Promotion of Energy Efficiency Measures in SIBS Forward Payment Solutions

Ricardo Júlio Ruas Pessoa Dinis
ricardopessoadinis@tecnico.ulisboa.pt

Instituto Superior Técnico, Universidade de Lisboa, Portugal

January 2021

Abstract

To avoid extreme exploitation of fossil fuels and reenforce the need of growing sustainably, the European Union has strategized a plan and several targets to be achieved by the years 2020 and 2030, that force the implementation of renewable energy sources as well as the improvement in energy efficiency. Moreover, the building sector is crucial in this plan, being one of the most important points, the retrofitting of already existing buildings. Better and more energy efficient buildings improve the quality of citizens' life while bringing additional benefits to the economy. This case study is one of the national's internships programs provided by GALP21 and Instituto Superior Técnico. The study was carried out with the aim of performing the energetic and economic evaluation of implementing some energy efficiency measures to SIBS Forward Payment Solutions' building. Firstly, a careful analysis of the SIBS's electric consumption was performed and a review to existing literature to provide basis of knowledge to guide the implementation of the proposed energy efficiency measures. Those measures were the replacement of the current luminaries with more energy efficient ones and the installation of photovoltaic modules on the roof of the building. From an economic standpoint, the obtained results are reasonable. The net present value for the measures applied turned out to be positive, proving the project's profitability, returning 6592.34€ in annual financial savings for SIBS. On an energy standpoint, if applied, the measures will result in a 9% energy saving and 9% reduction in CO2 emissions for the company.

Key Words: Energy Efficiency, Energy management, Renewable energies, LED luminaries, Photovoltaic systems, Office buildings

1 Introduction

The transition to a climate-neutral society is both an urgent challenge and an opportunity to build a better future for all. To reenforce the need of growing sustainably, the European Union has strategized a plan and several targets to be achieved by the year 2020. The plan primarily focuses on three key targets: (i) 20% reduction in greenhouse gases emissions, comparing to 1990 levels; (ii) 20% of energy consumption must be produced by renewables sources; (iii) 20% improvement in energy efficiency [1]; The European Union strategy is a long-term plan, and so, there are already proposed more ambitious targets for 2030. These targets include: (i) 55% reduction in greenhouse gases emissions, comparing to 1990 levels; (ii) 32% of energy consumption must be produced by renewables sources; (iii) 32.5% improvement in energy efficiency [2]; A complete and formal proposal, with wide targets and policy objectives for means an economy with net-zero greenhouse gas emissions, which is the target by 2050 [3]. To achieve the proposed goals, there had to be an increase in investment by the governments in technologies based in renewable sources, energy efficiency and infrastructures that are less energy consuming, like Near-Zero Energy Buildings (NZEB), buildings with very high energy performance, having energy mostly coming from renewable sources. Moreover, the building sector is crucial in this plan, being one of the most important points, the retrofitting of already existing buildings. Better and more energy efficient buildings improve the quality of citizens' life while bringing additional benefits to the economy and the society. This is where this dissertation is inserted, on the retrofitting of one of SIBS Payment Solutions' buildings, by promoting energy efficiency measures.

1.1 Methodology

The study was carried out with an internship at SIBS Forward Payment Solutions with the aim of performing the energetic and economic evaluation of implementing energy efficiency measures to its building. First, a review to the existent literature was performed to guide the achievement of this project goal. The Literature Review encompasses important definitions associated with the project's theme and showcases previous work done in the area, presenting various articles with case studies to help choosing the measures to be applied in this case. The measures applied were the replacement of the current luminaries with more energy efficient ones and the installation of photovoltaic modules on the roof of the building. The promotion of these measures implied some visits to the facilities to understand its dynamics and goals, the study of the different technologies applied and the market search for the better equipment to install. The energetic study was carried out using different software to simulate the energy savings of the measures applied. After, the economic study was performed calculating the relevant financial indicators, to assess the viability of the different investments. In the end of the internship, due to the extraordinary conditions the world lived in, a study on the spread of the COVID-19 virus on the workplace was carried out, as well as the assessment of the impact of the imposed regulations on the energy consumption of the building.

2 Literature Review

The purpose of this chapter is to review the existing relevant literature to check the work already done in this field of study, to provide basis of knowledge and possible approaches to the problem presented in the previous chapter. The aim is to analyse ways of applying energy efficiency measures to buildings, particularly office buildings, and the challenges posed to applying them.

2.1 Energy Benchmarking values in office buildings

In Europe, Buildings are the single largest energy consumer, being responsible for approximately 40% of European Union energy consumption and 36% of the greenhouse gas emissions [4]. This makes Benchmarking of energy consumption in the building sector very important, especially in office buildings, to help verify if the energy consumption of a certain building is within the expected range of values and enabling the creation of strategies to decrease energy consumption. Basically, a "benchmark" is a reference or measurement standard used for comparison. It can be understood as a continuous activity of identifying and adapting the best practices and processes that will improve performance. The process of benchmarking is very useful, allowing the target setting for promoting best practices and achieving better energy efficiency in buildings and industrial facilities.

There are three general approaches to benchmarking: (i) Tracking approach: comparison of the building's performance to itself, i.e., previous performance data; (ii) Target finder approach: comparison to a sample of a similar buildings; (iii) Simulation model approach: energy simulation model, using predefined baseline characteristics, such as meeting an energy code or standard.

Benchmarking of these values is not an easy task, energy consumption in this type of buildings depend on too many different factors like location, building structure, size, number of occupants, type of activity, type of energy consuming systems, such as heating and cooling system, lighting system, ventilation system and office equipment. This disparity of factors makes it difficult to find an appropriate acceptable range of energy consuming values. Nonetheless, companies are constantly working on trying to consume less energy, because that benefits them on an environmental and economic aspect. Oliveira Veloso et. al. (2020) [5] developed a methodology to create a benchmarking of electric energy consumption for office building towers in a mild temperate climate using as an example the city of Belo Horizonte, Brazil. The methodology aimed to predict an accurate energy consumption range and it was found that simulation predictions can present a good estimation for the energy consumption of a fully conditioned office buildings but for office buildings conditioned in mixed mode, predictions show higher consumption levels than consumption measures let foresee. This means that a benchmarking scale set from measured data can better portray the actual electricity energy.

2.2 Promotion of energy efficiency measures

In this section, there is presented a short revision of different measures promoting energy efficiency applied in different case studies:

Sun et al. (2018) [6] presented a case study of a retrofitting of an already existing building to a Near-Zero Energy Building (NZEB). In his work, he showcased a different number of measures that could be applied to diminish energy consumption. According to Sun, measures can be categorized into active or passive measures. Active measures involve improving lighting systems, heating, ventilation, air conditioning (HVAC) systems, and other service energy intensive systems. Passive solutions aim to improve the energy efficiency of building envelopes (e.g., façade systems). The most relevant measures, for this work, are the active ones, particularly the one Sun analysed in the case study, replacement of T5 fluorescent tubes with LED (light-emitting diode) lighting. In addition, each LED panel was equipped with an intelligent sensor grid that could determine lighting levels according to occupancy conditions. These measures resulted in savings of around 71,264 kWh annually for the lightning retrofitting and 2990 kWh annually for the lighting control.

Yiqun Pan et. al. (2017) [7] presented a study of the energy performance of various lighting systems and control strategies applied in open-plan offices. All the experiments were carried out on a test bed. The energy saving potential of various lighting control strategies was simulated and analysed, and a combined lighting control strategy of background dimming lighting plus task lighting was studied on the test bed. Moreover, visual comfort was investigated to determine the optimal background dimming lighting illumination and energy performance of the combined lighting system. It resulted in savings from general lighting control of 50% or higher. With task lighting control combined with dimmable general lighting, the energy savings rate can be increased to 59%.

Luewarasirikul et. al (2015) [8] assessed the consequences of replacing compact fluorescent lights (CFL) or incandescent lights with LED lights, in an office, located in Thailand. His research provided useful information as he concluded that in both cases, LED lights are more energy efficient and have a much longer life span (of around 50000 hours). The payback period of replacing the lamps would be of around 10000 hours of use and would produce savings of $280.50 and $41.25, switching from incandescent and CFL respectively.

2.3 User comfort in the workplace

User comfort in the workplace is defined as the conditions wherein the average person does not experience the feeling of physical or psychological discomfort, and it is assessed by subjective evaluation. Due to this subjectivity, it is nearly impossible to gather the necessary work conditions to please everyone, thus the user comfort is predicted using a predicted mean vote (PMV) index and the predicted percent dissatisfied (PPD). The PMV index predicts the mean response of a large group of people according to the ASHRAE thermal sensation scale ranging from -3 to 3, from cold to hot respectively, where 0 is the neutral, the ideal state. After acquiring the PMV, the PPD can be obtained through a mathematical relation. This model has its comfort zone in the PMV range of -0.5 to 0.5, where it corresponds to 10% of people dissatisfied. Even with a PMV equal to 0, 5% of people are still dissatisfied, so there are no models that can please everyone [9].

This subject is a recurrent theme of investigation, being interesting to companies because it is directly related to productivity, so they are always looking to improve the user comfort in the workplace, to increase company's productivity. However, there should be a balance between user comfort and energy consumption, as Shahzad et. al. (2015) [10] had investigated. He compared the user comfort and energy efficiency of two office layouts, respectively Norwegian cellular and British open plan offices. The Norwegian office expected users to find their own comfort, since they were provided with control over a window, blinds, door, and the option to adjust heating and cooling. In opposition, in the British office, the users' control over the environment conditions were more limited, since only the occupants seated around the perimeter of the building could control the openable windows and blinds and a centrally operated displacement ventilation was the main thermal control system. Users' perception of thermal environment was inquired, and it resulted in 35% higher user satisfaction and 20% higher user comfort in the Norwegian office compared to the British open plan office. However, the consumption of energy was much higher in the Norwegian office compared to the British. This reenforces the importance of balancing between thermal comfort and energy consumption, as either extreme presents difficulties for the other.

2.4 Solar photovoltaic energy

It is very clear the benefits of using PV technology on both economic and energetic aspects. To prove that, Jurasz et. al (2019) [11] studied the contribution of photovoltaics to the reduction of peak load in office buildings, thus reducing the dependence on the grid and the energy costs. He presented a case study of an office building in Poland and performed an economic and energetic simulation using three different energy tariffs. The results showed a decrease of approximately 27% (from 60kW to 44kW) on peak load and reduction of 5.8% on energy costs using the most expensive energy tariff.

The constant development of technology and the recurrent search for more greener energy production technology allied with the implementation of regulations by the governments limiting the emission of greenhouse gases and encouraging renewable sources of energy, created a significant increase in the implementation of solar photovoltaic technologies, in a global scale, in the last decade. The global solar installed capacity grew from 40 GW in 2010 to 579 GW in 2019 [12]. In figure 1, one can see that in 2019 there was an increase in solar installations in Europe, representing 16,7 GW of new installations added, thus a 104% increase over the previous year [13]. This increase was very accentuated in some countries, being Spain the largest solar market, adding 4,7 GW, followed by Germany with 4 GW and then the Netherlands with 2,5 GW. However, it is possible to see that some countries have been reducing their solar PV installed capacity throughout the years, this could be justified with the end of some government subsidies. Nevertheless, the global values of solar installations have been increasing every year, the decrease in Europe from 2011 to 2018, has been highly compensated by the recent growth in the Asian market, particularly in China and Japan.

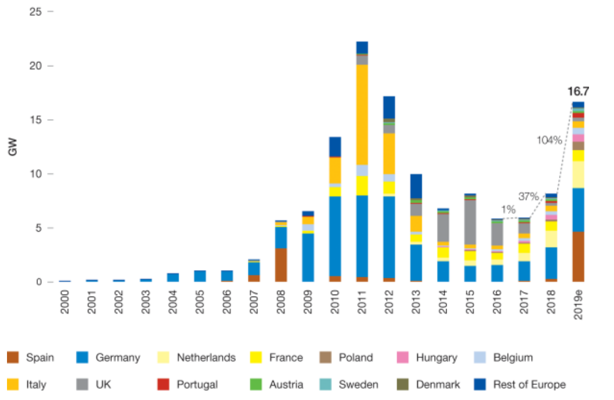

Figure 1: EU-28 annual solar PV installed capacity 2000-2019 [13]

In the year 2019, Portugal registered an electric energy consumption from the public grid of 50,3TWh, 51% of this energy was produced from renewable sources, being 2.1% produced by solar photovoltaic [14]. Portugal's renewable production suffered a significant growth in the last few years, being well positioned to meet the EU's target for Portugal's renewable production, that is 31% of the gross final consumption of energy, having registered 30.3% in 2018 [15]. The Installed capacity also has been growing in Portugal, mainly for renewable, increasing from 8459 MW in 2008 to 14370 MW in 2019, representing 64.7% of total installed capacity in Portugal [16]. The solar photovoltaic sector is the one that has suffered the major increment in installed capacity, with 914 MW in 2019, more 36% in comparison to 2018, and 8 times higher than in 2009 [16].

In the last 15 years, environmental awareness increased significantly, leading to the industrialization and development of the renewable market, turning it into a global scale. Therefore, new countries adopted and started producing this kind of technology, creating competition in this sector. This worldwide awareness and improvement in production, lead to more demand, that consequently increased the production, which lead to falling prices. This created an economy of scale in this sector, that explains why the cost of manufacturing solar panels has plummeted dramatically in the last decade, making solar the world's cheapest source of electricity today [17]. The figure 2 represents the decrease of the price per watt of solar photovoltaic modules from 1976 to 2019. It shows that the price of solar modules decreased from $106 to $0.38 per watt, representing a decline of 99.6%. Both axis on the graph are represented on a logarithmic base and on a logarithmic axis a measure that appears to follow a straight line, represents an exponential growth. This means, that the price per watt decreased exponentially as the installed capacity increased exponentially.

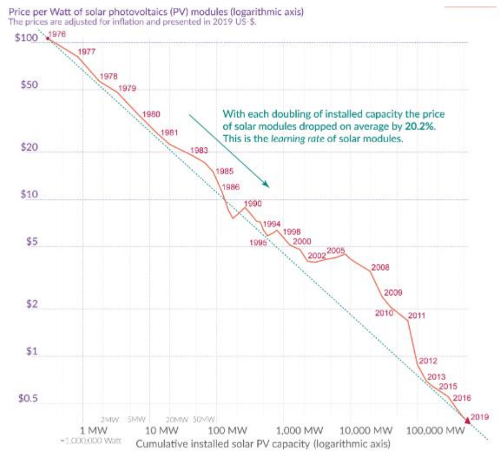

Figure 2: Evolution of price per watt in function of installed PV capacity 1976-2019 [18]

More deployment means falling prices, which means more deployment. In the year 2020, the price per watt registered the lowest ever for photovoltaic modules, having reach the price point of $0.17 per watt [19].

3 Case Study: SIBS Forward Payment Solutions

SIBS Payment Solutions is a Portuguese company that provides financial, modern, and secure services, in the sector of payments, to more than 300 million users in a global scale. This company gathers all the bank operation in Portugal, including the entire debit card system, the network, the local payment machines, and the automated teller machines (ATM's). Moreover, they have created digital payment platforms like MBWay and MBnet, providing different alternatives to their users, always investing in innovation. In addition to Portugal, their field of action includes several countries in Europe and Africa, like Angola, Poland, Romania, Mozambique. To support this broad field of action, SIBS has different infrastructures, serving powerful datacentres, which implicate a substantial energy consumption. This is where this dissertation is inserted. The aim is to decrease energy consumption by performing a case study of one of their buildings.

The building is very populated, receiving daily 800 workers, from security staff, office staff to maintenance staff, creating an elevated energy demand. In the year of 2019, SIBS registered, in this building, an annual energy consumption of 1.58 GWh, thus, this case study is focussed on the promotion of two energy efficiency measures to the building, aiming to decrease the energy consumption of the building, and consequently the money spent on electricity by the company. These promoted measures were, as explained before: (i) The replacement of the installed luminaries for LED luminaries, on the six open spaces; (ii) The installation of photovoltaic modules on the roof;

In this work, the proposed investments will be evaluated using three financial measurement tools: the net present value (NPV), the payback period (PP) and the internal rate of return (IRR). These tools will assure the quality in the investment's decision.

4 Illumination replacement project

This chapter aims to present the different phases related to the replacement of the existent luminaries with LED based luminaries, in the open spaces. To this end, it will be presented the methodology used on the project conception. One of the objectives of this work is to study the energy and cost savings of changing the lamps installed with LED type lamps. LED based luminaires are an attractive alternative comparing to the ones already installed because they present properties such as: (i) Long lifetime; (ii) Flexible design; (iii) Dimmability; (iv) Almost negligible heat transfer in the light beam; (v) More energy efficient luminaires. On the other hand, LED type lamps are more expensive than the halogenic lamps, which means the replacement of the lamps would imply an investment by the company, for that reason it is necessary to evaluate the project on a financial side, to see in how much time and if the investment will be worth it. Another aspect to take in consideration is if the LED type lamps provide the acceptable level of illuminance referred previously in this section.

In this work, illumination will only be analysed in the six open space areas, since in an open space office, illumination is one of the most energy consuming parameters. Most of the time, natural light is not enough to achieve the value of illumination needed to work properly without health implications to the workers. These areas have the most concentration of people working at the same time in the building, so the lights must always be turned on. The procedure used to perform this analysis, on an energy standpoint, was the following: 1. Inquiry of the installed luminaries and current energy consumption; 2. Survey of the LED market to choose the models with an equivalent, or approximated, luminous flux to the lamps that will be replaced; 3. Selection of two brands with different models suggested; 4. Calculation of the power reduction and respective energy consumption for each lamp; 5. Choice of the most beneficial combination of lamps.

The current luminaries installed were divided in three categories according to the lamp model as shown in table 1. These lamps are T5 models from the brand Iledo.

Table 1: Characteristics of the installed lamps

	Quantity	Power [W]	Efficacy [lm/w]
Type 1	68	21	90.48
Type 2	28	28	92.86
Type 3	768	35	94.29

The two alternative manufacturers chosen were Philips and OSRAM, since they were the ones that had the best options for this case. After the extensive review of both brands' catalogues, it was decided to propose for each type of lamp a T5 and a T8 alternative. Since T8 LED lamps are also more energy efficient than the installed lamps and less cost demanding than the T5, they may signify a better investment for the company. It is important to clarify that using T8 lamps, instead of T5 lamps, would imply the replacement of the electronic ballasts. This replacement would involve in a larger investment, although this type of cost will not be considered in the present dissertation.

An energetic and economic study was performed, comparing the specifications of the proposed lamps with the current scenario, as well as the application of the financial indicators to assess the viability of the investment, as explained before in this dissertation. The current situation presents an annual energy consumption of 122884.61 kWh, obtained by the sum of the energy consumption of the three types of lamps installed, producing a total annual electricity cost of 5794.62€. To simplify the calculations, it was assumed a 16h hours daily usage, since the lamps are usually turned on around 6 am and turned off around 10 pm, varying by 2 hours some other days. Also, it was assumed that each month had 22 working days. The obtained consumption represents 7.78% of the total electricity consumption of the building registered in 2019. A 7.78% share might not seem very significant, but when taken into context, the importance of it reasonably increases. Since this building has a lot of energy consuming systems, that make it reach high annual energy consumption numbers, this share just for the illumination in six open space offices might be higher than expected. The financial indicators have an important role in analysing the results. Even though, the diminishing in energy consumption is a crucial part in this project, the economic factor is what makes it feasible for the company. As predicted, the LED T8 models present a more attractive alternative to this situation, comparing to the LED T5 models. Since the T5 models are more cost demanding, implying a large investment, obtaining higher payback periods, in most cases higher than the lifetime period of the lamp, negative IRR's and NPV's. This indicates, that investing in the LED T5 models, would not be a viable investment and the company would lose money. Since the initial investment is very high, due to the lamps' price, the replacement will only be worth it, if the proposed lamps produce significant annual energy savings, otherwise the payback period will be too high and the financial indicators will turn out to be negative, because the produced savings are not big enough to compensate the initial investment. It is important to refer that the NPV was calculated using the lamp lifetime as the time period and a discount rate of 5%. The indicators should only be compared between models of the same type, since the quantity of lamps needed for the different types varies and that influences the initial investment needed. This is the factor, on par with the monetary savings, that most influences the results. The selected alternatives are:

Table 2: Characteristics of the proposed lamps

Proposed Alternatives				
	Model	**Power [W]**	**Efficacy [lm/w]**	**Price [€/unit]**
Type 1	T8 OSRAM	11.3	150.44	15.4
Type 2	T8 OSRAM	15.1	165.56	20.5
Type 3	T8 Philips	18.2	170.33	27.05

These models were the ones that provided the best balance between energy and monetary savings, being the ones with the lowest payback period and the highest NPV's and IRR's. The chosen models imply a payback period of around 8 years, which can be somewhat high for a luminaire investment. However, the average lifetime of this lamps is 14,2 years, the payback would be achieved in 56% of the time of the investment. The new scenario would need an initial investment of 22395.6€ and have an annual energy consumption of 64073.01 kWh, implying an annual cost of 3021,36€. This investment would produce a reduction in annual energy consumption of 58811.6 kWh, lowering the 7.78% share of the luminaries of these six open spaces in the total consumption of the building, to 4.06%, returning 2773.26€ in annual savings.

5 Solar photovoltaic project

This chapter aims to present the different phases in the integration of photovoltaic modules on the roof of the SIBS's building in study. To this end, it will be presented the methodology used, the important calculation and design tools used in the technical phase of the project conception.

The choice of the right module starts very much from the customer's energy needs, but also from the expertise of the project's responsible engineer, especially in terms of selecting the perfect brand. Obviously, the characteristics of each brand differ in price, but in general, the higher the capacity, the higher the cost for the same module area. After a brief market search, one of the manufacturers brands that stood out was the Hanwha Q.cells. This brand is one of the most popular and recognised manufacturers in the photovoltaic industry in Europe, and the average price of their PV modules is generally lower comparing to other modules with similar specification from other renowned brands. After deciding the module's manufacturer, the objective was to find its module that fitted the most the needs of this project. The decision fell up on the module Q.PEAK DUO-G7 335. This module is a monocrystalline module and fills all the needed requirements. It was chosen based on the MPP power and the high efficiency it presents, comparing with other modules of this brand.

Two alternatives were developed, the first which has the modules tilted with the ideal inclination for Portugal (35º) and a second one, which has the modules tilted with a small and not ideal inclination (15º). The second alternative allows the system to have more modules installed, since the shading distance is reduced amongst the modules. However, the tilt angle of modules is not ideal, which will affect the modules' efficiency and performance, nevertheless it is expected that this alternative produces more energy since it enables the installation of more power. Both alternatives were studied and dimensioned using the SMA's software *SunnyDesign.* After inputting the chosen PV modules and the different PV arrays created, the software supports the search of the most suitable inverter, providing automatic designs and suggestions to the user. In both alternatives SMA's inverters were used.

It was proposed the utilization of 111 modules on the first alternative, and two SMA STP 20000TL-30 inverters. The modules were tilted 35º and placed facing to the wall on the roof, having an 11º azimuth angle. The choice of orienting the modules this way instead of placing them facing the optimal orientation, south, was done due to geometrical reasons, having the rows of modules parallel to the wall allows for more modules to be installed. For the second alternative, it was proposed the utilization of 147 modules and SMA STP 15000TL-30. The modules were tilted 15º and just like the previous alternative, they were placed facing to the wall on the roof, having an 11º azimuth angle. The displacement of the modules for both alternatives on the roof can be visualised on figure 3:

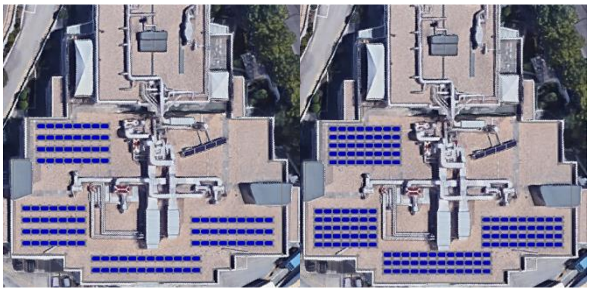

Figure 3: Modules displacement for alternative 1 (on the left) and alternative 2 (on the right)

At first sight, the use of more than one inverter in both alternatives does not appear to be the most economical solution since having a single central inverter would minimise the costs. However, less energy would be generated, because there would be an increase in the current produced in the system and therefore, larger losses would be felt in the cables due to the joule effect.

Alternative 1:

The number of modules chosen represents a system with 37.19 kWp of peak power. Clearly, this system is not dimensioned to fulfil the complete energy demand of the building, that consumes around 1.58 GWh per year. This kind of production would be impossible to satisfy with the available area, nevertheless, the system was optimised to fulfil the energy demand as much as possible. The performed simulation predicted a production of 64198 kWh in the first year, this value represents a 4.06% of the total annual energy consumption of 2019. In terms of production per month, it appears that for the summer months the production values are in between 6000 kWh and 7200 kWh and for the winter months in between 3000 kWh and 5000 kWh. This makes sense, since the solar irradiation is greater in the summer, enabling more energy production.

Alternative 2:

The number of modules chosen represents a system with 48.91 kWp of peak power, a value greater than the previous alternative. Clearly, this system is dimensioned to produce more power than the alternative 1 however it is still not dimensioned to fulfil the complete energy demand of the building. The performed simulation predicted a production of 83459 kWh in the first year, this value represents a 5.28% of the total annual energy consumption of 2019. In terms of production per month, just like the previous alternative, the production is greater in the summer, ranging from 7500 kWh and 10100 kWh and for the winter months in between 3000 kWh and 6000 kWh. The main difference between the two alternatives relies on the summer months production, since in the winter, the production values range around the same values for both systems. On an energy standpoint, the second alternative might seem better than the alternative 1, due to having more power installed. The system produces more energy, representing a bigger share in the total annual energy consumption.

The results show a viable investment for the company for both alternatives. It is important to refer that the NPV was calculated using the modules lifetime as the time period and a discount rate of 5%. Also, the modules will suffer erosion and will worn out, making its efficiency lower. According to the manufacturer, the module will suffer a maximum of 0.54% degradation per year in efficiency, conserving at least 85% of nominal power up to 25 years. The decay in efficiency per year was considered in the economic study.

On the alternative 1, the payback period achieved was 7.02 years, which, considering the 25 years as the average lifetime of the modules, represents a return in the investment in only 28% of the time of the investment. The NPV returned a 20010.18€ of profit after 25 years. The IRR achieved was 14% for the same number of years. On the alternative 2, the payback period achieved was 7.91 years, which, considering the 25 years as the average lifetime of the modules, represents a return in the investment in only 31.6% of the time of the investment, being higher than the first alternative, but still low considering the complete time period of the investment. The NPV returned a 22835.67€ of profit after 25 years. The IRR achieved was 12% for the same number of years. The estimation of the installation costs of the PV system on the roof of the building presents some difficulties, since it is necessary that specialised technical teams visit the building to check all the conditions of the site. For this reason, the cost associated with the installation of this system were not considered.

The alternative 2 presents a greater investment. Having more modules and inverters installed, the investment costs are considerably higher than the ones for the alternative 1, both differing on around 9000€. However, this alternative represents more savings, producing more 30% on both energy and monetary savings than the first alternative. Just by looking at the financial indicators, the alternative 2 has a higher payback period, a lower IRR and a higher NPV, this higher NPV means that the company would have more 2825.49€ of profit, than the first alternative, at the end of the lifetime of the modules. The margin between the two alternatives is not considerable enough to make this alternative clearly more viable than the first, since the other two indicators favour the first alternative. There are two favourable viewpoints that the company can consider. The first, assessing the problem with the intend of generating more energy savings and less emissions, the alternative 2 is the one to consider. The second, with the intend of having a more economically viable solution, the alternative 1 is the one to consider.

6 COVID-19 effect on energy efficiency

In 2020, the world faced a health and economic crisis, the coronavirus disease 2019 (COVID-19) pandemic, caused by the outbreak of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). This outbreak was declared, by the World Health Organization, a public health emergency of International concern on the 30th of January 2020, and a pandemic on the 11th of March 2020. This virus spreads mainly through the air in the dispersion of droplets when people breathe, cough, sneeze, or speak or it might also be spread via contaminated surfaces. Being the mouth, nose and eyes the canals of transmission. The symptoms vary from person to person, being identified as the main symptoms: fever, dry cough, tiredness, and loss of sensations. In some case, people are asymptomatic.

When COVID-19 pandemic spread in Europe, governments imposed unprecedented confinement measures and remote work with mostly unknown repercussions on contemporary societies. The pandemic affected all sectors, especially the economy. Companies had to close and reduce severely their productivity. This led to the closure of some businesses due to the impactful financial hit. This subject is relevant for this dissertation because companies are facing times of adaptation having to follow the recommendations placed by the world health organization. Some of these recommendations imply an increase of energy consumption, so it is important to study ways of following the recommendations in a more energy efficient way to not significantly increase the annual cost of electricity.

In this specific case, SIBS was affected greatly. In Portugal, alike some countries in Europe, during the first months of the spread of the virus, a lot of companies had to close and have their personnel work from home. SIBS was no exception, changing the occupancy rate of 800 people daily to only 160 people. This affected the logistic and organization, having to adapt as best as possible. Due to the decrease of people working in the building, the energy consumption of the building in the year 2020, decreased comparing to 2019 registered consumptions. Comparing the consumption for the time period, starting at January 1st, until December 21st of the respective year, 2019 registered a consumption of 1.54 GWh and the 2020 registered a consumption of 1.40 GWh, indicating a 9.1% of decrease.

The decrease in consumption is easily justified by the decrease of occupancy rate. This means, less energy consumption equipment turned on. In 2020, the HVAC system consumption share was 50,87%, representing a consumption of 713.28 MWh, while in 2019, the HVAC system consumed 740.25 MWh, representing a 48.03% share. The increase of the HVAC system share was expected due to the implemented regulations, that obligate the increase in ventilation on the different spaces in the building, also having less energy consuming systems, due to having less occupation, the share in the total consumption had to increase. However, the consumption itself of the HVAC system decreased, what was not expected. This can also be justified due to the decrease of the occupation rate since less spaces in the building were occupied meaning they did not need to be climatized. The lack of spaces needed to be climatized helped to balance the consumption of the HVAC system, even though the ventilation increased in the spaces that were still being climatized.

Comparing the consumption of the months of march until July of 2020, when the regulations started to be implemented, with the same months of 2019, in 2020 the HVAC system consumed 286.78 MWh, representing a 52.35% share, while in 2019, the same system consumed 284.38 MWh, representing a 47.16% share. Thus, in those months, in 2020 the system consumed more energy than in 2019 even with less people in the building.

When looking at the consumption of energy per person, it has increased substantially from one year to another, since the consumption values are of the same order of magnitude, having only 20% of the usual occupancy rate. Even though the effect of COVID-19 haven not been felt on the total numbers of energy consumption in 2020, one can predict that if the occupation rate had not decreased, and the ventilation still increased as it was regulated, the energy consumption of the building would increase substantially.

7 Conclusions and future work

Buildings are in a process of transformation, shifting from being major energy consumers to more sustainable systems capable of generating, storing, and providing energy. Aligned with the strong political incentive in terms of legislation, which promotes investment in systems and equipment less harmful to the environment, especially in the sector of photovoltaics, and with the new technological advances registered in recent years in the same vein, it has been make it more and more advantageous for both public entities and institutions, to invest in this kind of technologies in order to amortize the increasing energy demand that today's world requires. With all the knowledge acquired before, during and after the internship, it was possible to promote two energy efficiency measures to the building in study, designing functional, balanced, efficient and financially viable options for the company, even with the limitations found throughout the project. Realizing which are the best options for each of the various steps was a challenge that, in the end, was successfully overcome. The proposed measures were the replacement of the current luminaries with more energy efficient ones and the installation of a photovoltaic system on the roof of the building. An economic and technical analysis was performed to both projects. From the technical analysis, the main results to point out are the following: (i) The proposed luminaries lowered the share of energy spent with the lighting of the studied six open space offices from 7.78% to 4.06% generating 58811.6 kWh in annual savings; (ii) Two alternatives were proposed for the photovoltaic system. A more efficient one with 111 modules distributed through the rooftop of the building, having an installed power of 37.19 kWp, producing in the first year of operation 64198 kWh. The second alternative although less efficient, had more power installed, with 48.91 kWp, having 147 modules in the system. Regarding the economic analysis the main results to point out are the following: (i) The analyses to new luminaries were carried out comparing each type of lamp used. The generated NPV's range in between 14.65€ to 2886.69€, producing IRR's between 5% to 7%, having an average of 8 years of payback period for each type of lamp; (ii) The PV systems proposed generated NPV's of 20010.18€ and 22835.67€ respectively, and IRR's ranging from 12 to 14%, having a payback period of less than 8 years.

In this way, if both measures are applied, there is potential of decreasing the annual energy demand of the building in 9%, generating annual energy saving of around 142270.6 kWh, making the company save around 6592.34€ a year. Also, it would reduce the CO_2 emissions in 9%, generating a 66867.18 kg reduction.

To finish the work, a study was carried out to understand the influence of the COVID-19 pandemic in the energy consumption of the building. For that a comparison between 2019 and 2020 energy consumption values was done. It was verified that the energy consumed per person increased in 2020 because, even though, the occupancy rate of the building decreased significantly, the required space ventilation increased. This did not change the total energy consumption of the building, having registered similar values of consumption to the previous year, however the personnel in the building were comparatively much less.

To really utilize the proposed measures in this dissertation, would be important to contact the different suppliers directly, in this case OSRAM, Philips and Hanwha, to determine the bulk price of the required equipment, since in this case study only the singular price for each was considered. Also, specialized technicians in the installation of PV modules in buildings should visit the facilities to properly assess all the costs in the project and give a concrete budget for the investment. Another measure that should be considered in the future is the installation of PV modules vertically in the south façade of the building. Since there are no other buildings around that generate shading on this façade, the potential of energy production of these implementation could be high. Looking at the façade, it can be predicted the installation of around 60 to 80 more modules, what would imply a considerable increase in energy production and consequently in energy and monetary savings. Also, if the company is not interested in installing PV modules on the façade, since it could ruin the aesthetic of the building, the installation of PV modules on the exterior spaces near the parking lots should be considered. Once again, it would increase the potential energy and monetary savings for the company.

References

[1] “2020 climate & energy package | Climate Action.” https://ec.europa.eu/clima/policies/strategies/2020_en (accessed Oct. 26, 2020).

[2] “2030 climate & energy framework | Climate Action.” https://ec.europa.eu/clima/policies/strategies/2030_en (accessed Oct. 26, 2020).

[3] “2050 long-term strategy | Climate Action.” https://ec.europa.eu/clima/policies/strategies/2050_en (accessed Oct. 26, 2020).

[4] “Energy performance of buildings directive | Energy.” https://ec.europa.eu/energy/topics/energy-efficiency/energy-efficient-buildings/energy-performance-buildings-directive_en#facts-and-figures (accessed Oct. 27, 2020).

[5] A. C. de Oliveira Veloso, R. V. Gonçalves de Souza, and F. N. dos Santos, “Energy benchmarking for office building towers in mild temperate climate,” *Energy Build.*, vol. 222, pp. 12–14, 2020, doi: 10.1016/j.enbuild.2020.110059.

[6] X. Sun, Z. Gou, and S. S. Y. Lau, “Cost-effectiveness of active and passive design strategies for existing building retrofits in tropical climate: Case study of a zero energy building,” *J. Clean. Prod.*, vol. 183, pp. 35–45, 2018, doi: 10.1016/j.jclepro.2018.02.137.

[7] L. Xu, Y. Pan, Y. Yao, D. Cai, Z. Huang, and N. Linder, “Lighting energy efficiency in offices under different control strategies,” *Energy Build.*, vol. 138, pp. 127–139, 2017, doi: 10.1016/j.enbuild.2016.12.006.

[8] N. Luewarasirikul, “A Study of Electrical Energy Saving in Office,” *Procedia - Soc. Behav. Sci.*, vol. 197, no. February, pp. 1203–1208, 2015, doi: 10.1016/j.sbspro.2015.07.379.

[9] H. Thermoregulation, “Chapter 8: Thermal comfort,” *ASHRAE Handb.*, no. Gagge 1937, 2001.

[10] S. S. Shahzad, J. Brennan, D. Theodossopoulos, B. Hughes, and J. K. Calautit, “Energy Efficiency and User Comfort in the Workplace: Norwegian Cellular vs. British Open Plan Workplaces,” *Energy Procedia*, vol. 75, pp. 807–812, 2015, doi: 10.1016/j.egypro.2015.07.135.

[11] J. Jurasz and P. E. Campana, “The potential of photovoltaic systems to reduce energy costs for office buildings in time-dependent and peak-load-dependent tariffs,” *Sustain. Cities Soc.*, vol. 44, no. July 2018, pp. 871–879, 2019, doi: 10.1016/j.scs.2018.10.048.

[12] “Solar energy.” https://www.irena.org/solar (accessed Oct. 06, 2020).

[13] “EU solar boom: over 100% solar market increase in 2019 – SolarPower Europe.” https://www.solarpowereurope.org/eu-solar-boom-over-100-solar-market-increase-in-2019/ (accessed Oct. 06, 2020).

[14] “REN - Publicações.” https://www.ren.pt/pt-PT/media/publicacoes/ (accessed Oct. 31, 2020).

[15] “Energia - Principais números.” https://www.dgeg.gov.pt/pt/estatistica/energia/publicacoes/energia-principais-numeros/ (accessed Oct. 31, 2020).

[16] “Energia em números.” https://www.dgeg.gov.pt/pt/estatistica/energia/publicacoes/energia-em-numeros/ (accessed Oct. 31, 2020).

[17] “Why did renewables become so cheap so fast? And what can we do to use this global opportunity for green growth? - Our World in Data.” https://ourworldindata.org/cheap-renewables-growth?fbclid=IwAR1U5wZyY_2--MziGWN4pFJZ8qUNPGw1agxwQT1ISCX_u-aU2veRiDPLVCk (accessed Dec. 16, 2020).

[18] “Solar PV module prices.” https://ourworldindata.org/grapher/solar-pv-prices (accessed Dec. 16, 2020).

[19] “Long read: UNSW’s Martin Green sets out solar’s accelerating technological development – pv magazine Australia.” https://www.pv-magazine-australia.com/2018/05/27/long-read-unsws-martin-green-sets-out-solars-accelerating-technological-development/ (accessed Dec. 16, 2020).