

# **Comparative Analysis Of Compact Fluorescent Lamps Versus Led Lamps: An Economy Factor**

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## **ABSTRACT**

*The general objective of this article was to promote through bibliographic studies the two types of lamps, in addition to the comparative analysis of compact fluorescent lamps versus LED lamps: an economy factor. The specific objectives were: - to explain the conceptual precepts on: lighting engineering, definitions, characteristics, invention, operation, defect, quality and the environments used and the NBRs regulations; - address the economic impact generated by the choice of LED lamps and compact fluorescent lamps; - emphasize on an economic feasibility study on the use of LED lamps and compact fluorescent lamps. The justification of the study is related, in the promotion regarding the use of LED lamps and compact fluorescents, in the factor that generates savings. Since the areas related to artificial lighting are responsible for a significant portion of energy demand, both on a large scale - such as lighting for public roads or industrial buildings - and on smaller scales - in commercial and residential buildings. Therefore, its promotion is crucial in the context of economic viability. The lamps provide the luminous energy, through which a better luminous efficiency is obtained. Currently, there are several types of lamps available, different in several aspects: luminous intensity, reproduction colors, energy efficiency, physical composition, method for emitting light, specific purposes, prices, among others. It is worth mentioning that the lamps differ from each other not only by the different luminous fluxes that they radiate, but also by the different powers they consume. In order to compare them, it is necessary to know how many lumens are generated per absorbed watt. This greatness is called energy efficiency. Thus, the proposal of a study was evidenced, in order to promote these luminous resources, in addition to emphasizing their economic viability.*

**Keywords:** Lamps of LED; Compact Fluorescent; Economic Viability.

## **1. INTRODUCTION**

A society's energy consumption is directly proportional to its economic and social development. In this way, when a society has a gain in the quality of life, in logic they have bigger houses, more electronic and home appliance there is a greater demand for energy and electricity.

According to Ferreira (2015), one of the sectors with the greatest impact on the global energy balance is that of urban centers, since the process of concentration of cities and the increase in energy consumption make them responsible for 70% of total energy consumption.

Therefore, it becomes interesting to seek solutions so that the units that consume energy produce their own demand more efficiently and with less losses. Therefore, the techniques that enable improvements in the use and also in the efficiency of electric energy must be analyzed and implemented according to their feasibility.

The photometric theory, formulated by Pierre Bouguer (1698-1758) and elaborated mathematically by JH Lambert (1728-1777), was completely forgotten until the mid-1900s, when, with the appearance of the electric lamp, humanity can aspire to better artificial lighting .

LEDs are the English initials for Light Emitting Diode. It is a semiconductor device that emits light with a certain wavelength when polarized in the direct position. This means, in other words, that the LED works with polarity, produces light by photoluminescence.

When lighting a fluorescent lamp, the filaments heat up and emit electrons. This process promotes the start of gas ionization, with the formation of ions. In these conditions, the mixture inside the tube, formed by free ions and electrons, is called "plasma". A "starter" then automatically interrupts the circuit and turns off the heating of the filaments. The reactor, connected to the lamp, immediately produces a high voltage pulse, which initiates the discharge in argon. This discharge heats and vaporizes the mercury, the largest amount of which is initially in the liquid state. There is then the possibility of cargo movement and the gas, inside the tube, becomes conductive. The electrons are directed towards the positive electrode (anode), while ions with positive charges are directed towards the negative electrode (cathode).

Compact fluorescent lamps have a high efficiency compared to incandescent lamps, that is, their power consumption is lower and their production of luminous flux is higher. Revolution in energy saving, they came to synthesize the concept of miniaturization of the light source in fluorescents. LEDs have advanced incredibly and are now used in all areas of lighting. These are the highlights of the new lighting projects. However, comparative studies are lacking that prove the economic viability of LED and compact fluorescent lamps.

### **1.1 GENERAL OBJECTIVE**

This work aimed to promote, through bibliographic studies, the comparative analysis of compact fluorescent lamps versus LED lamps: a saving factor.

### **1.2 SPECIFIC OBJECTIVES**

The specific objectives were: to explain the conceptual precepts on: definitions, characteristics, operation, defect, quality and the environments used and the NBRs regulation; address the economic impact generated

by the choice of LED lamps and compact fluorescent lamps; evidence the comparative analysis of compact fluorescent lamps versus LED lamps; emphasize on an economic feasibility study on the use of LED lamps and compact fluorescent lamps.

### 1.3 JUSTIFICATION

The justification of the study is related, in the promotion regarding the use of LED lamps and compact fluorescent lamps, in addition to the comparative analysis of compact fluorescent lamps versus LED lamps in the generating factor of savings. Since the areas related to artificial lighting are responsible for a significant portion of energy demand, both on a large scale and in the lighting of public roads or industrial buildings, as well as in smaller scales in commercial and residential buildings. Therefore, its promotion is crucial in the context of economic viability.

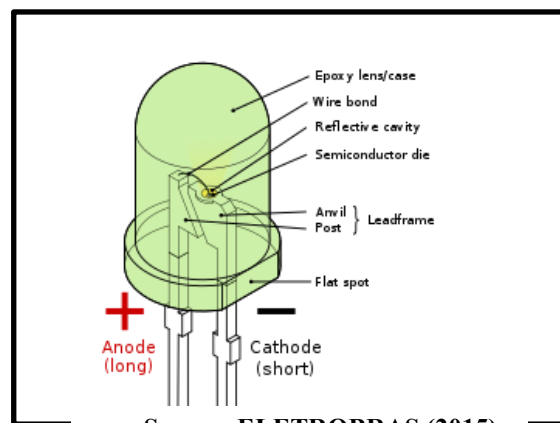
However, LED lamps in artificial lighting projects have been increasing in recent years and in many cases, their durability, energy and luminous efficiency have been proven in comparison with conventional lamps. On the other hand, compact fluorescent lamps have a high efficiency compared to incandescent lamps, that is, their power consumption is lower and their production of luminous flux greater.

## 2 THEORETICAL FRAMEWORK

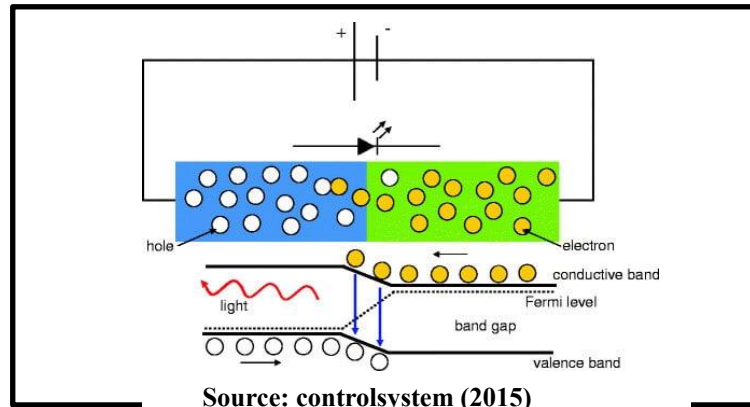
### 2.1 APPLICATION OF LED LAMPS

LED is the acronym in English for Light Emitting Diode, or Light Emitting Diode. It is a semiconductor diode (PN junction) that, when energized, emits visible light, that's why LED (Light Emitting Diode) figure 1. The process of emitting light by applying an electrical energy source is called figure 2 electroluminescence.

Figure1: Light Emitting Diode



Source: ELETROBRAS (2015)

**Figure 2: Principle of operation of the LEDs and diode symbol.**

At any directly polarized P-N junction, within the structure, close to the junction, recombination of gaps and electrons occurs. This recombination requires that the energy possessed by this electron, which until then was free, be released, which occurs in the form of heat or photons of light. As recombination occurs more easily at the energy level closest to the conduction band, the impurities for making the LEDs can be properly chosen, in order to display bands suitable for the emission of the desired light color (specific light length).

## 2.2 CHARACTERISTICS OF THE LED LAMP

According to Kalache et al (2017), the LED is the combination of different semiconductor materials used in the construction of the LED influencing the production of different colors (wavelength) and the efficiency of the device. The main combinations can be mentioned: AlInGaP (aluminum-indium-gallium phosphide) which produces the colors red and amber, and InGaN (indium-gallium nitride) which emits the colors blue, green and cyan.

The white light produced by current LEDs made it possible to obtain wavelengths closer to the limit of human vision. There are basically three ways to produce white light on LEDs.

However, to be used as a light source in general, white light is necessary, which can be obtained in three ways according to Santos (2015) cites the three ways:

- The first technique mixes the lights from three monochrome sources, the red, green and blue, a process known as RGB, in English red, green and blue. The combination of these colors produces a source of white light sensitive to the human eye;

The second uses an ultraviolet (UV) LED that excites the phosphor, which is deposited in the semiconductor material of the ultraviolet LED. This converts UV light to white light, similar to a regular fluorescent lamp;

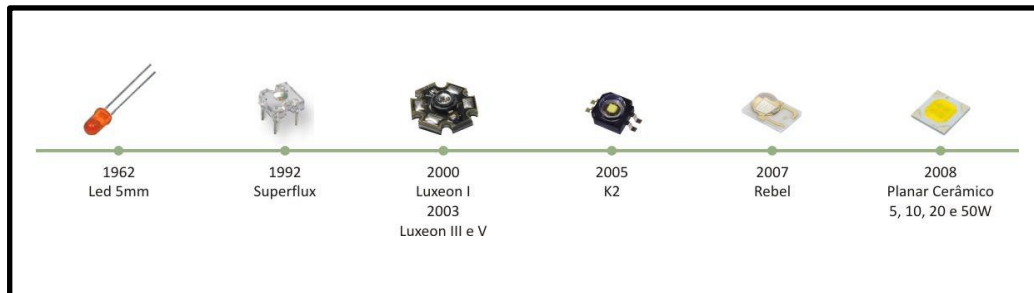
The third form uses a blue LED to excite the phosphor. Part of the emitted blue light turns yellow due to the presence of phosphorus, so the combination of the blue and yellow color produces white light. (SANTOS, 2015).

### 2.3 INVENTION OF THE LED LAMP

According to reports, the LED was present in everyday life, prevailing its red colors, in the 50s, and green, which appeared in the 70s. However, in order to have white LED light, it was necessary to discover the blue component.

Bakman (2018) describes that, for almost 30 years timeline as shown in figure 3, three scientists Akasaki, 85 years old, Amano, 54 years old, and Nakamura, 60 years old, sought to develop blue light, until in the 90s managed to achieve their goals, enabling their use for lighting.

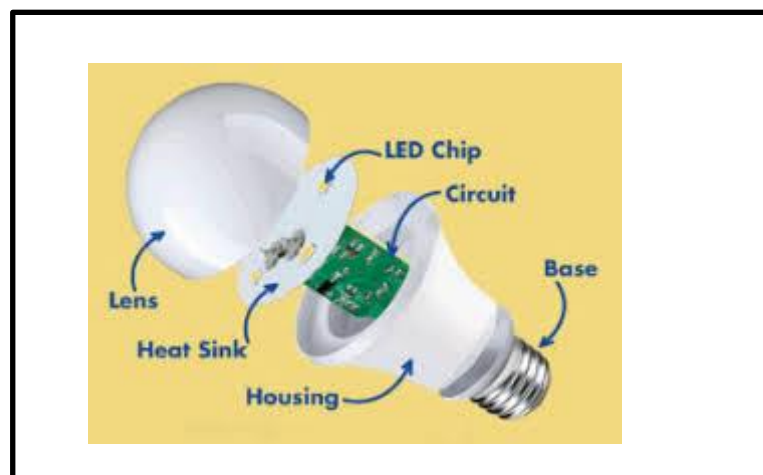
**Figure 3: LED and its evolution over the years.**



**Source: Torres (2015)**

Santos (2015) mentions that, the great discovery of the Japanese Akasaki and Amano and the American Nakamura made them in 2017 to be awarded the Nobel Prize in Physics, breaking the logic of past awards, much for having created a revolution in the sector as shown 4.

**Figure 4: LED lamps and their components internally.**



**Source: Total energy (2017)**

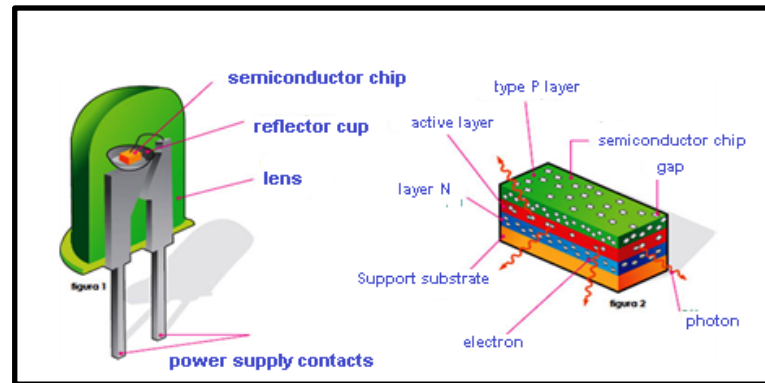
The creation of a blue light diode allowed a much more economical source of white light to be achieved. This invention was so important that it made scientists Isamu Akasaki, Hiroshi Amano and Shuji Nakamura win the 2018 Nobel Prize in Physics. In addition to the wide recognition of their work, they will receive 8 million Swedish kronor (US \$ 1.1 million) to share. (LUIZ; SILVA, 2017).

## 2.4 OPERATION OF THE LED LAMP

Cree (2018) mentions that the LED is a component of the bipolar type, that is, it has a terminal called anode and another, called cathode. Depending on how it is polarized, it allows the passage of electric current and, consequently, the generation or not of light.

The most important component of an LED is the semiconductor chip responsible for generating light. This chip has very small dimensions, as can be seen in figures 5 and 6, a conventional LED and its components.

**Figures 5 and 6: LED components**



Source: CREE (2018)

## 2.5 LED LAMP DEFECT

Fields; Santos; Roberto, (2015), mention that in the defect item there are some observations, there are issues that must be observed: the lack of manufacturing standards and standardization makes it difficult to control the quality of lamps found on the market due to the lack of a tax standard for LED products it generates discrepant differences in price and confuses the end consumer.

## 2.6 QUALITY OF THE LED LAMP

According to Santos et al (2015), LED lamps today are a real alternative to conventional lamps. They have several qualities such as:

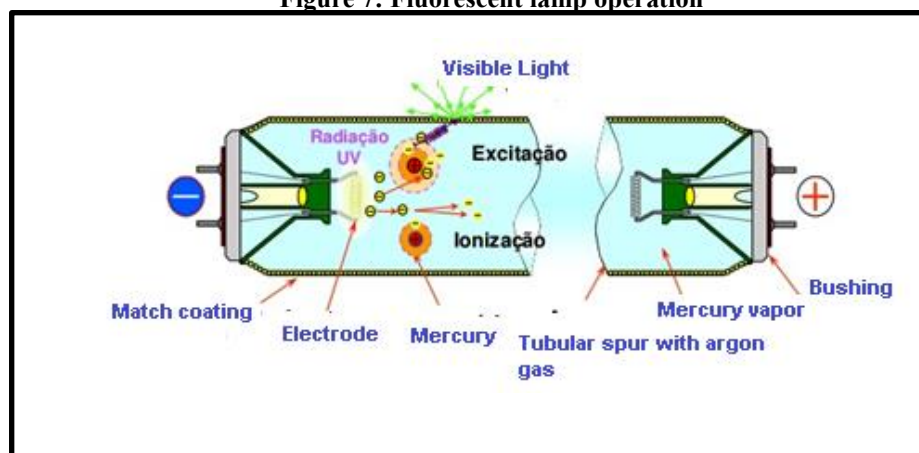
- ✓ Long durability, more than 100,000 operating hours;
- ✓ High luminous efficiency;
- ✓ Low energy consumption and little heat dissipation;
- ✓ Variety of colors;
- ✓ Great resistance to shocks and vibrations;
- ✓ Does not generate ultraviolet radiation and little heat dissipation;
- ✓ Little need for maintenance;
- ✓ Variable intensity control: varies according to the current flow;
- ✓ Bright, saturated colors without a filter: it occurs due to the monochromatic wavelength;
- ✓ Ecologically correct: does not use mercury or any other element that causes damage to nature;
- ✓ Absence of ultraviolet: Does not emit ultraviolet radiation and is ideal for applications where this type of radiation is undesirable. Ex .: Pictures - works of art;
- ✓ Absence of infrared: It also does not emit infrared radiation, causing the light beam to be cold;

- ✓ Reduction of electricity consumption, as they work with low power and great luminous efficiency;
- ✓ Absence of heavy metals, which makes it more advantageous for not having elements toxic to the environment and human health;
- ✓ Greater durability than that of all lamps used so far, estimated at up to 100,000 hours (if switched on for 12 hours / day, they last for about 22 years);
- ✓ Environmentally correct because its life cycle requires less energy and less raw material at all stages, from manufacture, use and disposal;
- ✓ Does not emit heat, which reduces the use of air conditioning and provides greater efficiency (converts more than 80% of energy into light);
- ✓ Does not emit IR and UV rays, which makes them suitable for lighting works of art and does not harm the skin;
- ✓ Does not attract insects;
- ✓ There are already marketable LEDs with high IRC, up to 90, which further increases the variety of applications for this type of lamp;
- ✓ With the use of lenses your beam can be directed;
- ✓ Possibility of dimming;
- ✓ Dynamic color control;
- ✓ Resistant to vibrations and impacts;
- ✓ The number of times and the fluency in which it is turned on and off do not change its useful life;
- ✓ Immediate ignition; Flexibility of use, shape, size and design.

## 2.7 COMPACT FLUORESCENT LAMP

Silva (2017) highlights, the following concepts about fluorescent lamps figure 7: they are lamps that use electrical discharge through a gas to produce light energy. Its efficiency is high and the service life is between 7000 and 10000 hours.

Figure 7: Fluorescent lamp operation



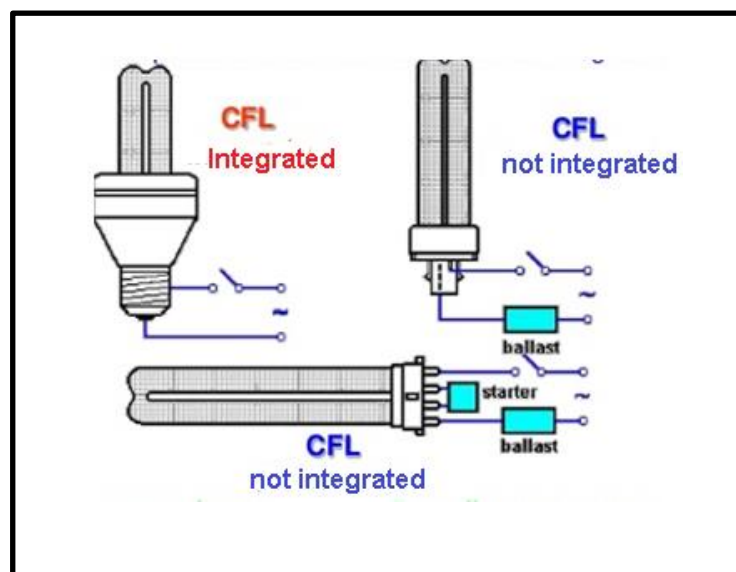
According to Miyashiro (2016) when an old fluorescent lighting is exchanged for modern fluorescents with an IRC of 85, there is a tendency to become entrenched. Some even say that the lamp is bad for your health,

as people get red. In fact, what happens is that we get used to seeing people in a light that reproduces colors poorly, making them pale and when we start to see them with their natural colors, we are strange.

### 2.7.1 CHARACTERISTICS OF THE COMPACT FLUORESCENT LAMP

Sousa; Ferrari (2015) cite that compact fluorescents D / E and T / E: they are similar in shape in relation to the two previous lamps, however, they have at their base four pins for fixing to the socket, thus indicating the use of specific electronic ballasts for its functioning. Unlike the two-pin ones that cannot use electronic ballasts for their operation, these four-pin D / E and T / E only work with electronic ballasts shown in figure 8.

Figure 8: Fluorescent lamps and their ballasts



Source: GIMI (2016)

### 2.7.2 INVENTION OF THE COMPACT FLUORESCENT LAMP

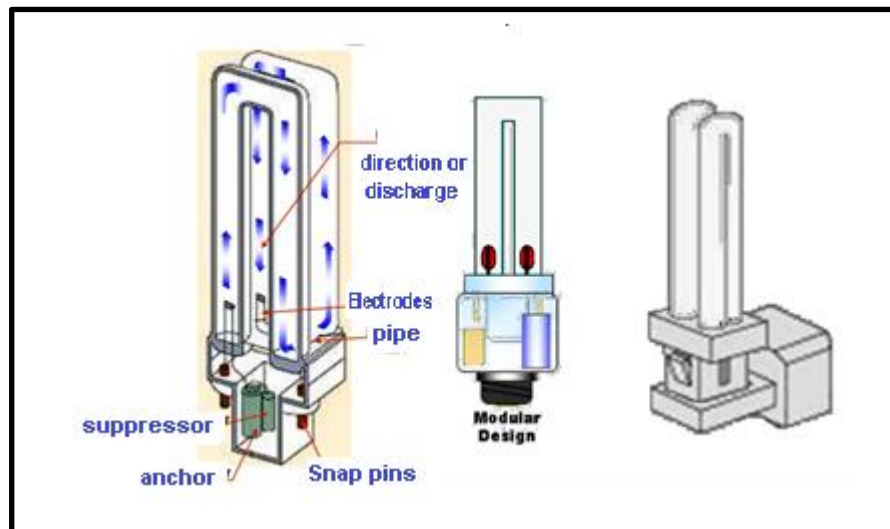
Fluorescent lamps have four basic components: a transparent glass tube, two electrodes, one at each end, a mixture of gases and a material that lines the tube internally. (VILUX, 2018, p.1).

### 2.7.3 OPERATION OF THE COMPACT FLUORESCENT LAMP

Godinho et al (2017) claim that the operation of compact fluorescent lamps consists of the electrical stimulation of special gases. They transform the ultraviolet rays into white light, as shown in Figure 09. This stimulation also follows steps such as:

- ✓ The electrodes generate an electric current that agitates the molecules of argon and mercury vapor, stimulating the emission of ultraviolet rays;
- ✓ UV radiation is absorbed by the inner lining of the tube, with a special chemical composition that transforms it into white light;
- ✓ The lamp circuits are composed of a wave rectifier, D1 to D4, the oscillators TR1 and TR2 13003 and the transformer L1, L2 and L3.



**Figure 09: Fluorescent lamp operation**

Fonte: GIMI (2016)

#### 2.7.4 DEFECT OF THE COMPACT FLUORESCENT LAMP

According to Sousa; Ferrari (2015) defects of the compact fluorescent lamp include:

- ✓ Constantly switching on and off: Compact fluorescent lamps should not be used in environments, or in a way that they are switched off and on repeatedly or repeatedly, as in corridors and presence sensors, as this causes great wear on the internal electrodes that make up the starting the lamp, and this means that the service life is greatly reduced.
- ✓ Vibration: It should not be installed in equipment prone to vibrations or mechanical shocks, as they will have a significant reduction in life.
- ✓ Moisture: Fluorescent lamps must be installed in locations that can provide protection from humidity, as their internal reactor can be damaged by containing electronic components.

#### 2.7.5 QUALITY OF THE COMPACT FLUORESCENT LAMP

Moraes Junior et al (2015) approach that, the quality of the compact fluorescent lamp is similar to the other conventional lamps, however with reduced size. They are available in various shapes and sizes and their base is threaded. They are of excellent quality of light, with high energy efficiency, in addition, they have a useful life of approximately 15,000 hours. Its electricity consumption is up to 80% lower compared to ordinary incandescent. Your IRC is approximately 85%.

#### 2.8 NBRS OF COMPACT LED AND FLUORESCENT LAMPS

Regarding ABNT NBR 14,538 (2000) - Compact Fluorescent Lamps with integrated ballast for general lighting:

The lamps with integrated ballast are units sealed at the factory and are not subject to repair. However, to simulate abnormal or fault conditions (as per sections 12 and 13), they can be opened.

## **2.9 ECONOMIC IMPACT GENERATED BY THE LED LAMP AND COMPACT FLUORESCENT**

As for compact fluorescent lamps of 15 or 18W replace a 60W incandescent lamp, however with consumption around 1,900 kWh, considering the same standards, quite economical when compared to incandescent. LED lamps equivalent to 60W of incandescent and 15W of fluorescent need only 8 Watts to emit light, reflecting a much lower expense than the others, about 1,000 kWh (KALACHE et al, 2017).

### **2.10 NATIONAL ELECTRICITY CONSERVATION PROGRAM (PROCEL)**

According to Bakman (2018) over these program years, more than R \$ 2.5 billion has already been invested by Eletrobrás, saving 92 billion kWh. In 2016, 11.7 billion kWh were saved, which is equivalent to the annual consumption of 6.02 million homes. The avoided CO<sup>2</sup> emission corresponds to 499 thousand vehicles in one year. In addition, more than 44 million pieces of equipment were sold under the PROCEL seal.

### **2.11 ACCEPTANCE ON THE BRAZILIAN MARKET**

Bakman (2018) claims that companies existing in the Brazilian market today can be classified as:

- a) Interference of inadequate illuminance levels and flicker in productivity levels;
- b) User satisfaction regarding the luminous flux of LED lamps in the work environment;
- c) Comparisons of the luminous flux of LED tubular and fluorescent tubes using Ulbricht integrating sphere, existing brands in the DIALux software and luminaire without reflector;
- d) Study of the Color Reproduction Indexes of LED lamps;
- e) Disposal of LED lamps; f) Reassess the calculation of the payback including the readjustments in the electric energy rate and the projected fall in LED prices.

## **3. MATERIAL AND METHOD**

### **3.1 COMPARATIVE ANALYSIS OF THE USE OF THE LED AND COMPACT FLUORESCENT LAMP**

Energy savings per year, including lamps, auxiliary equipment and air conditioning; - Savings in exchange for light bulbs, including equipment and labor; - Return on investment period; - Return on investment (RSI), defined as the relationship between money earned or lost through an investment, and the amount of money invested.

### **3.2 LIGHTING PROJECTS**

A quality lighting project must be given, by the relationships between: the distribution of light with visibility, integration with natural light and visual pollution; the relationship between the environment and the task location, considering light fixtures, color, glare, flicker and luminance: and the relationship between lighting and people or objects through modeling, points of emphasis, distributed within three aspects: architecture, economic and environmental aspects and human needs. (SOUZA, ET AL, 2017).

## 4 RESULTS AND DISCURSIONS

### 4.1. DISCURSIVE ANALYSIS

In the analysis, the prevalence of economy and quality of fluorescent lamps and LEDs was identified (62% quality LEDs and 38% fluorescent). In all discursive analysis, the importance to carry out the study was observed. By the calculation below:

$$\Phi = (E * S) / (Fu * Fd)$$

**Subtitle:**

$\Phi$  = Luminous flux in lumens (lm); E = Illuminance admitted to the environment; S = Area to be illuminated

Fu = Lamp usage factor

Fd = Depreciation factor of the same (luminaire or lamp);

To obtain the value of Fu, it is necessary to find the value of K, which is the reflectance index, in possession of the value of K. (BONA, 2010).

$$k = (l * c) / h * (l + c)$$

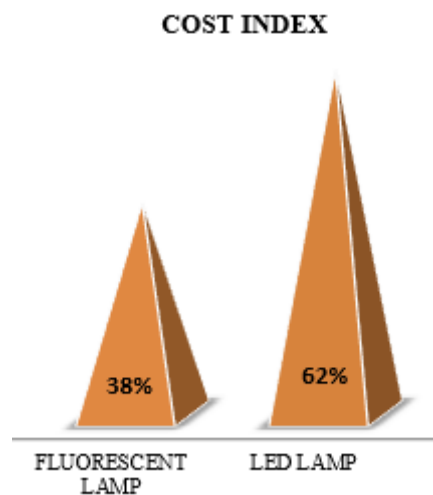
**Subtitle:**

K - Reflectance Index;

c - longitudinal length in meters; l - width in meters;

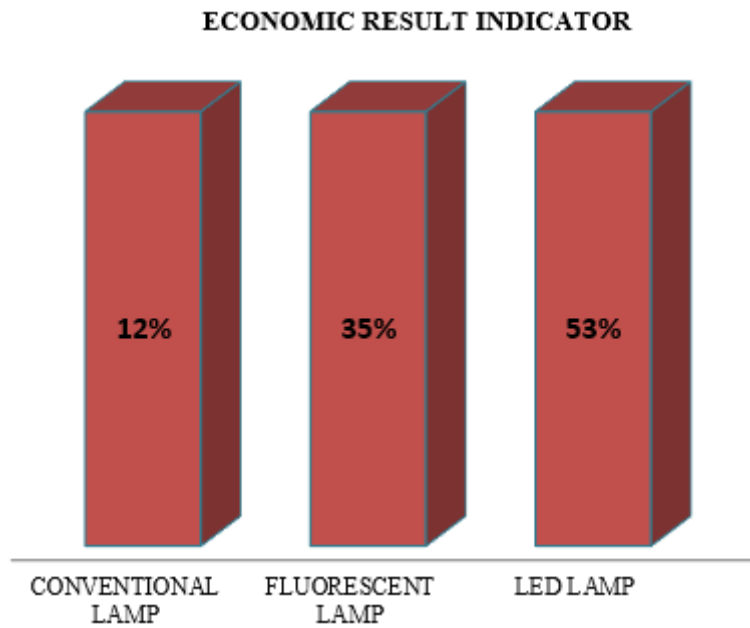
h - height of the installation floor in meters.

**Graph 1: Cost Index between LED and Fluorescent Lamps**



Source: Authors, 2020.

**Graph 2: Economy Result Indicator for Conventional, Fluorescent and LED Lamps**



**Source: Authors, 2020.**

The economic result indicators were calculated using the formulas of net present value (NPV) and internal rate of return (IRR), demonstrated at the beginning of the project, in the discursive analysis.

The result of the study addresses several benefits associated with the application of fluorescent lamps and LEDs. The advantage of using the compact fluorescent lamp system is 35%. As for LED it is 53%, and the conventional lamp is 12%.




While 26W compact fluorescent lamps have a median life of 10,000 hours (Reference: Osram Dulux® Superstar Micro Twist) 12W LED lamps have a life of 30,000 hours, that is, three times the first (KALACHE et al, 2013).

Considering the aforementioned useful lives and the scenario of use of the lighting system described above, replacement and replacement.

Kalache et al, (2013) cite some tips for recycling or repairing compact fluorescent lamps such as:

- ✓ Check if there is a fuse and if they are open;
- ✓ Perform visual inspection to detect cold welds, if in doubt re-weld;
- ✓ Measure the tube filament, the two filaments must be intact;
- ✓ Measure the semiconductors as transistors and diodes, making sure that none of the above items is damaged, one of these will be open.

**Table 1: Equivalence (W) of LED bulb**

		
<b>4,9W</b>	10W	35W
<b>7W</b>	15W	50W
<b>9W</b>	16W	60W
<b>13W</b>	23W	80W
<b>15W</b>	26W	90W
<b>18W</b>	29W	100W
<b>20W</b>	31W	110W
<b>30W</b>	46W	170W
<b>40W</b>	61W	225W
<b>50W</b>	74W	270W

Source: ELETROLUX (2020).

## 5. CONCLUSION

In this work, we approached compact fluorescent lamps and LEDs explaining an economic feasibility study. Describing information obtained from reference sources for compiling the study. It was found that Compact Fluorescent and LEDs are essential for the execution of a lighting project, where both represent an economically viable value for the professional and his client.

However, based on the analysis carried out, it is concluded that the use of LED technology for lighting entire environments is not yet economically attractive. This statement is justified due to the high costs of LED lamps on the market in relation to more traditional lamps such as compact fluorescent.

It should also be noted that the luminous efficiency of the LED lamp, in many cases, is superior to the luminous efficiency of compact fluorescent lamps, in some environments, depending on its purpose, this contributes to increase its attractiveness.

It should be noted, however, that due to the useful life of LED lamps, it is considerably longer than compact fluorescent lamps, being three times longer in the case analyzed.

As a suggestion for future work, a possible implementation of a lighting control of these luminous resources is left. The constant demand and improvements and technological improvement over time should decrease the price and access making future application feasible for the purely economic aspect. In the other contexts covered, we can highlight the quality of the LED and the main one the durability.

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