Economic analysis of an automated lighting system with presence sensor at a state school in the city of Manacapuru-AM

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Abstract

This work addresses the consumption of electricity in a state school in the interior of Amazonas, highlighting the importance of the search for available technologies to reduce energy consumption. In this context, the main objective of this study is to demonstrate the energy costs in the lighting system of a state school in the city of Manacapuru, and also to analyze economically the feasibility of an automated lighting system with presence sensor in classrooms. Since, the lighting of the classrooms is manual and depends exclusively on the need for a public servant to turn on and off the switches, thus, the energy consumption of the luminaires and the time in which the exacerbated consumption occurs directly affects the energy bills of the place. In the development of research, it was found that the use of presence sensors would result in both financial savings and an environmental issue. The results showed that it is possible to have a saving of 31.43% in the value of energy compared to the value currently paid. Therefore, the amount of the investment that costs R$ 1.998,00 would be paid in two and a half months. This way, it would contribute to the useful life of the lamps and thus avoid their early disposal, thus avoiding an environmental impact because the replacement and disposal of these materials are usually very harmful to the environment.

Keywords: *automation; energy saving; electric energy*

1. Introduction

Consumption of electricity grows along with the evolution of society. Thus, man has become highly dependent on this energy, which can be converted to generate light, move machinery and equipment, make various electrical and electronic products work, streamline communications, etc. Electric energy is an indispensable asset that plays a fundamental role in our homes, industries and businesses [1].

This energy can be used in many ways, but it is not available directly, it is usually obtained through the transformation of natural resources. The diversification of energy sources and the rational use of electrical energy are increasingly in the spotlight worldwide. This is partly due to the depletion of some energy sources and the high cost of producing others [1].

The Brazilian electricity sector has been suffering from difficulties in planning and guaranteeing the supply of electricity to meet the current increases in domestic demand. These difficulties are characterized both by the strong water crisis, more severe as of 2014, and by the increase in the consumption of electricity by Brazilians, which follows a global trend [2].

In Brazil, hydroelectricity is the main energy source in the country, however, since at the present time the environment still suffers a lot from conventional methods of energy production, which in their great majority are very aggressive to the environment [3].

Observing the relationship between generation and demand, it is noted that there is a great waste and inefficient use of electric energy. According to ABESCO (Brazilian Association of Energy Conservation Service Companies), between 2013 and 2016 alone, there was a waste of electricity in Brazil that cost R$ 61.71 billion, equivalent to 143,6 million GWh (gigawatt/hour) [4].

Therefore, there are several measures that can be taken to reduce energy consumption, such as the use of automation systems, enabling greater productivity, an optimization of processes, communication between equipment, greater accuracy in date and controls, increase in quality [5].

The use of measures of this nature, in addition to bringing direct advantages to the user, such as cost reduction, as well as ensuring indirect benefits, for example, reduction of maintenance costs, increased useful life of replaced systems. And in the same way it brings benefits to society, because it contributes to sustainable development, use of fewer natural resources and reduction of greenhouse gases [5].

Therefore, it is important that society seeks information and available technologies to reduce energy consumption. It is up to the government to create conditions for regulations and standards to encourage the development and use of more efficient equipment. Because wise use and concrete changes bring savings without diminishing comfort.

Energy saving imposes itself on any action within a company or institution and an automation system must provide the elements of decision making, through information based on date and history of operations performed.

Thus, large companies and institutions seek to control spending on electricity are concerned with emphasizing investments in the area of automation. For them, energy efficiency is a decisive factor when obtaining solutions aimed at maintaining the business [6].

This study aims to demonstrate the energy costs in the lighting system of a state school in the city of Manacapuru, analyze the economic of an automated lighting system with presence sensor in the classrooms, and also determine the benefits of inserting presence sensors to control unnecessary spending of energy.

2. Theoretical Reference

2.1 Importance of Energy in Contemporary Society

Energy is an indispensable input for society and in people's lives, since it is necessary to enjoy its benefits rationally and avoid waste.

It is coherent to affirm that technological advances are exactly associated with humanity's own growth, one of these perspectives can be shown when evaluating the function performed by electricity in people's daily lives. Electricity is now everywhere on the planet, in the homes of millions of people, it can be pointed out as one of the great revolutions of humanity since it has become one of the most relevant tools for the social and economic development of the modern world, consequently the contemporary society [7].

The consumption of electricity in the grid, for the years 2015 and 2016, by class of consumption and by subsystem. It is expected that the consumption of the industrial and commercial classes in the network will close the year with strong decreases of 3,0% and 2,5%, respectively. With this, consumption in the network for Brazil is down 1,1% [8].

The most diverse methods are used to obtain electrical energy, through hydroelectric plants, wind farms, photovoltaic panels, nuclear reaction, among many others, are many different ways to produce electricity. This variety of procedures for generating this energy is the result of a society that increasingly requires advantages provided by this innovation, and electricity is so important to the community in general, because it has also become an object of study in the academic field, in several lines of scientific research increasingly promising, thus motivating scientists and researchers in the development or design of new technologies for the capture of electricity and for its optimization [8].

Thus, even though energy resources may seem infinite or inexhaustible, in reality everything is exhaustible if not controlled, because they are very valuable resources for humanity, and it is necessary to seek a control, both for the individual economy and for society.

2.2 Efficiency in the Use of Electric Energy

It is always important to emphasize the need to question two fundamental points when the subject is efficiency of electric energy use. The first point is the environmental issue, whether the use of energy is sustainable or not. The second point is the financial issue, it is presumable that an electric energy optimization system will provide a possibly considerable saving, if it is well applied. Thus, it is not always easy to reconcile these points and have a system that satisfies everything, however, the search for effective and efficient systems should be permanent [9].

Involving the efficiency and effectiveness of the applicability of electric power "the fact that the consumer is particularly concerned with the initial costs related to the investment, without considering the operating costs that are significant and that act throughout the life cycle of the system deployed" [9].

Therefore, it is necessary to have a watchful eye so that it can eliminate waste and increase productivity. Therefore, energy efficiency consists in improving the use of energy sources, using them rationally. That is, a lower energy expenditure is studied to provide the same work or perform the same task [10].

The use of energy in societies generally goes through a series of stages of transformation from the stage when it is found in nature (primary energy) to the energy services that matter, such as light, movement or heat.

Energy efficiency is not rationing or "forced rationalization", which aims at reducing energy service or reducing the use of this service for energy saving. The term energy efficiency has been more widespread due to the need to reduce energy expenses as much as possible. This can be seen in industries, in commerce, in condominiums and even in residential installations, where the energy bill corresponds significantly in expenses [10].

Therefore, the use of initiatives that seek to achieve this improvement brings some benefits, such as positive impact on the economy, decreased emissions and impacts on the environment, improvement in processes and equipment and contribute to awareness against waste.

The use of a special purpose resource, designed to perform an action with greater efficiency is one of the first strategies of automation. Therefore, the automation and the truck productivity in parallel, in order to achieve the objectives previously defined, helping the organization to evolve with efficiency and effectiveness.

2.3 Lighting Automation

Artificial lighting is a tool where it has helped man in the adaptation of the new context, industrialization, man as a visual being above all. With this, the lighting that used to be rustic and archaic when passing through time was being transformed and gained other functionalities as an object of decoration. However, the artificial lighting remained with a continuous growth and its use each day more intense, emerging resources for its use [9].

The automation of lighting is the result of the development of artificial lighting, being a recent and innovative concept. However, today, we consider this resource as a limiter of energy expenditure, in order to optimize the use of electrical energy. Since electric power is not only a financial issue, but also an environmental issue, because its consumption causes environmental impacts, which may lead to the extinction of future energy production, being this a fundamental resource the basic needs of contemporary society. And, search for sustainable solutions aiming at minimal impact on the environment, has become a global priority. Thus, one of the best ways to save energy is by managing your own lighting system through the use of presence and movement sensors. Since the use of sensors enables a better environmental gain in terms of energy savings [9].

Presence sensors are proximity sensors that operate in order to detect the proximity, presence or passage of solid, liquid or gaseous bodies. Being characterized as passive infrared sensors, because they use infrared radiation or thermal radiation to detect proximity, where it is thanks to the heating due to agitation of atoms and molecules of the material that it can identify hot mass. And they are called passive, because they do not emit infrared light only to detect the movement of infrared light [11].

Thus, the procedure for managing the status of lighting by presence sensor this process occurs as follows: the lighting user approached the environment and is soon perceived by the sensors that immediately send the information so that the lamps can turn on, as shown in figure 1:

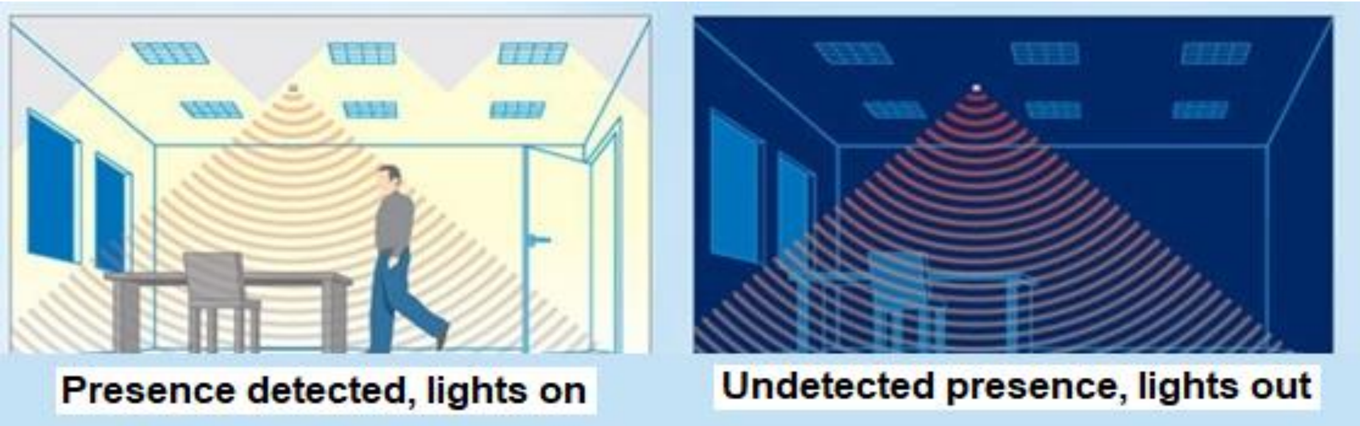

Figure 1 - Detection area of the presence sensors.
Source: Electrician Brazil, 2014.

The presence of the human body can produce enough infrared radiation to excite a sensor with pyroelectric material. In other words, the light signal emitted by the human body diverts the light beams emitted by the beams activating the sensor and this beam is converted into an electric signal, activating the lamp through an electric circuit between the lamps and the presence sensors [12]. Therefore, there is the capitation of the hot mass.

Consequently, after leaving the environment used, the sensors do not recognize the presence of the user, i.e., the movement of hot bodies, instantly sending the information to the lighting shutdown after the set time and not being detected any more movement in this interval. It can have the adjustment of the expected time between 10 seconds to 10 minutes, depending on the preference of the user [12]. Thus, turning off the lamp. Figure 2, shows the installation of the Intelbras ESP 360+ presence sensor:

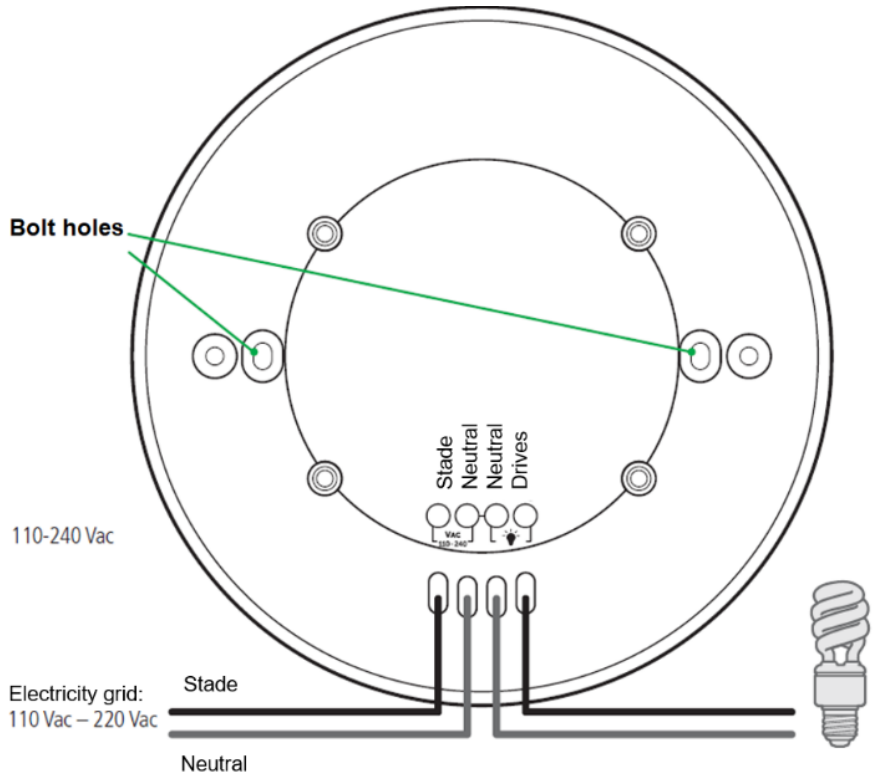

Figure 2 – Installation of the presence sensor.
Source: Intelbras, 2018.

Different from the complexity of some other mechanisms for optimizing the consumption of electrical energy, when viewing figure 2, we notice the simple connection of the sensor in the lighting circuit. In addition, depending on the type chosen for the location of the sensor in the wall vertically or in the ceiling, will determine the model of 360 degrees or 180 degrees [12].

In close proximity to places that have a very large variation in temperature, such as, for example, place where we have a lot of sun exposure or strong wind, such as windows, doors, fireplace, heater, air conditioning [12].

In short, they have the advantage of being easy to apply, making them low cost and high return, considerably avoiding energy waste, generating sustainability and financial gain. Although, it can cause a visual discomfort, even if it is minimal, and in its installation and presents a cost of installation and purchase of equipment, however it is only at the time of investment for a future economy.

3. Methodology

3.1 Study Area

The study area is a state school, located in the Terra Preta neighborhood of the city of Manacapuru/AM, on Carolina Fernandes street. The public institution works in the morning, afternoon and night shifts, serving students of regular high school and education of young people and adults (EJA).

Figure 3 – Study Area.
Source: Google Earth Pro, 2019.

The field of study was limited to classrooms only. Allowing the specificity of the theme and thus it was possible to obtain the date for the formulation of the problem of each item pointed out by the analysis of the field research, proposing viable solutions for the competences of the people involved.

3.2 Date Collection

The study was characterized as an exploratory and descriptive research, in which it seeks to make the subject explicit or build hypotheses, involving bibliographic survey, while in the descriptive the researcher needs to raise various information about what he wants to research, seeking to describe facts and phenomena of a reality [13].

As for the approach, the qualitative/quantitative method was chosen. This method explains the reason for things, specifying what needs to be done to solve a problem without worrying about the proof (qualitative) [14].

The date collection took place through visits to the educational institution, and by observing the students and school collaborators, in order to seek information on how the lighting system is used and how to avoid wasting energy, using the exploratory research method.

It was observed the consumption by school shifts, the times are: morning time (from 07h to 11h and 30min); afternoon time (from 13h to 17h and 30min); and night time: (from 18h and 30min to 22h and 15min), according to the functioning of the school.

Another method used was the comparative analysis between the use or not of sensors for the activation of fluorescent lamps. The comparison was made based on a financial simulation of the price spent for each of these two systems and on the economic feasibility of implementing the sensors and the time of return on your investment.

4. Analysis and Discussion of Results

For the analysis of the date are presented in table 1 the quantities of lamps in each environment and their powers, there is only 1 type of lamp in operation at the study site, which is 40W fluorescent and the model of the luminaire is gutter type, which then receives 2 lamps. Although some lamps are burned out, in this calculation we will consider the full operation of all devices. Below table 1:

Table 1 - Survey of wattage consumption per room.

Shift	Classrooms	How many luminaires	How many lamps	Lamp wattage	Power per room	Power per room (total)
Morning	18	6	12	40 W	480 W	8.640 W
Afternoon	18	6	12	40 W	480 W	8.640 W
Night	18	6	12	40 W	480 W	8.640 W
TOTAL POWER CONSUMPTION IN WATTS						25.920W

4.1 Consumption Calculations

The monetary value charged for energy consumption is generally based on consumption in kWh (kilowatt-hour), for each kWh is multiplied by the service charge, as shown in equation 1:

$$V\text{alue } (R\$) = \text{quantity } (K\text{Wh}) \; x\text{tariff } \left(\frac{R\$}{kWh}\right) \qquad (1)$$

The rate adopted here is: R$ 0,70 /kWh. It was based on the average of the 2018 tariffs charged by Eletrobrás Amazonas Energia, which is the company responsible for energy distribution in the state of Amazonas.

The consumption time includes the period that the lights are turned on, which starts at 6 hours and ends at 23h and 15min. It has an operating period of 17 hours and 15 minutes. Taking into consideration a month with 30 days, being 22 working days, we have the amount of hours of use per month. According to table 2 below:

Table 2 - Hours of use of classroom lighting - monthly

MONTHLY HOURS OF USE					
CONSUMPTION	**START**	**END**	**DAILY HOURS**	**WORKING DAYS**	**HOUR/MONTH**
	06:00	23:15	17:15	22	377,3

Monthly monetary consumption kWh = (216 lamps x 40W x 377,3 hours/month)/1000 x tariff (0,70) kWh = R$2.281,91 monthly, considering manual lighting.

However, with the use of presence sensors there will be a lower consumption of hours, and thus achieve a noticeable saving in energy consumption, as shown in table 3:

Table 3 - Hours of use of lighting with presence sensors.

MONTHLY HOURS OF USE WITH PRESENCE SENSORS					
SHIFT	**START**	**END**	**TOTAL HOURS**	**WORKING DAYS**	**HOUR/MONTH**
Morning	07:00	11:30	04:30	22	91,3
Afternoon	13:00	17:30	04:30	22	91,3
Night	18:30	22:15	03:45	22	75,9
Total hours of luminaire consumption					258,5

4.2 Comparison of Consumption

Figure 4 can bring a better visualization of the comparison of the two processes manual (with switch) and automatic (with sensor):

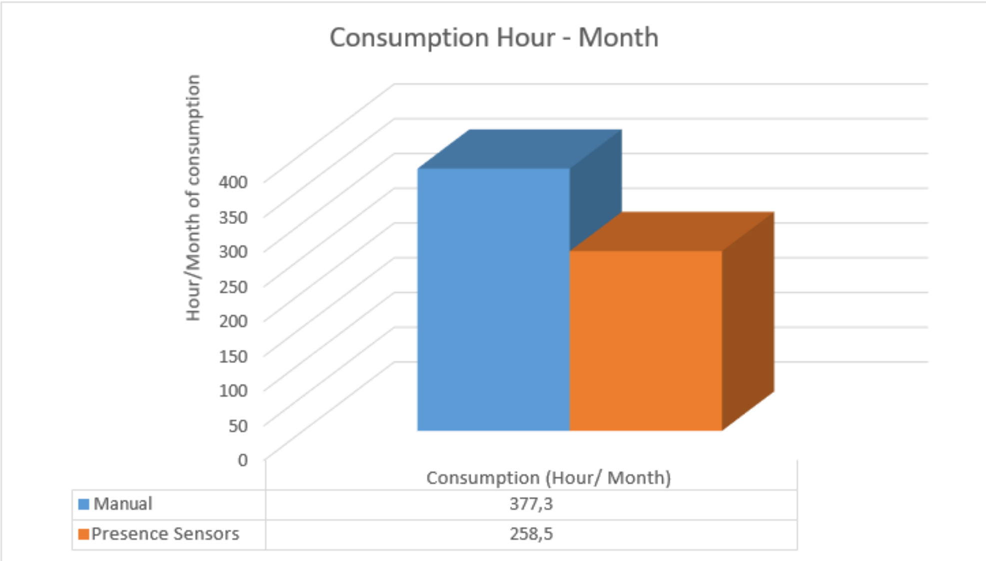

Figure 4 - Comparison of hour-month energy Consumption.

From figure 4, it is noted the reduction of 31,43% of consumption in the energy of the luminaires, which results in the economy of the cost of energy expenses, calculated above the tariff of R$ 0,70, as shown in figure 5.

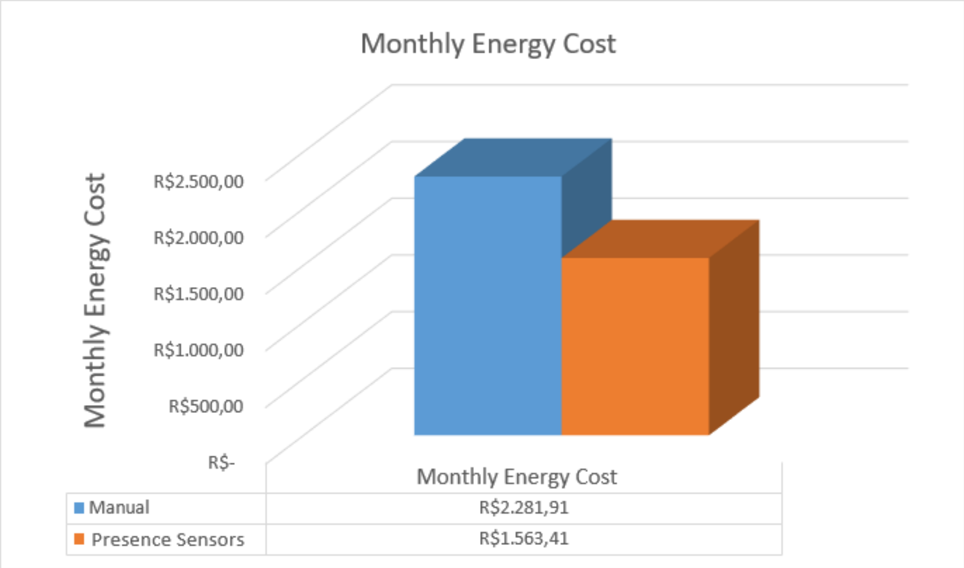

Figure 5 - Comparison of hour-month energy consumption.

The comparison of figure 5, in which brought a monthly result of R$ 2.281,91 for the use of switches, and R$ 1.563,41 for the automatic process with sensor. That is, a saving of R$ 718,50 per month, then a saving of R$ 8.622,00 per year.

4.3 Calculations for Decision Analysis and Investment Evaluation

It was performed the measurement of the present value of the cash flows generated by the project throughout its useful life according to the Intelbras manual of the ESP 360+ sensor has a maximum detection distance of 18 meters and 360 angle of detection, so it will be necessary 1 sensor for each environment, 18 sensors leaving everything in a range of R$1.008,00. As shown in Table 4.

Table 4 - Sensors for each environment.

Environments	Quantity of sensors	Unit Value R$	Total Value R$
18 ROOMS	18	R$ 56,00	R$ 1.008,00

Adding the total value of table 4 to the value of the installation service that costs R$ 55,00 [15],that is, R$ 990,00, so the value of the investment is R$ 1.998,00with a minimum required rate of 10%a year and a useful life of five years, we have table 5.

Table 5 - Implementation cost.

Environments	Quantity of sensors	Sensor value	Installation value	Total value
18 ROOMS	18	R$ 56,00	R$ 55,00	R$ 1.998,00

With the value of the investment we can apply the Net Present Value (NPV) method and perform the analysis of the economic feasibility [16]. The following equation refers to the NPV formula:

$$\text{NPV} = -\text{I} + \sum_{t}^{n} = 1 \frac{FCt}{(1+k)^t} \tag{2}$$

Replacing the data, we have in the equation 2, read the equation 3:

$$\text{NPV} = -1.998{,}00 + \frac{8.622{,}00}{(1{,}1)^1} + \frac{8.622{,}00}{(1{,}1)^2} + \frac{8.622{,}00}{(1{,}1)^3} + \frac{8.622{,}00}{(1{,}1)^4} + \frac{8.622{,}00}{(1{,}1)^5} = \text{R\$ } 30.682{,}12 > 0 \tag{3}$$

The NPV is positive, which indicates the economic viability of the alternative. Thus, the implicit protection of R$ 30.682,12 is actually a profit of economic value, which exceeds the required minimum earnings standard – 10% per year.

Another method to be implemented is payback, which consists of knowing the recovery time of an investment. Let's consider then that the Minimum Rate of Attractiveness (MAT) is established as 10% per year for this investment. This way, it is enough to make the following calculation to find the value of the discounted payback:

$$\text{I} = \sum_{n}^{T} = 1 \frac{FCt}{(1+k)^t} \tag{4}$$

Replacing the values in equation 3, we get equation 5:

$$\text{T} = \frac{1998}{\frac{8622}{1{,}1}} = 0{,}21 \text{ years} \tag{5}$$

Therefore, the investment of R$ 1.998,00 shall be recovered on at least 0, 21 year, calculation obtained by the above equation, enabling a very promising economic viability. This indicator is used together with the NPV in which they indicated that the investment is viable and the payback that the value of the investment will be recovered. That is, in 2 months and 15 days, the investment in sensors is paid, which results in a viable cost-benefit.

5. Conclusion

One of the purposes of automation is to achieve energy savings by making the process efficient through presence sensors, without the real need for manual handling either to turn on or off the lights. In this context, the construction of an innovation in which the optimization of energy resources competes and the possibility of a new way to reduce costs for public institutions are potentially efficient perspectives. They aim not only at improving the current economic situation, but also at stimulating people to change their attitudes and behaviors in relation to the exacerbated consumerism of natural resources.

The presence sensor control system, if applied at school, enables a possible innovation in the lighting structure. The results showed that it is possible to have a saving of 31,43% in the value of energy compared to the value currently paid. Therefore, the investment amount that costs R$ 1.998,00 would be paid in 2 and a half months.

In this way, it would generate a constant economy, with a guarantee of up to 5 years, avoiding waste and contributing to a more sustainable environment, because in addition to minimizing unnecessary consumption would contribute to the useful life of lamps and thus avoid their early disposal, thus avoiding an environmental impact because the replacement and disposal of these materials are usually very harmful to the environment.

As future works, it is proposed to expand the forms of energy control, not only with lighting, but also with air conditioners, since they are turned on in the same period as the luminaires and consume an even greater amount of energy. Thus, to propose the insertion of automatic trigger controls based on the shift times. And also, to verify the use of natural lighting and the feasibility of changing fluorescent lamps for LED lamps.

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