Assessment of Energy Conservation Resource considering the Lighting service in Academic buildings seeking sustainable Energy planning

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Abstract. The objective of this work is to evaluate the full potential, since include technic-economic & environmental & social & policy dimensions, of the benefits of applying a demand side energy resource for considering for implementation of an energy efficiency project. Methodologically, this assessment was made by establishing values for energy resources in attributes and sub-attributes in the four different dimensions of the Integrated Resources Planning, which are: environmental dimension, social dimension, political dimension, and economic-technical dimension. The analysis of the energy efficiency project in four different perspectives makes this work innovative, most of the papers found in the academy does not consider the four dimensions studied here. The accounting of the full potential is also considered within this methodology, which makes it possible to evaluate its benefits in traditional and economic-technical aspects, as well as the dimensions of sustainable development. A case study was also developed on the replacement of traditional lamps for LED lamps in higher education institution. Results showed a decrease in CO2 emission in the atmosphere of 11.94 tons, the creation of 21 temporally job positions, reduction in the release of 52g of mercury in the environment and an injection of nearly 2 million dollars into the economy. Therefore, it was systematically proved that the benefits of the energy efficiency evaluated in the four dimensions increase sustainable development to all of society. With this work it is possible to concluded that all the society is impacted in different aspects after the implementation of an energy efficiency project in an energy consumer company e not only these companies

1. Introduction
Energy efficiency has had an impact to society, governments, and companies since the 1970s. It can be explained as a way of ensuring safety in energy supply [1], a result of the world oil crisis in 1973 [2]. In addition to this important factor for the implementation of energy efficiency projects, it also started to be considered as a good opportunity to reduce costs for consumers with the implementation of energy efficiency [3]. In other words, it was also considered to use less energy to produce the same planned volume. However, since the 1990’s, energy efficiency has become more relevant to companies and society, forcing governments to create public policies geared towards such projects [4]. Until then, energy efficiency consisted of creating educational materials and programs for a more efficient consumption of energy, and adequacy to the hours when sunlight can be better used during the day [3].
Later, the implementation of more efficient equipment became an alternative for energy efficiency projects [5]. Since the beginning of the 21st century, energy efficiency has become a way for companies to reduce costs [6], as well as a fundamental way to reduce global warming, a critical subject in debates on sustainability [7]. Energy efficiency now incorporates all the previous concepts; it is considered a group of actions that, when combined, can provide options of sustainability, economic development, cost reduction to companies, and a guarantee of energy supply to society [8].

Due to increasing competition, companies are seeking cheaper and more efficient processes. In this context, the energy bill has become one of the most relevant costs that need to be worked on. Energy efficiency measures tend to have positive economic impacts in addition to their environmental appeal. Light retrofit in builds is a very common energy efficiency project also with efficient results, it offers significant savings in the energy account and potential reduction in the CO2 emissions [9].

This study aims to evaluate the full potential, since include not only for its financial aspect, what is done in the economic-technical dimension, but also, systematically, for all the aspects that regard sustainable development, to provide a complete validation of the benefits of energy efficiency measures, that are made in the environmental, social and politic dimension. To this end, it was conceptually and methodologically based on the Integrated Energy Resources Planning (IRP), which is described as a formation of a set of strategies to optimize the use of energy resources [10], a combination of energy management actions on the supply side and the demand side [11], or even as a planning that incorporates actions and strategies of Demand Side Management (DSM) to structure energy supply [12], with the possibility to provide the same level of importance to the demand and supply resources [13].

Full potential is achieved by the IRP methodology, which provides the basis for energy resources demand side management and has as focus of study: a higher education institution of a large company in the Brazilian educational sector. Specifically, this work analyses a retrofit of the lighting system in the studied company.

The fact that an actual energy efficiency project was studied as it was applied in a consuming company supports and validates its replication in other companies or other energy efficiency projects

2. State of Knowledge

Analysing a project feasibility, since its technical and financial situation to its result monitoring phase is fundamental in any type of company. From this importance arise different models and methods for projects evaluation.

An example is the Balanced Scorecard (BSC), considered a strategic management tool to analyse internal and external scenarios of the company, also, its purpose is supporting the company's managers in the development and execution of strategic actions in the long term [14]. Another method for project evaluation is Goal Question Metrics (GQM), this is an approach that starts with the goals and from them are outlined strategies [15]. It is also cited a very famous method in the financial field, the Monte Carlo Simulation, which uses probability distribution to simulate financial return on a given investment [16]. Finally, a last example is the Life Cycle Assessment (LCA), which analyses environmental impacts associated with a given product, process or activity, the application of this method has as a sequence: to define the project’s goal and scope: list analyses that should be made and the outputs of each of them; expected impact assessment [17].

Meanwhile, to evaluate energy efficiency projects, specifics methods can be used. The most common and simple way to measure the energy efficiency obtained by implementing a certain resource is to compare the consumption required for the operation of a consumer with the actual energy supplied to this consumer; the lower the volume of required energy and the closer the delivered energy is, the more efficient will the consumer’s energy management be [18].

Another way to measure energy efficiency projects or structure energy management is by creating four different modules: developing a database of the studied company; structuring the company’s demand regarding energy efficiency; structuring the company’s consumption profile; and estimating future
energy consumption. With these data, it is possible to make decisions on energy resources implementation [19].

As mentioned before, the IRP methodology used as reference in this work considers the characterization of energy resources on supply and demand sides in four dimensions of analysis: environmental, social, economic-technical, and political. This characterization is given by the Full Potential Accounting and Validation (FPAV) methodology.

The goal of FPAV is to estimate the impacts of the use of an energy resource and incorporate the externalities of each of the dimensions into the analysis of these resources. More specifically, FPAV is a method in which both the Full Costs Analysis (FCA) and the Analytic Hierarchy Process (AHP) are applied [20]. The FCA can also be defined as a method in which political, social, environmental, and economic-technical subjects can be connected to traditional models [21]. The AHP is a method created in 1987 by Saaty that requires hierarchy or relationship structure in a problem to create measures between the analysed groups or objects [22].

The relationship among the methodologies cited above is best shown on Figure 1. Where AHP and FCA are the inputs for FPVA, on the other hand, Full Validation of the four dimensions is the output for FPVA.

![Figure 1. Relationship among AHP, FCA and FPAV](image)

In this study, the starting point of the analysis is the lighting system, an important Energy Resource on the Demand Side (ERDS). Is evaluated the impact of replacing the inefficient fluorescent, incandescent and halogen lamps lighting system with an efficient LED lamps lighting system. To this end, the analysis of all IRP dimensions, and their respective attributes and sub-attributes, was based on the FPAV.

Before the analysis of each dimension, the attributes and sub-attributes that were considered or disregarded in the analysis are presented. The ones indicated with the ✓ symbol was included in the analysis, and the ones that were not analysed are marked with the ✗ symbol.

Analyses that show currency were made in Brazilian real (R$), but were converted to U.S. dollar (USD), considering the exchange rates on December 31th, 2019, when USD 1.00 equalled to R$ 4.031. It is already known that the lighting system retrofit can show significant results in different aspects, electricity consumption and demand reduction, indoor comfort and environmental benefits [22].

3. Description of the case

The higher education institution studied in this work is in the city of São Paulo and belongs to a large private company in the education market of Brazil and the world. With more than 4,000 attending students and a little more than 30,000 m² of constructed area, including the areas that most consume energy, as classrooms, Health and Engineering laboratories, recording studios for online classes, an auditorium, administrative areas and a large common area for students, and the areas that are not energy intensive consumers, as outdoor garden, staircases, corridors and car parking. For all year 2019 its total energy consumption was 1,132,815.10 KWh and the monthly contracted demand was 200KW.
Due to the pandemic crisis of 2020, this work analyses energy consumption in 2019, when classes were in person and not online, as it had been in 2020. Such consumption curves in which both years are compared are shown in figure 2, in KWh.

![Energy consumption in 2019 and 2020](image)

**Figure 2.** Energy consumption in 2019 and 2020

In overall there are about 40 different energy consumers equipment, for instance, televisions, computers, printers, fans, etc. However, the main ones that are always used in efficiency energy programs by the studied company are the lamps and air conditioner, due to them intensity energy consumption.

One of the essential steps for the elaboration of the FPAV is the listing and selection of resources, where all the possible types of energy resources in the evaluated company must be identified [23], as presented in Table 1, where the first column refers to the energy resources, that are installed in the education building consume or generate energy, on the other hand, the second column refers to the equipment of usage and related to the energy resource.

| Energy Resource   | Related Equipment         |
|-------------------|---------------------------|
| Lighting          | Lamps                     |
| Cooling system    | Air conditioner           |
| Sound system      | Microphones and speakers  |
| Video system      | Video cameras             |

The implementation of ERDS consists in combining energy efficiency measures with energy use management measures to optimize the end use of energy [21]. Thus, the analysis with the lighting resource was chosen for its representativity in the company’s energy bill and for being easily replicable to other facilities of the same company.

Led lamps are less damaging to the environment and consume 85%, 65% and 50% less energy than incandescent, compact fluorescent and sodium-vapor fluorescent lamps, respectively [24].

Table 2 presents the relation of the current lighting system installed in the education institution, referred to as the inefficient lighting system, which was collected by the own researchers, with its respective models and power (in watts). Table 3 presents the replacement system, referred to as efficient system, with LED lamps compatible with the inefficient system’s lamps which was proposed by a specialist company of the sector.

| Lamp         | Power W | Quantity | Total Power in KW |
|--------------|---------|----------|-------------------|

**Table 1.** Inventory of the energy resources.

**Table 2.** Inefficient lighting system
### Table 3. Efficient lighting system

| Lamp                           | Power W | Quantity | Total Power in KW |
|--------------------------------|---------|----------|-------------------|
| T8 18W LED                    | 18      | 3,151    | 56.72             |
| 30W LED bulb                  | 30      | 3        | 0.09              |
| 15W LED tube                  | 15      | 576      | 8.64              |
| 18W Downlight                 | 18      | 43       | 0.77              |
| 15W LED bulb                  | 15      | 93       | 1.40              |
| T8 8W LED                     | 8       | 149      | 1.19              |
| 7W LED PAR                    | 7       | 16       | 0.11              |
| 44W LED HO                    | 44      | 34       | 1.50              |
| 5W LED bulb                   | 5       | 25       | 0.13              |
| 10W LED bulb                  | 10      | 51       | 0.51              |
| 120W LED reflector            | 120     | 8        | 0.96              |
| **Total**                     | **4,149**| **72.01**|                   |

4. Development and evaluation methodology

The presented results consist in the validation of the energy resource studied in the IRP dimensions. To make the validation possible, it is necessary not only to apply the FPAV method, but also to determine which attributes and sub-attributes can, and must, be validated in the resource in question. For some sub-attributes, it is necessary to establish premises that can be applied to all energy resources that may be analysed in a consuming company.

Once the validation in the analysed dimensions is carried out, it is possible to structure the result of the analysed resources, which becomes the output required for decision making by the consuming company.
company’s managers. The results obtained from the analysis in one facility can be expanded to the other facilities, with a proper comparison parameter, such as the size of the constructed area.

4.1. Environmental dimension
Validation of the environmental dimension consists in analysing three attributes: Airborne environment, Land environment and Aquatic environment, which are presented in Table 4 below, with their respective sub-attributes [20].

| Attributes            | Sub-attributes                          | Analysis |
|-----------------------|-----------------------------------------|----------|
| Airborne environment  | Atmospheric pollutants                  | ×        |
|                       | Greenhouse gases                         | ✓        |
|                       | Ozone-depleting gases                    | ×        |
| Terrestrial environment| Waste                                   | ✓        |
|                       | Land occupation                          | ×        |
| Aquatic environment   | Water demand, consumption, and flow      | ×        |

The environmental characterization of demand side energy resources must be made considering the environmental impacts caused by the implantation of the resource and the impacts avoided by the energy savings brought by such resource [20].

The replacement of the inefficient lighting system lamps for LED lamps reduced total power used, the consumption in KWh of the education institution with the lighting resource can be determined. As informed by the Utility Department Manager of the Company, all the numerical analyses must be done considering 1,485 hours per year of operation. Thus, to find the saving in energy consumption, must be considered that:

IS: Full power of the inefficient system
ES: Full power of the efficient system
H: Hours of operation in one year
S: Savings in KWh

Reduction in energy consumption (in KWh) can be obtained by the following formula:

\[ S = (IS - ES) \times H \]

\[ S = (144.22KW - 72.01KW \times 1,485) \]

\[ S = 114,380.84 \text{KWh/year} \]

Reduction in energy consumption also reduces greenhouse gas emission, including carbon dioxide (CO2). According to the Brazilian National Energy Balance, in 2018, carbon intensity in energy generation in Brazil was 104.4kg CO2/MWh [25]. Considering Brazilian matrix as parameter, the savings in KWh presented above result in a yearly reduction of 11.9 tons of CO2.

Since LED lamps are mercury free and do not contaminate land and water [24], the environmental damages to land that can be caused by the disposal of fluorescent lights must be analysed within the scope of the Terrestrial Environment attribute, considering the frequency in which an LED lamp is disposed of, having as basis for calculation its lifetime in hours in relation to the frequency in which fluorescent lamps are disposed of.

This attribute would not suffer any impact if Brazil’s National Solid Waste Policy (PNRS) of 2010 were correctly adopted [27]. In that case, the removed lamps would be correctly disposed of, which would not result in any environmental impacts on the terrestrial environment.

As determined by PNRS of 2010, lamps must be disposed of through a reverse logistic system, which should be structured by the manufacturers, importers, distributors, and dealers. However, even though PNRS is considered an environmental landmark in Brazil, it was not capable of changing the population
behaviour regarding waste disposal. More than that, according to the policy, the cities are responsible for developing local solid waste plans; however, in many of them, the plans were not developed, which led to failure in solving the problem of solid waste disposal.

If we also add to this condition the fact that the education institution does not have any specific solid waste disposal policy, as informed by the managers of the studied company, the analysis of this attribute becomes highly important, once it makes it clear that the lamps removed for the installation of the LED lamps will not have the proper destination for disposal.

Since the T8 18W LED lamp is the direct substitute for T8 36W tube fluorescent lamp, 32W fluorescent lamp and 40W fluorescent lamp, this specific analysis about the environmental impacts involves a comparison between these three models of fluorescent lamps and the T8 18W LED lamps. The fluorescent lamps have a total lifetime of 8,000 hours, while T8 tube LED lamps have a total lifetime of 40,000 hours [26]. Therefore, considering the same premises regarding hours of use, the 3,151 T8 tube LED lamps would be replaced after 26 years; on the other hand, in the same period, 15,755 T8 tube fluorescent lamps would be replaced. Complementing the technical data presented by Cepel (the Electrical Energy Research Centre), the three fluorescent lamps models cited above have 3.5mg of mercury per unit [27]. Thus, by avoiding the disposal of 15,755 T8 tube fluorescent lamps, the disposal of 73.5g of mercury in the environment would also be prevented, a volume that is way above the determination of Resolution No. 420 of 2009, which determines the maximum volume for prevention of 0.5mg per 1kg of dry land [28].

As it is true for the terrestrial environment, the fact that Brazil has not yet successfully implemented PNRS, along with the fact that the studied company also does not have any type of specific policy for lamps disposal, it can be concluded that the modernization of the lighting system also prevents environmental damages to the aquatic environment. Regarding the Water Quality sub-attribute, a single fluorescent lamp has enough mercury to pollute 20 thousand liters of water [31]; therefore, the 15,755 T8 tube fluorescent lamps could pollute more than 317 million liters of water. Still on the aquatic environment, the maximum accepted mercury level in non-predatory fish is 0.5mg per Kg, while in predatory fish, the maximum accepted mercury level is 1.0mg per Kg [32]. Therefore, the 73.5g that were prevented from disposal would be enough to contaminate 111 tons of non-predatory fish and 55.5 tons of predatory fish.

4.2. Political dimension

Within the IRP perspective, in the political dimension, factors that can lead and assess the development and implementation of a given energy resource were analysed [19]. This dimension approaches the Government’s actions towards the development and implementation of the energy system, which can be made by creating public policies that encourage the development of projects connected to energy efficiency, such as ICMS Convention 16, published on April 22nd, 2015, that allows the States to exempt from the Brazilian value-added tax (ICMS) the energy obtained from micro generation, when consumed by the generator agent themselves. Table 5 below presents the attributes and sub-attributes of the political dimension.

| Attributes                                      | Sub-attributes                                      | Analysis |
|------------------------------------------------|----------------------------------------------------|----------|
| Political support                              | Political instruments                               | ✓        |
|                                                | Legal aspects                                      | ✓        |
|                                                | Possession                                         | ✓        |
| Possession and energy integration of resources | Ownership                                          | ✓        |
|                                                | Energy integration                                 | ✓        |
|                                                | Residential, commercial, and industrial consumers  | ✓        |
|                                                | Generators, distributors, and producers            | ✓        |
|                                                | Federal, state and city government                 | ✓        |

Table 5. Political dimension attributes and sub-attributes
Overall, it can be said that the political support deems fundamental to have actions in a global level, such as the Paris Agreement, whose purpose is to limit the increase of Earth’s temperature in 1.5°C, regarding pre-industrial levels [30]. Therefore, Brazil is compromized to the UN, as it is a signatory of the aforementioned resolution, and must establish policies and goals that contribute to the reduction of Earth’s temperature, which can be achieved through the encouragement of new energy efficiency projects.

Another form of political encouragement in Brazil is Law No. 9,991, published in July 2000, which determines that holders of concessions or licenses destine 1% of their operational income to research and development in the energy sector, and to energy efficiency programs in end use, where 0.75% should go to the former and 0.25% should go to the latter. These energy efficiency projects include several actions, including the creation of incentives to the replacement of fluorescent or incandescent lamps with LED lamps. In this case, the Public Call for Energy Efficiency Projects 01/2017 of Eletropaulo, the energy company of the state of Sao Paulo (currently Enel), can be used as an example, in which the concession holder destined USD 1,240,479.32 (considering the exchange rate of December 31th, 2019) to energy efficiency projects, including improvements in lighting facilities, meaning, in this case, the replacement of fluorescent, incandescent and halogen lamps with LED lamps.

Regarding the Ownership sub-attribute, considering that the company buy the lamps, it has total control over the equipment, however, remains to the company to elaborate a maintenance agreement to avoid the normal equipment’s operation.

Regarding the Possession and Energy Integration of resources attribute, its sub-attributes can be analysed together, when it refers to ERSS (Energy Resources on the Supply Side). The first one means refers to the LED technology, which is not a Brazilian property, once the LED lamps sold in the country are imported from China market. The second one, when applied to the ERDSs analysis, consists of exchanging ERDS technology between different parts [19]. This specific resource is produced in China, however, there is no effective exchange of technology between China and Brazil.

As for the three other attributes of the political dimension – Level of acceptance of the resource (stakeholders), Level of motivation of the agents (stakeholders), Conjunction and encounter of interests (stakeholders) – they are directly related to the stakeholders involved and interested in the project and consist not only of those in the education institution, but also employees of the company, public and private agents who are part of, and are directly involved in, the Brazilian energy sector, as well as other institutions that are not part of this sector.

Provided that energy efficiency works tend to benefit society in general, not only on environmental issues, but also financial matters, it is correct to infer that stakeholders inside and outside the organization present converging strategies and goals among themselves. It is worth highlighting that the energy providers are not necessarily benefited by the energy efficiency projects, once the implementation of these projects can reduce energy consumption and, consequently, the provider’s recipe. However, they still show an interest in the process, specifically because their financial planning is impacted after the implantation of an energy efficiency project.

4.3. Social dimension
With IRP, social dimension represents the possible impacts caused to population, society and the inhabitants of a certain area that is suffering direct or indirect interference from an energy project [16]. This dimension directly or indirectly, positively or negatively, impacts the life of the individual who has some sort of relation to the area affected by the energy resource project [33]. The attributes and sub-attributes of this dimension are presented in Table 6.

**Table 6. Social dimension attributes and sub-attributes**

| Attributes                               | Sub-attributes          | Analysis |
|-----------------------------------------|-------------------------|----------|
| Environmental imbalance in the social environment | Impact on Agriculture | x        |
| Perception of comfort | Impact on Health | x        |
| | Odor pollution | x        |
| | Thermal pollution | v        |
| | Visual pollution | v        |
| | Sound pollution | x        |
| Influence on development | Human development | x        |
| | Economic / Infrastructure | x        |
| Impact on projects space occupation | Direct jobs | v        |
| | Quality and safety | x        |

About the Comfort Perception attribute, which measures the comfort a person experiences after the implantation of the energy project, the first thing to emphasize is that the education institutions must follow lighting rules as defined by the Brazilian Association of Technical Standards (ABNT), as described in NBR 8995. This standard explains that compliance to the illuminance specifications described therein leads to a better visual comfort, as well as improves the performance of those who study or work in the environment, which is entirely related to the Impact on Health, Visual Pollution and Thermal Pollution sub-attributes.

Regarding visual pollution, as it is presented in detail in the economic-technical dimension, the inefficient system has low capability to enlighten a classroom than the efficient system, despite the lower colour temperature emitted by LED lamps when compared with fluorescent lamps, 3,500 Kelvins versus 6,000 Kelvins, respectively [26]. Even more, there is also a benefit in the Thermal Pollution, whereas LED lamps emit less heat than fluorescent lamps, there is also an improvement in the thermal attribute [29]. Depending on the characteristic of the local where the lamps are installed, the heat reduction can be felt by the people present, or even, less power from the cooling system may be required to maintain the temperature in the local. Therefore, the application of the resource positively impacts the Thermal Pollution and Visual Pollution attributes.

In the Job Creation attribute, more specifically the Direct Jobs sub-attribute, and based on information obtained from employees of the studied company, we can cite the departments involved in this project, with their respective functional positions, as described in Table 7. In this case, it does not consist in direct job creation, however it still means that workforce is allocated in the project.

**Table 7. Employed workforce in the lamp replacement project**

| Department   | Position                        | Action                                         |
|--------------|---------------------------------|------------------------------------------------|
| Supply       | Director; Manager; Responsible buyer | Negotiation and purchase with the responsible supplier |
| Infrastructure | Director; Manager; Responsible engineer | Demand survey and installations monitoring |
| Legal        | Lawyer                          | Development of the purchase agreement         |
| Financial    | Analyst                         | Invoice payment and tax collection            |
Sustainability Analyst
Education institution Director; Manager; Operations assistants

Measurement of the benefits and disclosure of results
Following and approving the work of lamp replacement

In the lamps vendor it is also possible to quantitative the workforce employed during their replacement operation. According to a documental research made in the studied company, 21 employees of the vendor was allocated in this project, as presented in Table 8.

Table 8. Work team in the lamp replacement

| Project engineer | 1 |
| Administrative manager | 17 |
| Operations supervisor | 1 |
| Electrician | 7 |
| Assistant | 11 |
| Total employees | 21 |

4.4. Economic-technical dimension

The economic-technical dimension, in comparison to the other ones, includes most of the measurable parameters, since the focus of the analysis of this dimension is to calculate the cost of energy generation, when considered on the supply side, or the cost of the energy saved, in the case of demand resources [19]. Moreover, the validation of this dimension is made by calculating the different technical and economic indexes [23]. It must also be considered that this dimension consists in searching for the lowest possible cost and the highest expected financial return [33].

The attributes and sub-attributes of this dimension are presented in Table 9.

Table 9: Economic-technical dimension attributes and sub-attributes

| Attributes                  | Sub-attributes                  | Analysis |
|-----------------------------|---------------------------------|----------|
| Technology domain           | Project and logistics           | ✓        |
|                             | Technology and equipment        | ✓        |
|                             | Distance from the consumption   | ✓        |
|                             | centre                          | ×        |
|                             | Implantation time               | ✓        |
| Technical ease              |                                 |          |
| Energy quality              |                                 |          |
| Energy potential            | Power range                     | ✓        |
|                             | Energy volume                   | ✓        |
| Reliability                 | Availability                    | ×        |
|                             | Intermittence                   | ×        |
|                             | Internal return rate            | ×        |
|                             | Net present value               | ✓        |
| Generation cost             | O&M Cost                        | ×        |
|                             | Implantation cost               | ✓        |
|                             | Useful life                     | ✓        |

Once there is an alternative to reduce energy consumption through the implantation of new energy efficiency projects, they start to be evaluated in a pragmatic manner. The evaluation must consider two different paths: the technical analysis, which must report whether the project will reach the goal of energy consumption reduction; and the validation of the financial viability of the project implementation, determining whether the final financial result will be the one expected by the company [34].
The analysis of this dimension is made based on the technical differences between fluorescent and LED lamps, which makes it possible to carry out financial assessments that can prove the highest economic viability of either lighting technologies. Regarding the technical analysis, a comparison between the T8 tube fluorescent lamps and the T8 tube LED lamps, is presented to the reader, once both models of lamps were the most numerous in the studied build. These specifications are presented in the table below, which was developed based on the report obtained from Cepel, and on the report issued by the company Eaton [35].

Table 10. Technical profile of the LED and fluorescent lamps

| Characteristics    | T8 tube fluorescent | T8 tube LED  |
|--------------------|---------------------|-------------|
| Size               | 120cm               | 120cm       |
| Power (Watts)      | 36                  | 18          |
| Kelvin             | 3000                | 6500        |
| Lumens / Watts     | 72.22               | 102.78      |
| Hg Content         | 1.7mg               | 0           |
| Light emission     | 21%                 | 35%         |

The first attribute analysed is the Technology Domain. It represents the nationalization index of the technology used, which can be considered: national technology, if the entire production process is made in Brazil; foreign technology, in case the entire production process is made abroad; or mixed, when part of the production process is made abroad, and part of it is made in Brazilian territory [21]. More specifically, this attribute includes the type of technology, equipment and logistics used in the execution of the project, which are explained by the Technology and Equipment and Project and Logistics sub-attributes, respectively. The final sub-attribute cited refers not only to the place of origin of the analysed resource, but also to the logistic transportation until its final destination. The first sub-attribute cited refers to the technology availability on the site where the project will be carried out. The LED lamps are characterized for having a foreign and mixed technology, since part of the product is manufactured in China, and part of it is made in Brazil [35].

The Technical Ease attribute, composed by the Implantation Time and Distance from the Consumption Centre sub-attributes is analysed in this work only through the first sub-attribute, which represents the period of execution of the project, from the development of the technical project to the beginning of operations. Moreover, the same sub-attribute varies according to the technology used, project location, financial resources, and available workforce [20]. Finally, according to the project scope provided by the company, the conclusion of the project, including the removal and disposal of the inefficient system lamps and the installation of the LED lamps takes three working days.

The Energy Potential attribute is characterized as the capacity of each technology to generate the energy required to attend a given region, considering the available physical potential [19]. This attribute, when analysed on demand side, represents the savings potential obtained from power, in KWh, of the consumed energy [19]. This difference in power is presented in tables 2 and 3, and it is possible to observe that LED lamps have less power than the other lighting technology used.

The difference in power between one technology and the other is decisive to identify the financial viability of replacing the inefficient system for an efficient lighting system; the lower the lamp power is, the less will energy consumption be, leading to financial savings in the energy bill. This sub-attribute makes it possible to analyse the last attribute of this dimension, Generation Cost, an attribute that is entirely financial, and is composed by the following sub-attributes: Useful Life; Implantation Cost; O&M Cost; Net Present Value; and Internal Return Rate.

Since it is a lamp replacement project, the financial analysis developed in this dimension approaches the purchase cost of new lamps, considering the material and additional services, removal and disposal of the inefficient system lamps, and installation of the LED lamps. Other important items are also considered for the development of the project’s business case, and are presented below:
Freight: CIF (Cost In Freight), in which the cost of the lamps sold involves delivery of the material, including transportation insurance until destination.

WACC (Weighted Average Capital Cost): WACC is 13.5%, as informed directly by the company.

Conditions for usage: The same ones used in the analysis of the other dimensions.

Lamps lifetime: Overall, the lifetime for the inefficient lighting system lamps will be considered 5 years, and 25 years for the efficient lighting system lamps.

The financial values were initially calculated in Brazilian real and were later converted to U.S. dollars, with the exchange rate mentioned in the Methodology section herein.

The energy fee of the consumption used is the one currently charged by the energy provider where the institution was installed, on the same year of the consumption’s analyses, 2019.

The value consists of the sum of the distribution charge (TUSD – Fee for the Use of the Distribution System) and the energy fee (TE) at peak hours, which were, respectively, R$0.642 + R$ 0.382, resulting in a R$1.024 fee, that is, USD 0.254 per kWh. And sum of TUSD and TE at the out peak hours, respectively R$0.080 + R$0.237, resulting in R$0.317, that is, USD 0.079 per kWh.

As informed by the company, the energy consumption represents 70% during peak hours and 30% during out peak hours.

The energy fee of contracted demand used is, R$ 0.110 or USD 0.027 per KW as informed in the company’s energy bill.

In a business case, the main goal is to calculate the project’s viability, through the calculation of the Net Present Value (NPV).

### Table 11: Comparison of consumption between LED and CFL lamps

| Lamp             | Unitary power W | Quantity | Total power KW | Total investment in USD |
|------------------|-----------------|----------|----------------|-------------------------|
| 18W T8 LED       | 18              | 3,151    | 56.72          | $19,801.73              |
| 30W bulb LED     | 30              | 3        | 0.09           | $122.74                 |
| 15W tube LED     | 15              | 576      | 8.64           | $4,777.25               |
| 18W Downlight    | 18              | 43       | 0.77           | $2,747.04               |
| 15W bulb LED     | 15              | 93       | 1.40           | $467.23                 |
| 8W T8 LED        | 8               | 149      | 1.19           | $1,186.62               |
| 7W LED           | 7               | 16       | 0.11           | $191.85                 |
| 44W HO LED       | 44              | 34       | 1.50           | $792.07                 |
| 5W bulb LED      | 5               | 25       | 0.13           | $33.24                  |
| 10W LED bulb     | 10              | 51       | 0.51           | $159.43                 |
| LED Reflector 120W | 120            | 8        | 0.96           | $579.25                 |
| **Total**        | **4,149**       | **72**   |                | **$30,858.45**          |

Following up, in table 12, the discounted cash flow is presented, considering the investment made, the reduction in consumption and in the contracted demand on the energy bill (in Brazilian Real) obtained after the replacement of the lamps, and the eventual financial gain after the application of the revenue resulted from the savings. These analyses are shown on the formulas below.

#### 4.4.1 Financial reduction:

First, is calculated the reduction in KW power. As seen as seen in formulas 2 and 3

\[
S = IS - ES
\]  

\[
S = 144.22\text{KW} - 72.01\text{KW} = 72.21\text{KW}
\]
This same reduction means a possible reduction on the contracted demand, therefore, the contracted demand would be:

Demand reduction = actual contracted demand – New contracted demand  

\[ \text{Demand reduction} = 144.22 \text{ KW} - 72.01 \text{ KW} \]

\[ \text{Demand reduction} = 72.21 \text{ KW} / \text{month} \]

\[ 71.21 \text{ KW} \times 12 = 866.48 \text{ KW} / \text{year} \]

Financially, considering the contracted demand cost of USD 0.027/KW, the annual addiction saving with this reduction is:

\[ \text{Saving with demand} = \text{Demand reduction} \times \text{contracted demand cost} \]

\[ \text{Saving with demand} = 866.48 \text{ KW} \times 0.027 \]

\[ \text{Saving with demand} = $23.67 / \text{year} \]

Next, the financial monthly saving is calculated based on the reduction of energy consumption during peak hours and out of peak hours.

Consumption saving at peak hours

\[ \text{Consumption saving at peak hours} = \text{Total consumption saving} \times 70\% \]

\[ \text{Consumption saving at peak hours} = 107,227.40 \text{KWh} \times 70\% = 75,059.18 \text{ KWh per year} \]

Consumption saving at out of peak hours

\[ \text{Consumption saving at out of peak hours} = \text{Total consumption saving} \times 30\% \]

\[ \text{Consumption saving at peak hours} = 107,227.40 \text{KWh} \times 30\% = 32,168.22 \text{ KWh per year} \]

Financial consumption saving per year

\[ (75,059.18 \times 0.254) + (32,168.22 \times 0.079) = $19,074.20 + $2,526.08 = $21,600.28 \]

Yearly total financial saving

\[ ($21,600.28 + $23.67 = $21,623.95 \]

In this analysis it is assumed that the entire investment is made by the consuming company, i.e., the object of study in this work. In this case, the business transaction is recognized as CAPEX, once an investment in asset is made by the own company.

It assumed that the investment amount of USD 30,858.45 is based on a turnkey agreement, in which is considered not only the cost of the lamps, but also the freight and the payment of the labor force for the additional services.

Table 12: Discounted cash flow

| Capex Model         | Year 1  | Year 2  | Year 3  | Year 4  | Year 5  |
|---------------------|---------|---------|---------|---------|---------|
| Investment          | $30,858.45 |         |         |         |         |
| Consumption profit  | $21,623.95 | $21,623.95 | $21,623.95 | $21,623.95 | $21,623.95 |
| Balance per period  | $21,623.95 | $21,623.95 | $21,623.95 | $21,623.95 | $21,623.95 |
| Financial profit    | $2,220.78  | $2,448.85 | $2,472.28 | $2,474.68 | $2,474.93  |
| Accumulated balance | $23,844.73 | $24,072.80 | $24,096.23 | $24,098.63 | $24,098.88 |

With the discounted cash flow, it is possible to calculate the NPV of the project, using the following formula:

\[ \text{NPV} = -I + \sum (\text{CF}_n / (1 + WACC^n)) \]

\[ \text{NPV} = 39,012.51 \]
Calculate the payback of an investment is also a representative index that must be considered when taking a decision of implement or not an energy project. A financial analysis made about replace inefficient lighting system by LED lamps in an university campus proved that is possible to achieve a payback a short payback [23]. Also, a good and short payback is found in this study, less than one year and half.

\[
\text{Payback} = \frac{\text{Initial Investment}}{\text{Yearly Saving}} \quad (10)
\]

Payback = 1.43

Another possible financial analysis that does not lead to a direct impact on the company that purchases the lamps is the revenue obtained from such project, which can be done based on the temporary job vacancies creation, which analysis presented in the social dimension and represented in table 8.

Based on the current minimum daily wage on the period when the project was executed – R$34.83 (R$1,045.00 per month), which converts to dollar is $8.64 ($259.26 per month), as established by decree No. 9.255 of December 29th, 2017 – it is possible to calculate the labor force revenue generated on the work period, as presented below.

First, that the daily minimum wage is $7.89 dollars. Second, as already described, it is a 3 workdays project. Finally, there are different kinds of occupation in the project, moreover, each occupation has its own mensal minimum wage quantity, as explained in table 14.

| Occupation               | Minimum salary quantity | Number of employees used | Total wage in USD |
|--------------------------|-------------------------|--------------------------|-------------------|
| Operational Assistant    | 1                       | 11                       | $285.19           |
| Electrician              | 1.5                     | 7                        | $272.22           |
| Operational Supervisor   | 2                       | 1                        | $51.85            |
| Administrative Supervisor| 3                       | 1                        | $77.78            |
| Project engineer         | 4                       | 1                        | $103.70           |

Therefore, it is calculated that the total labor force revenue generated is USD 790.74.

5. Results and analyses

After all analyses done, the results are showed in the below tables:

Table 13: Calculation of revenue generated from the project

| Occupation               | Minimum salary quantity | Number of employees used | Total wage in USD |
|--------------------------|-------------------------|--------------------------|-------------------|
| Operational Assistant    | 1                       | 11                       | $285.19           |
| Electrician              | 1.5                     | 7                        | $272.22           |
| Operational Supervisor   | 2                       | 1                        | $51.85            |
| Administrative Supervisor| 3                       | 1                        | $77.78            |
| Project engineer         | 4                       | 1                        | $103.70           |

Table 14: Results in environmental dimension

| Attributes               | Sub-attributes         | Results                                      |
|--------------------------|-------------------------|----------------------------------------------|
| Airborne environment     | Greenhouse gases        | Reduction of 11.9 tons per year of CO2       |
| Land environment         | Waste                   | Prevent the disposal of 53g of mercury in the environment |
| Aquatic environment      | Water quality           | Avoid the risk to pollute more than 306 million litters of water |
| Aquatic environment      | Water quality           | Avoid the risk to contaminate 111 tons of non-predatory fish and 55 tons of predatory fish |
| Airborne environment     | Greenhouse gases        | Reduction of 11.9 tons per year of CO2       |

Table 15: Results in political dimension

| Attributes               | Sub-attributes         | Results                                      |
|--------------------------|-------------------------|----------------------------------------------|
| Political support        | Political instruments   | Publication of the law 9.991 in 2000         |
| Political support        | Legal aspects           | Signatory country to the Paris Agreement in 2016 |
Possession and energy integration of resources

Possession

LED technology does not exist in Brazil and the lamps are imported from China, thus there isn’t possession over the ERDS

Ownership

The company has total control over the equipment, once it is bought from the vendor, however, a maintenance agreement must be done

Energy integration

There is no technology exchange between China and Brazil, what beneficial for the Brazilian’s buyers

Conjunction and encounter of interests (stakeholders)

Residential, commercial, and industrial consumers

Generators, distributors, and producers

Federal, state and city government

Civil society, NGOs, and associations

These Stakeholders present strategies and objectives converging among them.

Table 16: Results in social dimension

| Attributes          | Sub-attributes       | Results                              |
|---------------------|----------------------|--------------------------------------|
| Perception of comfort| Thermal pollution    | Better control of a mild temperature. |
| Perception of comfort| Visual pollution     | Increase in the illuminance level, from 248 lux to 523 lux |
| Job creation        | Direct jobs          | 21 jobs opportunities                 |

Table 17: Results in economical-technical dimension

| Attributes          | Sub-attributes       | Results                              |
|---------------------|----------------------|--------------------------------------|
| Technology domain   | Project and logistics| Mixed technology: China and Brazil   |
| Technology domain   | Technology and equipment| Increase in the illuminance level, from 248 lux to 523 lux |
| Technical ease      | Implantation time    | 3 working days                       |
| Energy potential    | Power range          | Reduction of the power from: 36W (Fluorescent T8) to 18W (LED T8) |
| Generation cost     | Net present value    | USD 39,012.51                        |
| Generation cost     | Implantation cost    | USD 30,858.45                        |
| Generation cost     | Useful life          | 40,000 hours                         |

Reaching the results expected by the consuming companies is only possible through the implantation of energy efficiency projects. There are three different energy efficiency projects that can be implemented in a corporation: replacing or installing equipment with new, or more efficient, technology to reduce energy consumption; monitoring energy consumption together with the client or the company’s employees, in a way that makes it possible to develop educational material that can teach them how to reduce energy consumption; and financial incentives for the development of new energy efficiency projects [34].

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In this context, the factor of political uncertainties must also be highlighted. Investments in energy efficiency projects mitigate risks in the company’s future strategic planning, once it keeps it from being exposed to variations in energy fees, which is extremely important in countries where the energy fee is susceptible to constant and meaningful variations.

Overall, considering that there is a world trend in the energy field to reduce consumption, especially due to environmental issues, it is assumed that energy efficiency projects represent actions that lead consumers to reduce energy consumption in their facilities.

6. Conclusions
It can be concluded that the application of an energy efficiency project in consuming companies is awarding not only for the company, but also for the entire society, including the Government. Benefits were observed in all analyzed dimensions. It can be considered here that the study project also impacts the government's tax policy, taxes can be collected with the purchase and installation of lamps, as well as a smaller portion of taxes is collected due to the reduction in energy consumption. However, such analysis is not considered in the IRP methodology.

Even more, FPAV showed to be an excellent tool to assess and validate the impacts from implanting energy efficiency projects, which means that if the same method is applied in other energy efficiency projects, it will be possible to obtain, in a structured manner, the results of this energy efficiency project in each of the dimensions. This makes it possible to evaluate the impacts of each resource in a more objective manner, to help decision making. Eventual ERSSs of the company are not excluded, once FPAV can also be used to validate them.

This work further reinforces the importance of energy management in companies. The systematics to define energy resources that must be studied together with the application of the FPAV method for their assessment, as well as the structure of result in such a way that can help decision making for the company’s energy bill, can only be made if worked together, in an organized and planned manner, that is, through the implantation of an energy management model pursuant to each company’s profile and reality.

Furthermore, the work shows the possibility to connect knowledge developed in the academic field with the necessities and opportunities found in the corporative field. Also, it opens possibilities to analyze the application of other resources energy, as cooling system through the method stated here. And finally, it is also worth highlighting that the results presented herein can be replicated to other education builds of the company. However, to obtain an accurate result, future studies must be done.

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