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STUDY OF COST REDUCTION AND APPLICATION OF ENERGY EFFICIENCY IN THE LIGHTING AND AIR CONDITIONING SYSTEMS OF IFES CAMPUS SÃO MATEUS

Vinícius Francisco do Nascimento[1]
Rodrigo Fiorotti[2]
Igor Chaves Belisario[3]
Bruno de Oliveira Schneider[4]
Federal Institute of Espírito Santo, Rod. BR 101 Norte, km 58, Litorâneo, São Mateus, Espírito Santo, Brazil.
vfn14@hotmail.com[1]
rodrigo.fiorotti@ifes.edu.br[2]
igor.belisario@ifes.edu.br[3]
bruno.schneider@ifes.edu.br[4]

***Abstract.** Lighting and air conditioning systems are among the main end uses of energy consumption in Brazil. It is estimated that 44% of the electricity consumed in the commercial and public services sectors are due to lighting, whereas in buildings, 60% of the electricity is spent on air conditioning. At Ifes Campus São Mateus, about 20% of all funds is used to pay electricity bills, representing a considerable percentage. In sight of this, the present work aims to identify poorly dimensioned systems and propose actions to reduce the energy bill. Initially, the verification was made that the installed lamps were in accordance with the recommended standards, followed by the luminotechnical calculation. In order to find the ideal scenario of the analyzed environment and the feasibility analysis of possible replacements of the lamps by LEDs were made through the calculation of payback. For air conditioning systems, a comparison was evaluated considering thermal load and actual system installed capacity of each environment analyzed, since some structural changes have been made at the institute. In addition, it was proposed solutions in order to reduce energy costs by reducing the thermal load and/or using more efficient equipment. The results showed that the analyzed rooms were with average illuminance, however, the current lamps should be replaced by OLTUBOLEDT8 lamps (18W) to reduce the cost, representing a monthly savings of R$ 126.58 and a payback of 10.91 months. Regarding air conditioning systems, in 4 out of 5 facilities analyzed were either undersized or oversized. The energy costs by air conditioning can be reduced by 8.37% trough thermal load reduction, just considering the classrooms chilled with internal temperature at 24°C, representing a monthly reduction of R$316.66. The results achieved contributed to demonstrate that simple solutions can have a positive impact in the institution's electric bill.*

Keywords: Lighting, Air Conditioning, Energy Efficiency, Electricity, Cost Reduction

1. INTRODUCTION

Nowadays, electricity energy usages are indispensable, since several tools and devices that allow greater comfort of society are only possible due to the existence of electric energy. According to data from the EPE (2019), between 2015 and 2016, the growth in world consumption was estimated at 2.8%, additional consumption of 601.1 TWh, with the largest portion of this increase coming from Asian and Oceania countries. Brazil is ranked as the 8th largest word energy consumer and has one of the highest tariffs in the industrial and residential sector, 9th and 22nd place respectively.

In Brazil, public lighting is responsible for a significant amount of the share of electricity consumed by municipalities, ranging between 70% and 80% of the total. In addition, it is estimated that the electrical energy spent in public buildings is predominantly due to the use of air conditioning, followed by lighting systems (Barandier et al., 2013). According to PROCEL (2021), it is estimated that electricity consumption in Brazil will tend to increase and is strongly linked to the increased use of air conditioning equipment to ensure hygrothermal comfort. The data show that in the next decade, the growth in electricity consumption can reach 3.8% per year for the residential class and 4.3% per year for the commercial ones.

Due to the need to reduce the use of energy resources, energy efficiency has attracted attention in recent years. In buildings, for example, it is discussed that the application of energy efficiency contributes to the use of systems that consume less energy without impairing comfort, saving money, and reducing possible harmful emissions (Bataineh and Alrabee, 2018). The fact that lighting and air conditioning systems are responsible for a large part of the consumption of electricity, makes their fields of research aimed at reducing spending and the search for more efficient technologies.

Gorgulu and Kocabey (2020) investigated the energy-saving potential of the external lighting of a campus. In this work, they proposed alternatives to ensure energy efficiency, which were related to good practices and the use of LED lamps. From this study, it was concluded that 60% of electricity could be saved. The work done by Oliveira *et al.* (2018) sought efficient lighting through retrofit, using LED lamps, where it was observed a power reduction of up to 34% of the energy consumed.

As well as for lighting systems, studies have been conducted to understand and minimize the expenses due to air conditioning systems. Focused on an educational institution, Inário (2014) investigated the installation conditions of the air conditioners and observed that all the rooms analyzed were outside the recommended by the standards, operating at up to 10.24% of the recommended heat load. Through energy-saving strategies, Fasiuddin and Budaiwi (2011) concluded that HVAC (Heating, Ventilating and Air Conditioning) systems in commercial buildings could reduce energy use by up to 30%. Thus, it is possible to conclude that there are opportunities to reduce energy consumption in air conditioning systems.

The present aims to evaluate the current scenario of the Ifes São Mateus campus and define possible energy efficiency measures to reduce the cost of electricity. In 2017, the campus spent approximately R$ 280000.00, about 20% of the annual costing budget of the campus. Given this considerable amount, it becomes interesting for the study to propose the reduction of electricity costs on campus, attacking the largest sources of consumption of the public network, lighting and air conditioning.

2. METHODOLOGY

2.1 Lighting System

The Ifes Campus São Mateus can be separated into three buildings, Annex 1, Annex 2 and Shed, with each building basically consisting of classrooms and laboratories. To proceed with the analysis of the lighting systems, 3 classrooms were used to represent them all, that is, most of the rooms in the buildings have the dimensions and layout of the lighting fixtures similar to one of the 3 rooms analyzed in this work. The rooms chosen were S1, S4 and S5. In these rooms, the lamps used were surveyed, the amount of lux was measured, and the geometric dimensions of the room were obtained in order to verify if the system was in accordance with the ABNT NBR ISO/CIE 8995-1:2013 standard (ABNT, 2013) and to estimate the cost of electricity in the real scenario.

Measurements to verify the amount of illuminance of the rooms were also made based on the recommendations of the ABNT NBR ISO/CIE 8995-1:2013 standard (ABNT, 2013). According to this standard, the average illuminance of the interior of classrooms varies according to the need for task accuracy, so that the performance and comfort of students are satisfactory the standard recommends the average value of 300 lux.

After verification, a luminotechnical sizing was conducted according to the recommendations of PROCEL (2016) with different LED lamps, in order to identify the scenario in which the comfort conditions were adequate and the lighting systems were economically feasible. The flow of calculations began by determining the site factor (K), which depends exclusively on the geometric characteristics of the room. This factor is shown in Eq. (1).

$$K = CL/(C + L)A \tag{1}$$

where C, L and A are the site length, site width and height of the luminaire to the working plane, respectively.

The Utilization Factor (Fu) is defined, which represents the ratio between the useful flow over the total emitted. Thus, the Utilization Factor takes into account the percentage of reflection of each surface in the analyzed environment and relates it to the Site Factor (K). The percentages are already pre-established and identified by the following numbers.

1 - Dark surface - 10% reflection;
3 - Medium surface - 30% reflection;
5 - light surface - 50% reflection;
7 - white surface - 70% reflection.

Figure 1 demonstrates the possible Fu values for the luminaire used on campus. The numbers in the first row of the table represent the combination of digits that identify the type of reflection on the ceiling, wall and floor surfaces, respectively. Therefore, if the ceiling and walls have white surfaces (value equal to 7) and the floor is medium (value equal to 3), the environment will be identified by the number 773. The intersection between this value and K will determine the value of Fu.

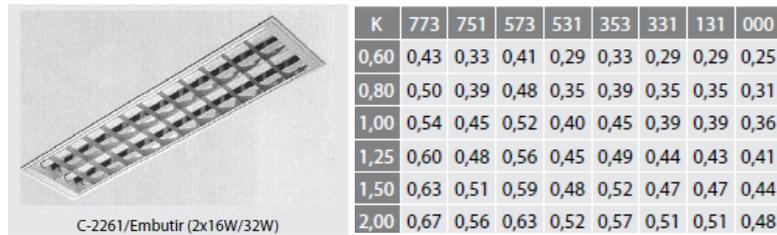| K	773	751	573	531	353	331	131	000
0,60	0,43	0,33	0,41	0,29	0,33	0,29	0,29	0,25
0,80	0,50	0,39	0,48	0,35	0,39	0,35	0,35	0,31
1,00	0,54	0,45	0,52	0,40	0,45	0,39	0,39	0,36
1,25	0,60	0,48	0,56	0,45	0,49	0,44	0,43	0,41
1,50	0,63	0,51	0,59	0,48	0,52	0,47	0,47	0,44
2,00	0,67	0,56	0,63	0,52	0,57	0,51	0,51	0,48

C-2261/Embutir (2x16W/32W)

Figure 1. Utilization factors (Procel, 2006).

The next step is to estimate the Total Flux (ϕT) to the environment, made possible by the expression in Eq. (2).

$$\phi T = \frac{EmS}{FuFm} \qquad (2)$$

where Em, S and Fm are the average illuminance, room area, and the maintenance factor.

As previously mentioned, for calculation purposes the average illuminance was considered to be 300 lux, while the Maintenance Factor (Fm) depends on the period of use without cleaning and the ambient conditions, as shown in Figure 2.

Period of use without cleaning (months)	Clean environment	Average environment	Dirty environment
0	1,00	1,00	1,00
2	0,97	0,92	0,85
4	0,95	0,87	0,76
6	0,93	0,85	0,70
8	0,92	0,82	0,66
10	0,91	0,80	0,63
12	0,90	0,78	0,61
14	0,89	0,77	0,59
16	0,88	0,76	0,57
18	0,87	0,75	0,56
20	0,86	0,74	0,54

Figure 2. Maintenance Factors (Adapted from Procel, 2006).

Finally, the number of luminaires (n) is defined by Eq. (3), with each luminaire containing two lamps. At this point, different types of lamps will be analyzed, which are available for purchase by the Ifes Campus São Mateus. The lamps are shown in Table 1.

$$n = \frac{\phi T}{\phi l} \qquad (3)$$

where ϕl is the number of lumens per luminaire.

Table 1. Lamps analyzed.

Lamp Type	Power (W)	ϕl (lúmens)	Price (R$/lamp)	Status
TUBO LED T8 (18W)	18	2070	25.57	Available
Bulbo Compacta LED (15W)	15	1510	20.50	Available
LED Vance Base G24D-3 (26W)	26	1800	16.99	Available
T8L12-S 20W 4000K	20	2150	26.50	In use
GOLDEN FLUOR TUB 40W T10 6500K	40	2500	-	In use
GE F32T8/BF 4100K	32	2500	-	In use

2.2 Air conditioning system

The study regarding the air conditioning systems was carried out in five specific rooms: S1, S2, Library and Lab. Inf. 1 and Electricity Lab. The current air conditioning system installed in each these rooms is composed for one or more types present in Table 2.

Table 2. Current air conditioning system.

Air-conditioning Type	Power (BTU/h)	Performance Coefficient (COP)
Komeco SPLIT	48000	2.82
HITACHI Cassette	48000	3.10

In order to analyses and compare the current air conditioning system capacity installed, the thermal load was calculated according to Creder (2004), considering the different types such as heat transfer through the wall (including roof and door) (Q_p), glazing window (Q_{ins}), renewal air ($Q_{totaren}$), electronic equipment (Q_{eletro}), people (Q_{people}), lighting (Q_{lamp}), and air infiltration through doors and windows ($Q_{totalinf}$).

For the thermal load due to thermal conduction in the walls, doors and roof, the thermal resistance is determined, which takes into account the materials that constitute them. Table 3 shows the estimated thermal resistances for the internal and external walls and the roof.

Table 3. Thermal Resistances.

Element	Thermal Resistances (m²°C/W)
External wall	1.17
Inside wall	3.42
Roof	5.11
Doors	0.22

The thermal load through the walls and roof was estimated from Eq. (4), where an increment of temperature due to the walls orientations is considered. The increments values were obtained from Creder (2004).

$$Q_p = A \frac{1}{R}[(T_e - T_i) + \Delta T] \tag{4}$$

where Q, A, R, T_e, T_i and ΔT are the thermal load, area of the analyzed element, thermal resistance, external temperature, internal temperature, and the temperature increment, respectively.

The thermal load through the glazing windows is estimated from solar gain factors and depends on its orientation as described in Creder (2004). The factor values used correspond to the conservative analysis case and they are described below.

- North – 1690.40 kJ/h.m²;
- South- 464.42 kJ/h.m²;
- East – 1870.25 kJ /h.m²;
- West – 1870.25 kJ/h.m².

Furthermore, heat transfer is influenced by the type of window and the color of the curtain used, so the solar gain factors must be corrected. The windows were considered to be the metal frames type, therefore, their correction factor is 1.15, whereas for the curtains, its correction factor varies according to the color that is directed to the sun. In the Institute rooms, the dark gray part is the one used, so the correction factor is 0.65. In this way, Eq. (5) can be used to define the thermal load due to the glazing windows.

$$Q_{ins} = A_j F_s F_{cr} F_c \tag{5}$$

where A_j, F_s, F_{cr} and F_c are the window area, solar gain factor, correction factor for metal frames, and correction factor due to the curtain, respectively.

The infiltration of the outside air can be added to the total load, which occurs due to the fact that the external air enters at a higher temperature than the internal temperature of the enclosure. In this type of infiltration, the sensible and latent heat parcels of the external and internal air are considered. This portion cannot be precisely determined, however, there are methods to have an acceptable approximation, such as the gap method, which takes into account the windows

and doors fit type, in addition to the sum of the length of the gaps. From Eq. (6), (7) and (8), the sensible, latent and total heat are defined respectively (Creder, 2004).

$$Q_{Sinf} = 0.29 Q_{fresta} L_{fresta} (T_e - T_i) \tag{6}$$

$$Q_{Linf} = 583 Q_{fresta} L_{fresta} (w_e - w_i) \tag{7}$$

$$Q_{Totalinf} = Q_{Sinf} + Q_{Linf} \tag{8}$$

where Q_{Sinf}, Q_{fresta}, L_{fresta}, Q_{Linf}, w_e, w_i e $Q_{Totalinf}$ are the infiltration heat load, flow rate per meter of gap, gap length, infiltration heat load, external absolute humidity, internal absolute humidity, and total infiltration heat load.

Another part of the heat load related to the external air intake is the renewal air. The renewal air is purposely performed in order to keep the indoor air pleasant since, due to human respiration, there is an increase in CO_2 content, which can be harmful to people in the enclosure. Similar to the heat load due to infiltration, the sensible and latent heat are calculated. However, the heat load due to air renewal takes into consideration the number of people, the amount of air flow per person, and the way in which the air is distributed in the room. Eq. (9), (10) and (11) describe sensible heat, latent heat and total thermal load, respectively (ABNT, 2008).

$$Q_{Sren} = 0.29 \frac{(P_z F_p + A_z F_a)}{E_z} (T_e - T_i) \tag{9}$$

$$Q_{Lren} = 583 \frac{(P_z F_p + A_z F_a)}{E_z} (w_e - w_i) \tag{10}$$

$$Q_{Totaren} = Q_{Sren} + Q_{Lren} \tag{11}$$

where Q_{Sren}, P_z, F_p, A_z, F_a, E_z, Q_{Lren} e $Q_{Totaren}$ are the renewal sensible heat load, maximum number of people in the ventilation zone, flow per person, floor area occupied by people, flow per floor area, efficiency of air distribution in the zone.

Besides considering the thermal load as a function of human behavior, it is necessary to determine the heat emited from each person, since metabolism makes people dissipates different amount of energy depending on the activity considered. The NBR 16401 standard (ABNT, 2008) defines the heat dissipated by each person according to the activity they do.

The internal equipment that consumes power is also responsible for promoting the thermal load. According to Lima (2017), the equipment has ohmic losses that are dissipated as sensible heat. For lighting systems, Creder (2004) considers factors depending on the type of lamp, and this factor is a correction factor of the dissipated power, so the thermal load due to lighting can be estimated from Eq. (12).

$$Q_{lamp} = F_{Crlamp} P_{lamp} n \tag{12}$$

where Q_{lamp}, F_{Crlamp}, P_{lamp} e n are thermal load due to the lamps, correction factor due to the type of lamp, rated lamp wattage, and the quantity of lamps.

2.3 Considerations

For the thermal load survey, it was necessary to know the geometrical characteristics of each room and its climatic conditions. The dimensions of the rooms were measured and the climatic conditions, such as: dry bulb temperature, wet bulb temperature, relative humidity and absolute humidity, were adopted values recommended by NBR 16401 (ABNT, 2008) for the closest region (Vitória - ES). Thus, an external temperature of 33.1° and an internal temperature of 24°C were considered. For the internal walls of the environment to be acclimatized, it was used 3°C less than the outside, as recommended by Pirani ([20--]). For refrigerated environments, the temperature was 24°C, which is the same internal temperature used for the analyzed environments. All the doors are in environments whose external side is not refrigerated. For the north, east and west walls (clear color) which receive insolation, 2.7°C, 5.5°C and 5.5°C were added, respectively. The roof was considered to be clear, so it received a temperature increase of 8.3°C. Regarding infiltration, it was considered that the door is well fitted and the window common.

Table 4 demonstrates the geometric characteristics of each room analyzed.

Table 4. Geometric characteristics of the rooms.

	S1	S2	Library	Lab. Inf. 1	Electricity Lab
Length	7.8 m	10.4 m	14.88 m	7.80 m	10.40 m
Width	7.28 m	5.88 m	7.80 m	7.40 m	3.93 m
Height	2.80 m	2.80 m	2.80 m	2.80 m	2.80 m
Floor area	56.78 m²	61.10 m²	116.03 m²	57.72 m²	40.82 m²
South wall area	20.38 m²	29.12 m²	41.65 m²	20.72 m²	27.18 m²
North wall area	18.44 m²	14.51 m²	41.65 m²[1]	19.04 m²	29.12 m²[1]
West wall area	21.84 m²	29.12 m²	21.84 m²	21.84 m²	10.99 m²
East wall area	21.84 m²[1]	29.12 m²	21.84 m²[1]	21.84 m²	10.99 m²
South glass area	6.86 m²	9.14 m²	-	6.86 m²	-
North glass area	-	-	11.43 m²	-	9.14 m²
West glass area	-	-	-	-	-
East glass area	5.72 m²	-	5.72 m²	-	-
Door area	1.94 m²	1.94 m²	1.94 m²	1.68 m²	1.94 m²
L_{fresta} window	47.74 m	34.72 m	65.10 m	26.04 m	34.72 m
L_{fresta} door	5.80 m	5.80 m	5.80 m	5.80 m	5.80 m

[1] walls that need temperature increase.

For the calculation of air renewal, the values of flow per person and flow per floor area were considered to be in accordance with level 1 in an educational establishment. In addition, it was considered that all rooms would hold 40 people seated without working, with the library being able to hold up to 44 people seated without working. In addition, each room and laboratory would have one person standing still.

Finally, the lamps used are fluorescent type, with F_{Crlamp} equal to 1.2. The other electronics were grouped and shown in Table 5, where the lamp power is also identified separately.

Table 5. Total powers of lamps and other electronic equipment used.

	S1	S2	Library	Lab. Inf. 1	Electricity Lab
Lamps[1]	288.00 W	480.00 W	576.00 W	374.40 W	364.80 W
Equipments	190.00 W	55.00 W	270.00 W	5455.00 W	190.00 W

[1] already corrected.

3. RESULTS

From the verification of the rooms, the number of lamps in each room was raised, where it was possible to observe that there is the use of different lamps in the same room, as presented by Table 6. The illuminance measurements in the rooms showed that both are in accordance with the ABNT NBR ISO/CIE 8995-1:2013 (ABNT, 2013), respecting the minimum average value of 200 lux per room. However, it has regions below the allowed. Figure 3 shows the distribution of illuminance in each of the rooms analyzed, these being measured point by point, with a distance of 0.5 m between measurements and approximately 1 m from the floor. The lighter regions highlight the points with higher illuminances. Table 7 describes the average illuminances and the standard deviation.

Table 6. Number of lamps installed per room.

	S1	S4	S5
T8L12-S 20W 4000K	12	-	-
GE F32T8/BF 4100K	-	8	6
GOLDEN FLUOR TUB 40W T10 6500K	-	8	12

To estimate the costs in each room, it was considered 22 days of operation in a month and the monthly expenses were obtained from the average daily usage time of the selected rooms, being 2 hours in peak charging time and 9.5 hours in off-peak charging for both rooms, with energy cost equal to 0.29 R$/kWh and 1.49 R$/kWh, for off-peak and peak, respectively. The energy price was obtained from the tariff for the year 2018. For the cost calculation, the TCL140SAF reactor (38W) was considered only in rooms S4 and S5, due to the fact that S1 is composed of LED lamps and does not require its use. Table 8 shows the monthly cost per room.
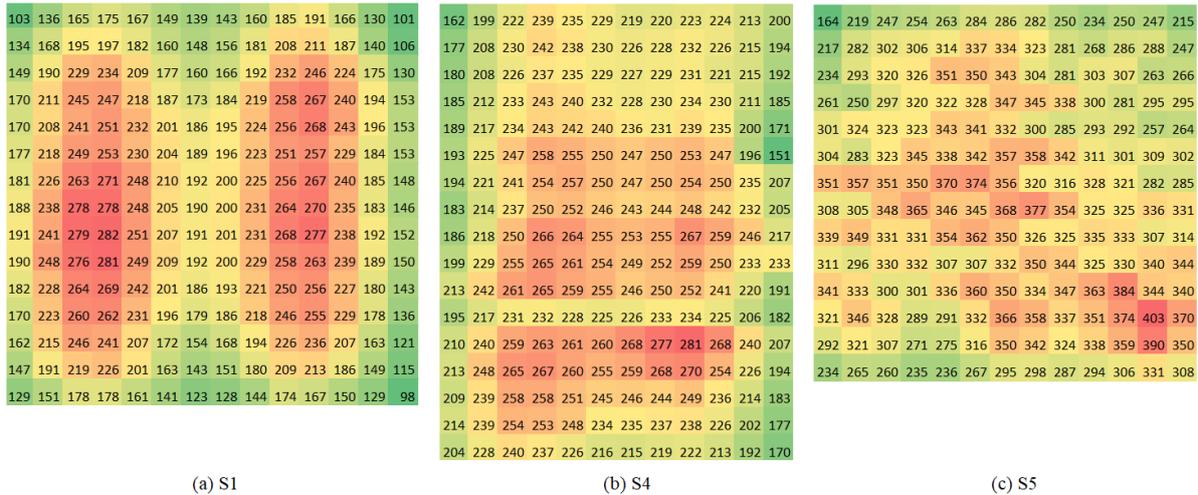
(a) S1	(b) S4	(c) S5

Figure 3. Illuminance distribution in Lux.

Table 7. Measured illuminance of the classrooms in Lux.

	S1	S4	S5
Average Illuminance	200.50	231.44	314.52
Standard Deviation	43.25	24.32	38.75

Table 8. Current monthly consumption.

	S1	S4	S5
Cost	R$ 41.34	R$ 124.03	R$ 174.67

To reduce the use of electricity, it was proposed the use of LED lamps, whose data is shown in Table 1, due to the fact that they promote lower costs than conventional lamps, as proven by Santos *et al*. (2015). Two possibilities were analyzed: the first being characterized by performing the luminotechnical calculations for each room, reconfiguring the lamps so that the average illuminance was 300 lux; while the second proposed only replacing the lamps, preserving the configuration of the fixtures in the rooms and without adjusting the average level of illuminance, but checking whether they were equal to or higher than the 300 lux of illuminance. The results are described in Table 9 and Table 10.

Table 9. Results by reconfiguring and adapting the lamp distribution.

Lamp	OL TUBO LED T8 (18W)	OL Bulbo Compacta LED (15W)	OSRAM LED Vance Base G24D-3 (26W)	T8L12-S 20W 4000K
Quantity in S1	18	26	22	18
Illuminance in S1	300 lux	300 lux	300 lux	300 lux
Quantity in S4	20	26	22	18
Illuminance in S4	300 lux	300 lux	300 lux	300 lux
Quantity in S5	16	22	18	16
Illuminance in S5	300 lux	300 lux	300 lux	300 lux
Investment	R$ 1380.78	R$ 1517.00	R$ 1053.38	R$ 1378.00
Monthly Savings	R$ 126.58	R$ 109.15	R$ 45.73	R$ 117.99
Payback	10.91 months	13.90 months	23.03 months	11.68 months

It is possible to observe that if only replacements were made, room S5 would be the only room to be adequate in at least one scenario, which highlights the need to resize the lighting system in the other rooms. Thus, without taking into consideration the cost to reconfigure the lighting fixtures in the rooms, the OL TUBE LED T8 (18W) lamp would be ideal to be used in the classrooms, since it has the lowest payback, equal to 10.91 months.

Considering the air conditioning system analysis, the thermal loads for each room described in Table 11 and the current cooling capacity of each room is also described.

Table 10. Results with only replacement for each lamp.

Lamp	OL TUBO LED T8 (18W)	OL Bulbo Compacta LED (15W)	OSRAM LED Vance Base G24D-3 (26W)	T8L12-S 20W 4000K
Quantity in S1	12	12	12	12
Illuminance in S1	200 lux	145 lux	175 lux	207 lux
Quantity in S4	16	16	16	16
Illuminance in S4	256 lux	187 lux	222 lux	265 lux
Quantity in S5	18	18	18	18
Illuminance in S5	356 lux	260 lux	300 lux	370 lux
Investment	R$ 1176.22	R$ 943.00	R$ 781.54	R$ 1219.00
Monthly Savings	R$ 144.77	R$ 162.20	R$ 98.28	R$ 133.15
Payback	8.2 months	5.81 months	7.95 months	9.15 months

Table 11. Thermal loads and installed capacity.

Losses	S1 (W)	S2 (W)	Library (W)	Lab. Inf. 1 (W)	Electricity Lab (W)
Wall	391.42	234.24	744.44	300.93	302.66
Window	2882.60	882.37	6235.21	661.78	3211.50
Roof	101.06	207.93	394.85	102.73	138.92
Infiltration	1437.14	1118.63	1861.82	906.29	1118.63
Renewal	8589.14	7358.75	9893.44	9343.44	4568.19
Occupancy	4760.00	4760.00	4600.00	5220.00	2460.00
Lighting	288.00	480.00	576.00	374.40	364.80
Equipment	190.00	55.00	270.00	5455.00	190.00
Total losses	18639.37	15096.92	24575.76	22364.77	12354.71
Installed capacity	14067.41	14067.41	42202.23	14067.41	14067.41

Analyzing Table 11, it can be seen that the library and the electricity laboratory are the only rooms capable of meeting the thermal load; the other rooms work with excessive thermal load, overloading the cooling system. It is worth noting that the rooms studied do not have air renewal. So, there is a difference between the dimensioned capacity and the installed capacity. This difference causes the air conditioners not to be able to meet the air conditioning needs. However, due to the lack of air renewal, it will increase the concentration of CO_2, thus compromising the efficiency of the students.

Observing from the cost aspect, the excess thermal load causes the air conditioner to work overloaded and increase energy consumption. So, it is interesting that there is a search for ways to avoid and minimize the excessive thermal load, for example: proper use of curtains, use of double glazing, use of lower power light bulbs, avoid open doors during the operation of air conditioning, use of more efficient devices and avoid operation at temperatures below the ideal for thermal comfort.

It was observed at Ifes São Mateus that the curtains have different colors on each side, with the darkest side facing the sun. According to Creder (2004), the color of the curtain influences the heat transfer through the glass. The lighter the curtain, the lower the heat transfer. So, the study of heat transfer reduction was performed using the lighter side of the curtain facing the sun.

A large part of the heat received is transferred by the glass window and, in order to promote the reduction of the thermal load, it is suggested to use a double-glazed window. Using a global heat transfer coefficient for double glass (3.13 kcal/h.m^{2}ºC) proposed by Creder (2004), it was estimated the reduction of the thermal load.

Lighting is also a thermal source of easy heat transfer reduction. As the thermal load depends on the power, it is enough to replace the lamp by one with lower power. In the luminotechnical sizing, the LED T8 TUBE lamp proved to be quite qualified for a possible replacement, therefore, it was used to estimate the reduction of the thermal load.

It is known that the work done by an air conditioner to remove the heat load defines the air conditioner's coefficient of performance (COP). The higher the COP, the less work is done for the same thermal load. So, the use of high COP air conditioners allows a lower energy cost. According to ENCE (2017), more efficient equipment receives the PROCEL class A seal, where the minimum COP is 3.23 for floor-to-ceiling split air conditioners. Based on this COP it was possible to analyze the cost reduction if the appliances in each environment studied were replaced by a class A model.

Due to the metabolic variety of each person present in the classrooms, often the internal temperature stipulated to comply with the standard is neglected, and is commonly changed to approximately 20ºC. The reduction in indoor temperature causes an increase in the heat load that must be removed by the air conditioner, promoting additional costs to the system. Table 12 describes the thermal load reductions from each analysis, while Table 13 presents the cost reductions.

Table 12. Reductions in thermal load.

Reduction	S1 (W)	S2 (W)	Library (W)	Lab. Inf. 1 (W)	Electricity Lab (W)
Curtain	399.13	122.17	863.34	91.63	444.67
Double Glass	2590.44	669.88	5836.80	502.41	2999.02
Lighting	28.80	220.80	57.60	180.00	192.00
COP class A	452.39	348.31	660.89	586.11	350.49
Optimal temperature	1941.43	1774.79	2357.71	1995.63	1188.82

The reduction of the thermal load resulting from the use of the curtain with the light part facing outwards promoted a monthly economy equal to R$ 34.07, double glazing in turn had its monthly cost reduced by R$ 223.96, lighting had the smallest reduction, equivalent to R$ 20.18 per month. Exchanging the current air conditioners for a more efficient model guarantees a monthly consumption reduction of R$ 225.19. Using the operation temperature of 24ºC instead of 20ºC promotes a reduction of R$ 316.66. The costs described above refer only to the rooms studied. The total cost reductions are presented in Table 13.

Table 13. Cost reductions in percent.

Reduction	Monthly Savings	Percentage
Curtain	R$ 34.07	- 0.90%
Double Glass	R$ 223.96	- 5.92%
Lighting	R$ 20.18	- 0.53%
COP class A	R$ 225.19	- 5.95%
Optimal temperature	R$ 316.66	- 8.37%

Another issue that should be highlighted is the use of air conditioning with the door open. The open door promotes a significant increase in the thermal load, with a flow of external air into the room equal to 2000 m^3/h (PROCEL, 2011), and this value is notably higher than the flow due to infiltration through windows and doors. The use of open doors produces an increase in the thermal load of 16997.25 W, estimating this occurrence during the interval, and the time between classes less than 3 classes, the opening of the doors represents an increase in consumption of R$ 82.51 and R$ 72.87 for rooms S1 and S2 respectively. The study was not carried out in the laboratories because they normally do not have air conditioning on when there are no students inside. The rooms S1 and S2 allow us to observe the impacts of opening the door, impacts that can be reduced by the awareness of students and teachers to keep the doors closed while the air conditioning is on.

4. CONCLUSION

Through the study, it was possible to observe that the lighting systems were with average illuminance below the recommended by ABNT NBR ISO/CIE 8995-1:2013 (ABNT, 2013), which is an important factor to ensure people's comfort. In addition, the advantages of using LED lamps for the classrooms of the Ifes Campus São Mateus were visualized, since their use would promote a reduction in the electric energy bill. The replacement of the current bulbs by LEDs proved to be interesting since the estimated payback time is less than a year.

The air conditioning systems have shown to be undersized, since the thermal load is above the air conditioning capacity, except for the library. Besides being overloaded, rooms such as S1 and S2 at certain times operate with open doors, promoting an unnecessary additional cost in the energy bill, a problem that can be solved by raising awareness of teachers and students. In addition, actions such as acclimatizing the room to 24°C, using double glazing and using more efficient air conditioners have proven to be more significant ways of reducing costs.

5. ACKNOWLEDGEMENTS

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