Analysis of Energy Efficiency Opportunities in the buildings of the Military Academy - Amadora

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Abstract: In Europe, buildings account for about 40% of energy consumption. A considerable part of this demand is supplied by the fossil fuels that, on the other hand, release high amounts of pollutants into the atmosphere. Alternatively, new ways of obtaining energy that are renewable, clean and sustainable. This dissertation emerges as another proposal to this demand for alternatives to fossil fuels and the reduction of energy consumption.

The scope of this work consists in a project study to reduce energy spending and evaluate the implementation of energy efficiency measures and the use of renewable energy sources in order to reduce consumption and financial burdens for the Military Academy. This study involves building a geometric and energy model in *DesignBuilder (EnergyPlus),* analyzing electricity consumption, proposing energy efficiency measures and simulating the reduction potential for a building that represents about 5.4% of the needs of the AAMA campus. In order to improve the energy efficiency of the building, an audit and a study for the energy certification of the building were carried out simultaneously according to the parameters of the legislation in force. In addition, a photovoltaic system has been scaled and its energy impact and economic viability have been estimated.

Keywords: Military Installations, Electricity Consumption, Energy Efficiency, Renewable Energies, Energy Simulation, Photovoltaic Modules, Self-Consumption.

1. Introduction

In today's global situation, most of the activities developed in society are dependent on energy consumption. Therefore, given the population growth that has occurred in recent years, it is natural that global energy consumption also increases, as stated by the *BP Statistical Review of World Energy* report of June 2018. There is also the supremacy of the contribution of fossil fuels in the supply of global energy consumption needs. For all these reasons, this superiority and dependence on fossil fuels should be reduced and/or replaced by other more efficient forms of energy.

To reverse this paradigm, the European Commission (EC) proposed in 2016 to the Council of the EU and the European Parliament a recast the Renewable Energy Directive (RED) 2009/28/EC2, which expires next year, where renewable energy sources increased by up to 20% of final energy consumption and 10% in the transport sector. The suggestion of improvement of the Directive, Renewable Energy Directive II (RED II), sets out a goal of achieving a 27% share of renewable sources in final energy consumption by 2030. In Portugal, according to DGEG's statistical report on renewable energy in December 2018, about 25% of final energy consumption in 2017 was renewable energy, which is a good indicator of the bet on renewable energy sources, although it is still far from the targets set.

The main objective is to carry out a study on the energy efficiency of an Portuguese Army building, the classes building of the Military Academy (AM) – Amadora, according to portuguese legislation in force and in order to promote a reduction in electricity consumption and a consequent reduction in monetary burdens. The audit for the energy certification of buildings, among other advantages, allows cost reduction and energy consumption so it is also the objective of this work to measure the energy class of this facility in order to suggest appropriate energy efficiency measures to reduce electricity expenditure, although military installations are legislatively exempt from mandatory audits for energy certification [1].

2. Literature review

The issue of energy efficiency has been discussed in the EU for some time and has been materialized with Directive No 2002/91/EC of the European Parliament and the Council of 16 December 2002 on the energy performance of buildings that was transposed into the national legal system through Decree-Law No 78/2006, April 4, which approved the National System of Energy Certification and Interior Air Quality in buildings [2]. The publication of Directive No 2010/31/EU, the European Parliament and the Council of 19 May 2010 on the energy performance of buildings has been reformulated, the scheme established in 2002 clarifies some of the principles and introduces new provisions aimed at strengthening the framework for promoting energy performance in buildings, with a view to the objectives taken by member states for 2020. In Portugal, these amendments and decisions come legislatively in 2013 with Decree-Law No. 118/2013 which ensures not only the transposition of the Directive in reference, but also a revision of national legislation, which is embodied in improvements in structure and scope by including, in a single diploma, the Energy Certification System of Buildings and Trade and Trade Buildings (SCE), the Energy Performance Regulation of Housing Buildings (REH) and the Regulation on energy performance of buildings of trade and trade Services (RECS).

2.1. Energy certification

The application of these regulations is ensured and verified by experts, duly qualified for this purpose, at various stages during the life cycle of a building. These agents together with ADENE (Energy Agency) ensure the operationality of the SCE. The product of this work is the energy certificate and indoor air quality that is sent for each audited building. This certificate is classified according to the performance of the building on a predefined scale of 8 classes (A+ to F). These classes are defined according to the value obtained for the energy class ratio, which is a quotient between the annual nominal primary energy needs and a benchmark regulatory value for a building with the same characteristics. The lower the value, the better the energy behavior of the building.

2.2. Energy efficiency in buildings

With the evolution of legislation and with the increasingly urgent need to implement active energy efficiency measures, in 2013 the concept of building with almost zero energy needs, "almost Zero *Energy Building*", which will become the standard for the new construction from2020, or 2018, in the case of new buildings of public entities, as well as a reference for the major interventions in the existing building.

Nearly Zero Energy Building (nZEB)

In 2010 for the first time in a European directive comes the concept of almost zero energy consumption buildings, which represents a building with very high energy performance and whose almost zero or very small energy needs should be covered largely by energy from renewable sources, including energy from renewable sources produced at or nearby [3]. A widely accepted definition shared by the international community is that nZEBs are buildings that are neutral when analyzed during a year [4, 5].

In this model, the desired final state is that the entire energy consumption of the building is supported by renewable energy sources.

Passive House

It is a concept that is based on passive measures for increasing energy efficiency and thermal comfort in buildings. Originally this concept appears in Germany in the 1990s entitled "Passivhaus". Currently the concept is widely recognized and applied a little throughout Europe. These passive solutions and measures are implemented in the building during its construction phase and aim to allow control of natural flows of energy, in the form of conduction, solar radiation, convection and wind action. The main objective is to ensure greater sun exposure to reduce the needs in artificial lighting and heating and cooling systems [6].

Building-Integrated Photovolthaics (BIPV)

The main difference between BIPV and the simple installation of photovoltaic panels is that BIPV, in addition to providing electricity to the building, are also structural elements of it [7]. The main difference between BIPV and the simple installation of photovoltaic panels is that BIPV, in addition to providing electricity to the building, are also structural elements of it [8].

Currently there is a wide range of options relative to the possibilities for the integration of photovoltaic panels in the construction of buildings. Most of these solutions can be grouped into two categories: façade systems and cover systems.

2.3. Photovoltaic System

As for the type of connection photovoltaic systems can be grouped into stand-alone systems and grid-connected systems. Among other points, what differs from these two systems is that in network-related systems energy needs are supplied by the public electricity grid whenever photovoltaic production is not sufficient. The energy generated by the photovoltaic system can be consumed by the installation itself or sold the public energy network, in accordance with the legislation in force in the country. The production of electricity by photovoltaic technology can occur in two regimes: the production of electricity destined for self-consumption and the sale to the Public Service Electricity Network (RESP), from renewable resources. These schemes are distributed in two aspects, self-consumption production units (UPAC) and small production units (UPP) [9]. For the purpose of this dissertation, information regarding the production units for self-consumption (UPAC) is relevant. These units produce preferably to meet the consumption needs and all the energy produced is instantly injected into the consumption facility.

3. Description of the study case

The case of study of this dissertation is the increase in energy efficiency in the AM class building. It is responsible for a considerable fraction of the energy bill and therefore has a high margin of improvement through the application of active energy efficiency measures. Before moving on to the detailed situation it is important to see the framework of AM in the Army and armed forces.

Figure 1: Main buildings of the Built Area of the AAMA

At this stage an audit and characterization of the building spaces, its equipment and its nominal powers was carried out. A study was carried out to the profiles of occupation of spaces, the power installed in lighting, equipment and the HVAC system. The lighting system stands out for the high installed power that is distributed by the building as follows:

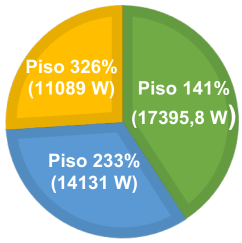


Figure 2: distribution of lighting power by floors

After the audit of the building, the equipment used in the different spaces and the characterization of its usage profile were collected.

4. Methodology

The methodology of this research begins with an analysis of the electricity bills data. Then an energy audit is carried out on building B and monitoring its consumption in order to estimate the energy fraction of this building in total campus consumption. With analysis of these results it was possible to draw conclusions and measures that could improve the energy efficiency of buildings and consequently from campus. The investigation was divided into 5 phases:

- Analysis of electricity consumption data;
- Creation and analysis of a model in DesignBuilder and EnergyPlus;
- Creation and analysis of the model in eco.ap;
- Energy certification;
- Analysis of the implementation of energy efficiency measures.

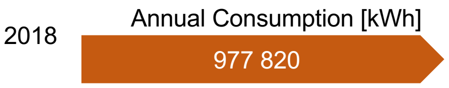
5. Results and discussion

The main products of the investigation will be detailed at this stage.

5.1. Analysis of electricity consumption

In 2018 the company that provided the service of supplying electricity to the campus was EDP Comercial. After analysis, AM's command decided to change the supplier company for 2019, thus relying on Iberdola's services. The goal would be to reduce the invoice.

Subsequently, the data analysis was performed the study of the consumptions of the campus. The results of annual and half-yearly electricity consumption are below.



The results include an annual consumption of approximately 978 MWh for the year 2018, representing an expense of €119 960,52 (no fees and taxes).

With the change of electricity supplier, its conditions and with the application of some energy efficiency measures in the student barracks building there is a reduction in campus consumption and consequently in the invoice, compared to the first Semester. This is a positive indicator and represents an optimistic view of what annual consumption could be for 2019.

From this it can be concluded that in 2018 the average energy cost was €0.1221/kWh, while in 2019 it was €0.1215/kWh, i.e. there was a reduction of €0.0006/kWh.

Analisando ao detalhe o consumo mensal de 2018 e do primeiro semestre de 2019:

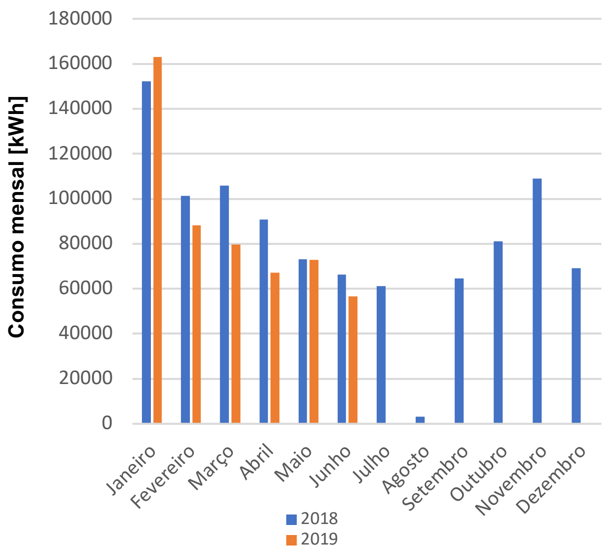


Figure 3: Monthy consumption in 2018 and in first half of 2019

In general, consumption in 2019 is lower when compared to the same period of the previous year. This occurs every month during the first half of the year, with the exception of January. This exception occurs by several factors among which stand out two: first because they are referring to slightly different periods (due to supplier change in 2019, the period recorded was 31/12/18 – 07/02/19 while in 2018 the period recorded was 02/01/18 - 07/02/18) and second because according to IPMA, the month of January 2019 presented slightly lower temperatures compared to normal which implies greater need for heating.

O consumo neste campus é fortemente dependente do calendário letivo dos cadetes. Para demonstrar são apresentados os valores detalhados dos consumos durante 12 dias para o período de aulas normal e para o período de exercícios militares.

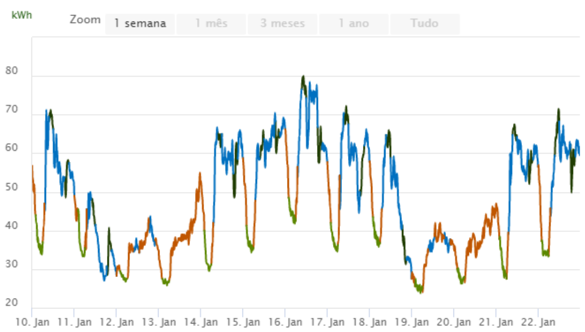


Figure 4: electricity consumption in January

In this period of classes and normal activity the total consumption of active energy on campus was 58 700 kWh. On the other hand, in the period of military exercises consumption is drastically lower.

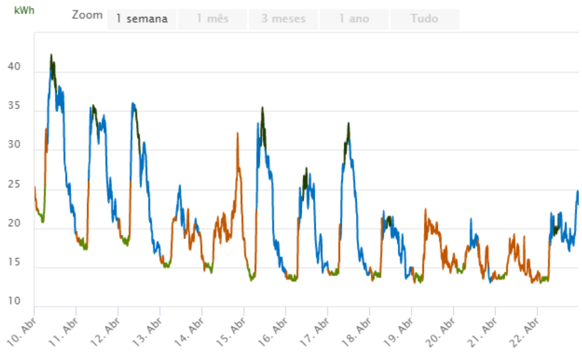


Figure 5: electricity consumption in April

In this period of military activities, the total consumption of active energy on campus was 25 070 kWh.

Despite the high number of employees and military personnel serving in this barracks, it is evidenced with this example that students are effectively the main consumers of electricity since their absence from the barracks represents a reduction of more than 50% in electricity consumption.

5.2. Impact of building B on campus

Building B is characterized by an energy consumption based only on electricity, which is used to trigger lighting, heating/cooling systems and also as a driving force for the various equipment in the building. This power is powered at medium voltage 380 v, and frequency of 50 Hz.

In order to determine the actual consumption profile and consequently the respective fraction of building B on the campus invoice, measurements were made to the general electrical framework of the building for periods of 7 days in different stages of activity of the school year in order to obtain a sample as representative as possible of the reality of operation of that installation and consequently a more detailed characterization of the study.

In general, the variation in campus occupation and consumption is similar to the variation in building B. There is an exception to this pattern of behavior at the time of examinations and in the period of internships and this is because campus consumption has expressive values while the B building has less significant values. That is why an audit was carried out during the class period and another during the exam period to estimate the fraction of this building in the total consumption of the campus in the two periods mentioned. Considering 9 months (8 of classes and 1 of vacation) in which building B has a pattern of consumption similar to that of campus and 3 months in which this behavior is distinct, thus determines a weighted average of the fraction responsible for building B in campus consumption.

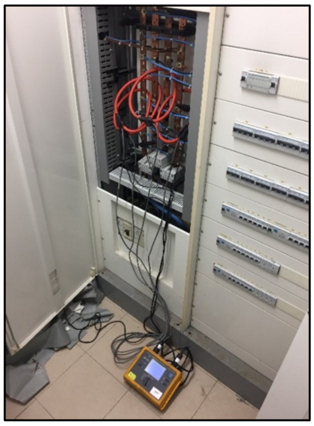


Figure 6: image of the Monitoring

Monitoring during the examination season is called 'Audit 1' and the results are presented in Figure 7.

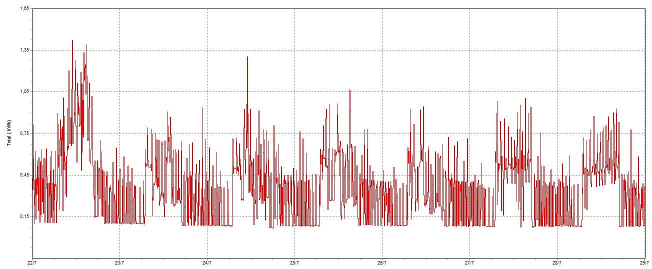


Figure 7: active energy at building B from 22/07 – 28/07

During this period the consumption of the building was 727,83 kWh. At night the active energy consumption is virtually nil, with values hovering around 0,06 kWh. Over the days a consumption pattern is verified, characterized by a predominantly increasing variation until shortly after noon and a decrease over the afternoon until its minimum value, reached overnight.

According to the energy provider's online platform, the recorded values for total campus consumption in the same period are presented below.

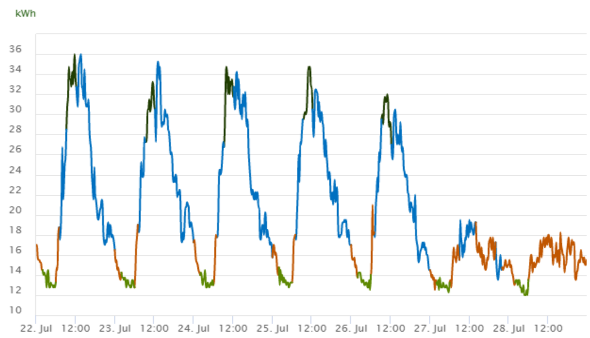


Figure 8: electricity on campus from 22/07 - 28/07

Although it is the time of examinations of the cadets, in the remaining quartering is a period of normal activity. it is evident the standard of consumption of working days with 5 peaks followed by 2 days with lower records representing Saturday and Sunday. During the period analyzed, the active energy consumption of the campus was 13,505 kWh distributed at 4 current tariffs. The value is substantially high in view of the value measured in building B due to the low occupation of the building and the normal functioning of the other campus organs. This is a period when the evolution of the consumption of building B is not similar to that of campus.

On the other hand, monitoring carried out during the class period is called 'Audit 2' and the results are presented in Figure 9.

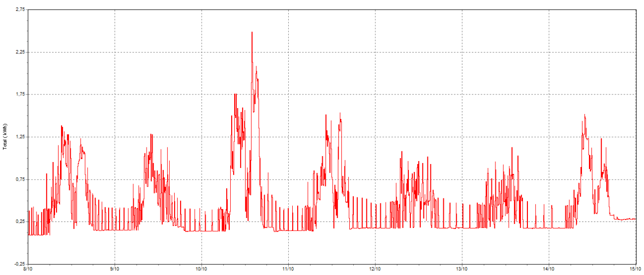


Figure 9: variation of active energy in building B of 08/10 – 14/10

During this period the consumption of the building was 888,092 kWh. This week refers to the second week of classes of this school year. The result presented represents monitoring that starts on a Tuesday and ends on a Monday so that there are 4 relatively high peaks, followed by two lower peaks, representing the weekend, and finally the peak for Monday. There is common behavior over the days that is distinct from audit 1. This behavior is characterized by a predominantly increasing variation until shortly after noon and with a decreasing peak during the lunch period. After this there is a decrease in consumption again, the similarity of the morning period, which extends until the late afternoon where a decrease begins until reaching its minimum at night.

The values recorded for total campus consumption in the same period were:

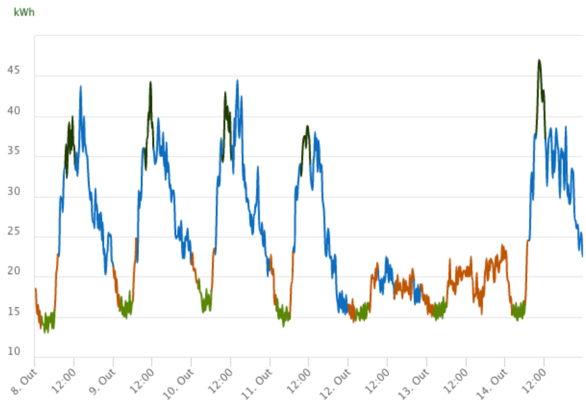


Figure 10: electricity consumption from 08/10 - 14/10

This period is exemplifying the pattern of electricity consumption for much of the year because it represents the normal occupancy period of building B. During the period analyzed the active energy consumption of the campus was 16 491 kWh.

Considering the data of audit 2 associated with energy simulation data, the daily consumption profile of the building was created that serves as a work base in the sizing of the photovoltaic system.

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5.3. Model in DesignBuilder e EnergyPlus

The creation of the three-dimensional model of the building aims to comply with legal procedures for issuing the energy certificate and to allow the virtual implementation of some energy efficiency measures and its estimate of reduction in the consumption.

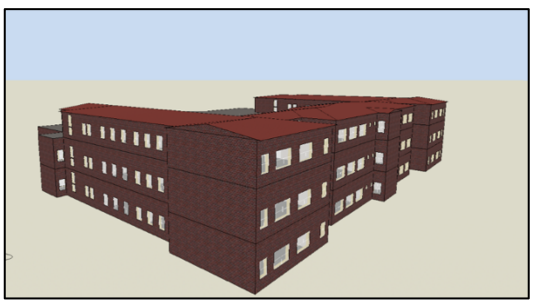

Figure 11: rendering of building B three-dimensional model in DesignBuilder tool

The model was built floor to floor and in detail, so it presents the high degree of complexity and all existing spaces in the building from classrooms to sanitary facilities through offices, leisure spaces and technical areas.

By floors, the spaces are grouped by thermal zones and according to their respective typologies. This identification of the zones depending on the activity is extremely important from the point of view of the simulation to the extent that all data introduced for occupation, equipment and activity in space influence stems from internal thermal gains and consequently on the energy requirements of each space.

In the software is introduced the maximum occupancy of each space according to the data collected in the audit. Regarding the consumption in equipment and lighting, a characterization of the spaces and the lifting of electrical equipment and their nominal power were carried out. All equipment was considered in the characterization of the three-dimensional model and associated with their spaces of use according to the actual thermal gains also identified in the audit phase. The HVAC system was also characterized in the model according to reality.

Dynamic thermal simulation was performed on EnergyPlus taking into account the detailed characterization of them made in DesignBuilder.

According to the simulation for a typical year in Lisbon, Figure 12, the annual consumption of the building is 53 542,17 kWh. According to the results of the energy simulation, lighting represents a considerable fraction of the total consumption of the building, about 40.1%, as well as equipment with about 33% and the air conditioning needs that represents about 26.9%.

5. 4. Validation

The validation was carried out with the objective of conferring credibility and acceptance to the methodology and results of the investigation. This process was carried out comparing the results of monitoring with the results of the energy simulation provided by EnergyPlus.

5. 5. Energy Certification

According to the legislation in force, for the purposes of energy certification, building B is defined as a Large Building Trade and Services (GES), as it has a useful area of more than 1000m^2 and also an installed heating/cooling power greater than 25 kW. Therefore, for this typology of buildings the energy class ratio, R, energy efficiency indicator is defined according to Order No 15793-J/2013 of December 3.

According to the theoretical assumptions presented and the legislation in force for energy class buildings means that the building belongs to class C. This result, although approximate, is important in that it serves as an indicator of the class the building and lays up some foundations for a future official certification that will be carried out.

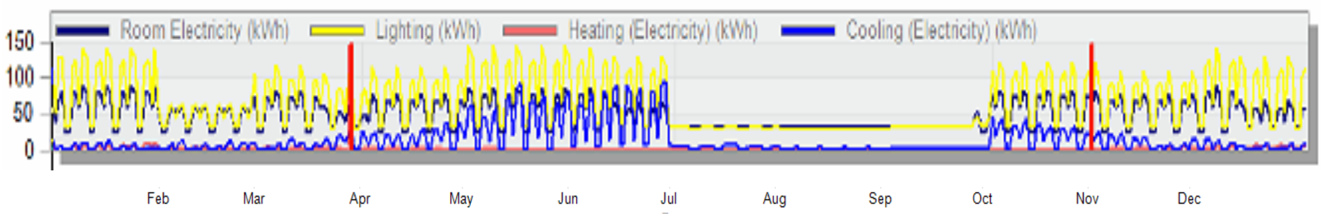

Figure 12: evolution of annual electricity consumption, lighting and heating/cooling

6. Energy optimization

In order to achieve the zero-energy balance, an improvement proposal can go through investment in more efficient equipment and use renewable energy sources. This option is economically favorable in view of the option of carrying out a major intervention in the building to implement energy efficiency standards and best practices, such as passive house. In this particular case, in order to transform the existing building into a building with zero energy needs it is necessary to combine a set of energy efficiency measures.

6.1. Energy efficiency measures: consumption

The main objective of this study and energy efficiency is to reduce consumption, but without harming the services and activities developed in the building. To this end, consumption in lighting and equipment used must be reduced, as they represent a large fraction of the building's energy needs [10].

A set of various energy efficiency measures are proposed, in the lighting sector, behavioral measures, improvement of equipment technologies, among others.

Replacing lamps

The lighting in building B represents an installed power of 42,6158 kW. Given this value it is estimated that the impact of lighting on global consumption is significant and this is verified in the simulation results in the computational model. With the replacement of lamps with LED technology, installed power drops dramatically to 17,457 kW, about 59% less.

From the computational model of the building it is possible to update the characteristics and configuration of the lamps of each thermal zone. The consumption needs of the building in relation to lighting reduce, according to Figure 13, and consequently fewer thermal gains which translates into lower consumption in heating/cooling.

This measure is estimated to decrease the consumption of the building by about 20,3% which corresponds to a reduction in the consumption of the building of 10 873,97 kWh/year.

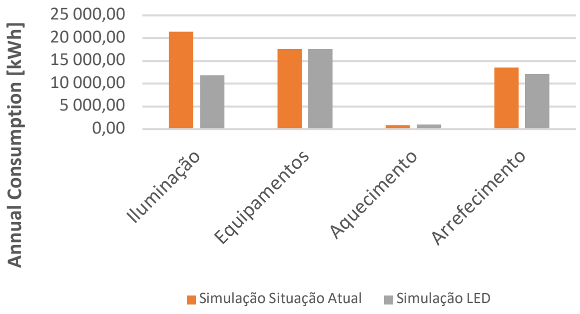

Figure 13: LED vs actual

Placement of Sensors

During audit, the habit of having the lamps always connected was identified when the spaces were occupied although in some situations it was not necessary in view of the availability of sufficient lighting by natural light. A solution to this issue could be the introduction of dual functionality sensors, motion detection and inhibitory photocell that prevents lights from lit when there is sufficient entry of sunlight into space and allows to reduce costs with the invoice Energy [11].

This solution is already in operation in the sanitary facilities with positive feedback from users who no longer have to turn on and off the lights beyond the efficiency in the lighting feature in these spaces.

Equipment Replacement

There is a lack of standardization in the equipment used, namely in projectors. The suggested improvement proposal would be the option for the most energy efficient model and implementation in all spaces that justify it. This measure would be implemented gradually due to the end of life of existing equipment today.

Behavioral Measures

To reduce energy consumption, you can't just stick to more efficient equipment. The human factor is increasingly important and therefore the good practices of conduct and use by the consumer are a key element in the entire energy management process. From this perspective it is important that users and occupants of the building be made aware of this. Thus, it is suggested some measures to be adopted that undergo the establishment of standard, care to be taken, among others.

6.2. Energy efficiency measures: generation

The current energy needs of building B are 53,54 MWh/year and in scenario B (with implementation of improvements in the lighting system, lamp replacement) has lower needs of about 20% corresponding to 42,67 MWh/year. Currently this energy demand of scenario A is fully guaranteed by the network. This point presents a complementary form for this supply through a renewable energy source. Thus, a photovoltaic system is sizing in the roof of the building.

Photovoltaic system sizing

For the photovoltaic system to be sized for the building, the energy produced is not restricted only to this installation. The remainder not used by the building is used to fuel other campus needs through $PT_{1.}$ This scaling was performed through an Excel spreadsheet as will be presented throughout this point.

As this is a network-connected UPAC it is necessary to assess some important factors for system installation: available area, orientation and tilt of modules, type of panel to consider, inverter, among others.

Design results

The useful coverage area that is available for the installation of photovoltaic modules is 600m^2. According to excel spreadsheet data, created for this process, and taking into account the selected modules, it allows the installation of 360 270W panels that make up an installed power of 97,20 kW. According to the study conducted, two possible scenarios to be evaluated are created. In this phase, two scenarios were created for simulation:

- Scenario A (current scenario), resulting from the characterization of building B under the conditions in which it is currently located;

- Scenario B (scenario with lighting efficiency), resulting from the characterization of the building with the energy efficiency measures in the lighting implemented, through the replacement of lamps by LED technology.

Figure 14: satellite image of the cover and areas to be considered

Simulation 1

The first simulation was based on the values and conditions related to scenario A representing the current situation of building B.

The intention is that the energy produced that is not consumed by the building will be harnessed by the other buildings on campus thus avoiding waste and promoting greater reduction of consumption on campus. This excess that is produced does not require that it be sold to RESP to the extent that there is a need for use in other campus spaces. According to the results presented, building B has a level of self-sufficiency of 74%, that is, it manages through photovoltaic generation to provide almost in full its energy needs. Given the production capacity of the photovoltaic system installed, the building consumes about 35% of the total production. It would be expected that the remainder would be conducted and used by the other facilities.

Simulation 2

And this simulation refers to the situation of scenario B that represents the simulation conditions with the improvements in the lighting system already implemented.

According to the results presented, building B has a level of self-sufficiency of 77%, that is, it can through photovoltaic generation provide more than half of its energy needs. Given the production capacity of the photovoltaic system installed, the building consumes about 29% of the total production.

6.3. Economic feasibility analysis

In addition to the energy simulation of the implementation of this measure, the economic feasibility study was also carried out based on the cost that is avoided with the production of electricity in the building. At this stage two simulation were also carried out for economic evaluation. Both have positive NPV, which means that the project is economically viable. During the lifetime of the system, which is 25 years old, is estimated a savings of 693 536 € for the case of simulation 1 and 696 864 € for the case of simulation 2. As for the return period of investment it is estimated that in both this is 4 years.

Conclusions

Given the current panorama and conjuncture that lives in the armed forces, the term of order common to all branches is cost containment and rationalization of resources. In this context, efficiency in the employment of the media and resources plays a vital role in carrying out the missions assigned.

In order to be able to act with criterion and effectively in the process of reducing energy consumption and its efficiency is useless to know when, where and how much is consumed by electricity. According to the results of the analysis for the first half of the current year, 527 591 kWh were consumed against the 589 664 kWh for the same period of 2018. As is the case, due to the change in supplier and implementation of some measures, there has been a reduction in consumption and monetary savings of 9 773,76 € (vat).

By installing an electrical monitoring equipment in the general frame of building B, it was possible to measure consumption and compare the values relative to the campus and calculate the fraction affecting the building. Thus, it is concluded that building B accounts for about 5.4% of the total annual consumption of the campus, which represents about 7,970 €. Through the geometric and energetic computational model *(EnergyPlus)*it was possible to simulate the impact of some measures to be implemented in the building. For lighting, the replacement of lamps with LED technology allowed, in a simulated environment, to reduce the energy consumption of building B by 20%.

This dissertation has confirmed the idea that the Armed Forces and the Army should also move at the forefront in this sector in order to increase energy efficiency and meet national and European Union targets. In addition to following energy and environmental policies allows the reduction of financial burdens and contributes to the affirmation of a modern, attractive and high-competence Army.

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