hundred and twenty four reais and sixteen cents).

In order to compare, valuing the results obtained, we used the results achieved in another study of the same nature, [22] which achieved savings of 55% (figure 1) in reducing energy consumption when replacing fluorescent lamps of 40%. W by 18 W Led lamps. However, the method used to calculate the monthly consumption was performed through online software simulation, which considers the number of lamps, nominal wattage (W), usage time (hours) and the average fare charged per kWh. Since, losses in the system were not considered as a function of power quality.

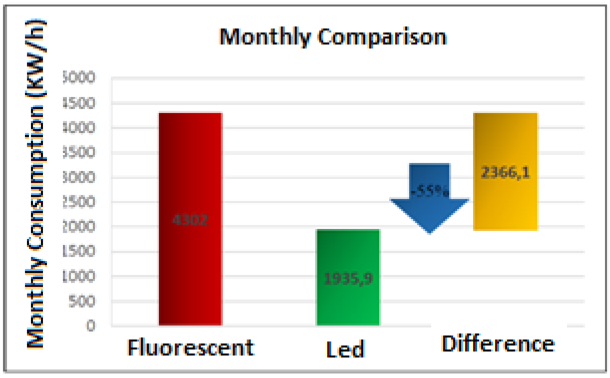

Figure 1 - Results of Sousa, Ramos and Campos. (2017) for comparison purposes.

Source: Comparative study between fluorescent and LED lamps, applied in the environment of a public university in the state of Amazonas, 2017.

Given the fact that, in the current study, the economy is around 35% (kWh) (figure 2). This is due to the nominal power difference of the LED lamps used in the retrofit that does not exceed 37.5% of the lamp power replaced.

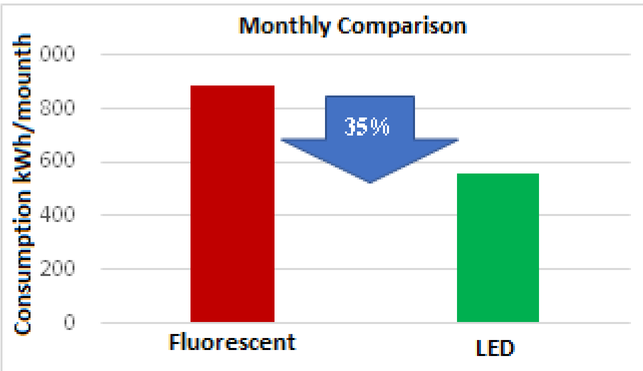

Figure 2 - Reduction of monthly consumption

Source: Adapted, Sousa, Ramos and Campos, 2017.

Another study used in comparison to the results, is in relation to the return on the capital investment initially used in the execution of the project. [23] The amount invested of eighteen thousand and eight hundred and sixty-nine reais and sixty cents (R $ 18,879.60) in the replacement of 32 W tubular and 26 W compact fluorescent lamps with 18 and 16 W LED lamps respectively, resulted 50% reduction in electricity consumption and provided a cash flow of five thousand nine hundred and seventy-six reais and fifty-six cents (R $ 5,976.56), this capital was recovered in 3 years and 1 month . As in the first comparative study, lamps with higher energy efficiency were used, above 40% on average compared to fluorescent lamps, lower consumption, ensuring greater energy savings annually.

The calculation method used in this study [23] does not consider the devaluation of money over time (simple payback), this substantially reduces the estimated return time. On the other hand, in the study in question, the indicator used to measure the return on investment was through discounted payback, where a compound interest rate (basic interest rate 6.5%) is inserted, causing the adjustment in the estimated cash flow, thus extending payback time (3 years and 4 months).

Finally, the study and execution of the project brought satisfactory results, and even greater savings in electricity are possible, since there are in the local market more efficient lamps of the same model that can also be used in future projects.

5. Conclusion

The implementation of this energy efficiency project met expectations, proved to be economically viable, with a positive profit margin in the middle of the third year after implementation. It contributed to the reduction of electricity consumption with lighting, consequently with the reduction of the electric current, the heating of cables and protection devices, the reduction of joule effect losses, the lower heat dissipation to the environment, also contributing to the reduction of thermal load relieving the cooling system.

Another relevant factor is the minimization of the risk of contamination of soil, air and water by heavy metals contained in discharge fluorescent lamps and their reactors after disposal.

The quality of the energy supplied by the Eletrobras Amazonas Energia concessionaire is one of the main problems encountered, in addition to the quality of the products (LED lamps) offered in the local market. The voltage level provided by the dealership can be up to 4% more during the day. Constant power outages and oscillations from the opening and closing of disconnecting devices and shields can lead to anomalies in the sinusoidal signal of the voltage, thus dramatically reducing the life of LED lamps and even premature burnout of equipment.

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