Application of Energy Efficiency in A Company Through A Photovoltaic Energy System on Grid

Samuel Guimaraes Ferreira
automacaoindustrial.maa1@gmail.com
Academic department, University Center FAMETRO, Amazonas-Brazil

Livia da Silva Oliveira
oliveira.livia@gmail.com
Academic department, University Center FAMETRO, Amazonas-Brazil

David Barbosa de Alencar
david002870@hotmail.com
Instituto de Tecnologia e Educação Galileo da Amazônia – ITEGAM - Brasil

Abstract

Energy consumption is a major factor in relation to an organization's costs and expenses, determining the need to apply methods that can minimize or reduce these expenses as much as possible. Having these factors in context, the present work aims to present the technical feasibility of implementing a project that uses solar energy through the on-grid solar system to supply the energy demand of a company. The methodology used was the descriptive, in which several data were collected and documentations were analyzed that supported and justified the elaboration of a photovoltaic project and development of the budget and analysis of the costs of a solar energy system. Through the results obtained, it was possible to arrive at a solar project that would be able to establish the necessary power for the company for a cost of R $ 20,916.96 and a payback of 5 years and 5 months. Thus, it is possible to conclude that the photovoltaic system is viable in its use and application, not only because of the advantages associated with the environment, but taking into account its self-sustainability over time and with a useful life of up to 25 years.

Key words: Energy; commercial building; efficiency.

INTRODUCTION

Commercial buildings through their business activities are responsible for the highest energy demand in Brazil and in most other countries. Some research on energy efficiency shows that this practice is essential for economy and sustainability. In Brazil alone, there are more than 100 thousand smaller companies, which do not have incentives or energy saving practices when compared to medium and large companies, demonstrating the importance of this practice as a factor for business optimization (MARQUES et. al., 2007).

Commercial buildings through business activities are responsible for 36% of global energy consumption (CHOI; EOM; MCCLORY, 2018). In Brazil, energy consumption was 80.9 Mtoe in 2018, corresponding to 31.6% of final consumption (EPE, 2019). In terms of electricity, in the same year, the sector consumed a total of 200.9 TWh, equivalent to 37.5% of the total electricity consumed nationally (EPE, 2019).

In addition to its growth, the energy sector moves huge economic figures every year, around 1.5 trillion dollars. Global investment in renewable energies reached $ 288.9 billion in 2018, exceeding financial support for the generation of energy from fossil fuels (UN BRASIL, 2019). With this factor in context, the energy options based on characteristic natural resources are being discontinued and the use of the current circumstance is no longer conceivable, due to the depletion of these raw materials in current reserves, in addition to the ecological effects and impacts.

The verified problematization that generated the question that guided this work, what are the practicable techniques in relation to renewable energies in commercial buildings to optimize the expenditure of electricity?

Therefore, based on the entire context presented, the objective of this research is to present the technical feasibility of implementing a project that uses solar energy through the on-grid solar system to supply a company's energy demand.

THEORETICAL REFERENCE

Energy Efficiency: Among the productive resources used in companies, electricity is an important resource for almost all activities in the productive system. Therefore, investing in the efficient use of electric energy brings a series of benefits both for the company and for the country and its end users (CASTRO, 2015).

Thus, energy efficiency is shown as the relationship between the amount of final energy used and the amount of a good produced or service performed (EPE, 2018). By saving energy, the need to build new generating plants and associated electrical systems is being postponed, making resources available for other areas and contributing to the preservation of nature.

Energy efficiency, as an instrument for energy conservation, comes close to the needs of the Brazilian citizen, who, as he becomes aware of its importance for the country's economy, for the environment and, therefore, for the whole society, begins to use resources in a sustainable way. With this purpose, it is necessary that systems, methodologies, technologies, materials and equipment, be known by technical professionals, mainly those of engineering and architecture, who are directly connected to the technicality involved with this theme (MARQUES; et al., 2007).

Energy efficiency is a performance indicator and one of the most important requirements for economic environments. Currently, electricity consumption is equivalent to about 44% of the national account consumption. Since Brazil is a developing country, this consumption tends to increase (SIMÃO, 2014).

The reduction in energy consumption can be achieved by eliminating unnecessary consumption, compensating for losses, functional improvements in existing equipment and using equipment with optimized performance (SÁ, 2010).

To achieve better energy efficiency in a given company or process, it is necessary to reduce energy losses and consumption and achieve the same results in production and / or services through the rational use of human, material and economic resources with measures to combat waste of energy, in addition to the modernization of industrial systems or processes (CAPELLI, 2013).

According to Mathias (2014), disputes between companies for competitiveness and profitability have become increasingly intense. In this scenario, it is important to develop methods to reduce inefficiencies and waste in the production processes.

Energy efficiency is recognized as one of the most important means to increase the competitiveness of the business sector, in particular for small and medium-sized companies, where energy efficiency measures are not implemented correctly (MATHIAS, 2014).

Photovoltaic Solar Energy: According to Goldenberg and Lucon (2007), solar photovoltaic energy is that generated through the direct conversion of solar radiation into electricity, through the use of a technology determined as a photovoltaic module, which makes the practice of the photoelectric or photovoltaic effect. The solar radiation reaching the Earth's surface is determined by two different types, according to Pinho and Galdino (2014), being: Diffuse radiation, which comes from all directions and dispersed by the molecules present in the atmosphere; Direct radiation, which comes directly from the Sun. Therefore, solar radiation is interpreted as the radiant energy transmitted by the sun in the form of electromagnetic radiation, through various wave frequencies. And its irradiation is the quantity related to the amount of incident solar radiation for each m^2, with its peak at noon solar (PINHO; GALDINO, 2014).

Types of Photovoltaic Systems: According to Pereira and Oliveira (2011), there are two photovoltaic systems that can be used today: a) Autonomous or isolated systems (OFF GRID); b) Systems connected to the electrical network (ON GRID).

According to Câmara (2011), autonomous systems are those that do not depend on the electricity network for operation, their use is therefore very much focused on areas in remote locations that do not need the electricity infrastructure. Two types of isolated systems can be used, with storage and without storage. The first is determined from the charging of electric vehicle batteries for lighting and even to supply some portable devices (VILLALVA; GAZOLI, 2012). And the second type, does not use storage instruments and directly supplies electrical equipment, being the most economically viable (PEREIRA; OLIVEIRA, 2011).

The photovoltaic systems connected to the electric grid, are called On-Grid or Grid-Tie systems, it is the type of system that operates in parallel with the electric grid. Unlike autonomous systems, the devices do not have energy storage, and all the surplus energy is increased in the electrical network, thus generating credits for the system owner (CAMARGO, 2017).

MATERIALS AND METHODS

As initially contextualized, the objective of the research is to implement a photovoltaic energy system on grid in the company. The purpose is to reduce the costs incurred with electricity, in addition to having an asset that can sustain itself in the future by implementing energy efficiency in the company.

Thus, in order to qualify the present research, the development of the application of a photovoltaic system in a company will be presented, addressing the context already presented, resulting in the analysis of the financial viability of the project based on the evaluation of the return on investment in the photovoltaic system. Thus, the procedures for project development were:

a) Survey of the company's energy demand, through the electricity bill.
b) Determination of geographic data, to record the city's insolation data for the study in question, from the survey of CRESESB data.
c) Then, according to Villalva and Gazoli (2012), it is possible to obtain the installation angle for photovoltaic panels using geographic data.
d) Present the photovoltaic module, according to the manufacturer and its material, demonstrating the feasibility of your choice based on its energy efficiency.
e) Demonstrate the inverter to be used, with the objective of converting the electric current, using the dimensioned system as a reference.
f) Quantify costs and demonstrate the budget for the project developed, based on the prices presented by the equipment manufacturers detailed previously.
g) As a viability determination, the payback will be calculated, and thus the return time necessary for the system to self-sustain will be evaluated.

From this information, it is possible to conclude and associate the objectives proposed by this research and the results obtained.

RESULTS AND DISCUSSIONS

The first step to obtain the necessary results is to establish the necessary energy demand for the photovoltaic system. Therefore, the electric energy bill for the analyzed company was used and through it the energy consumption was raised to supply the power that will be used as a parameter by the photovoltaic system. Figure 1 shows the electric consumption history of the account used as a reference.

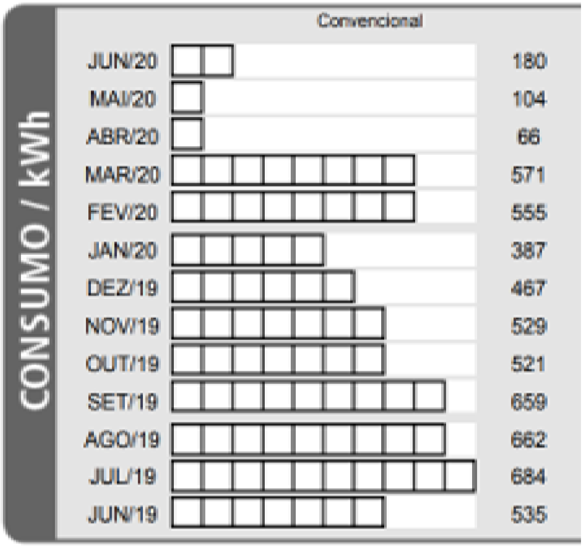


Fig. 1. Electricity consumption of the company

Source: Own Author (2020).

Analyzing Figure 1, the company's largest energy consumption in a year is 684 kWh, therefore, this value will be used as a measure for dimensioning the photovoltaic system, so that it can guarantee that the company is served in its electrical potential. In this way, the conversion of this quantity was carried out to result in the electrical power used by the company based on its daily 8 am operation from Monday to Saturday.

$$ENERGY \ = \ POWER \ X \ TIME$$

$$684 \ kWh = POWER \ X \ 192h$$

$$POWER = 3{,}562 \ kW \ ou \ 3562 \ W$$

Therefore, for the operation of the determined company it is necessary to have a solar system project that can generate at least 3.562 kW, thus meeting the loads measured by the electrical equipment and guaranteeing the effectiveness of the consumption of the electrical system.

Geographic Data of the Solar System:

Then using a geographic tool such as Google Maps, it is possible to obtain the geographic coordinates of the city, determined as an object of study of the research, which from its use was realized that the municipality of Rio de Janeiro is located at Latitude 22º 54 '10 "S and Longitude 43º 12' 27" W.

From the geographic data of latitude and longitude, and the use of the database with the insolation values, for the development of CRESESB photovoltaic systems, it was determined that the average solar irradiation value for an angle equal to latitude is 5 , 07 Kwh / m²dia, for the panel inclined at 18º N it is 5.07 Kwh / m²dia and for the smaller insolation with 22º the value of 5.06 Kwh / m²dia is obtained, Table 1 shows the results obtained.

Table 1 - Average daily solar radiation for the city of Rio de Janeiro - RJ.

Angle	Inclination	Average daily solar radiation of the month [kWh/m2.day]													
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average	Delta
Horizontal Plane	0° N	6,12	6,44	5,40	4,56	3,92	3,63	3,75	4,35	4,86	4,96	4,99	5,89	**4,90**	**2,81**
Angle equals latitude	20° N	5,56	6,14	5,51	5,04	4,67	4,50	4,56	4,97	5,11	4,84	4,63	5,30	**5,07**	**1,64**
Highest annual average	18° N	5,64	6,20	5,52	5,02	4,61	4,43	4,50	4,93	5,10	4,87	4,68	5,37	**5,07**	**1,76**
Highest monthly minimum	22° N	5,48	6,09	5,50	5,07	4,72	4,57	4,62	5,01	5,11	4,80	4,57	5,22	**5,06**	**1,52**

Source: CRESESB (2020).

Based on the results of solar irradiation, the value determined for use is 5.07Kwh / m²dia with a 1.64 delta, with the highest insolation value and the smallest possible variation.

Next, another fundamental parameter determined by the project is obtained, which is the installation angle for photovoltaic panels. Table 2 then details the relationship between the latitude and the slope of the plate.

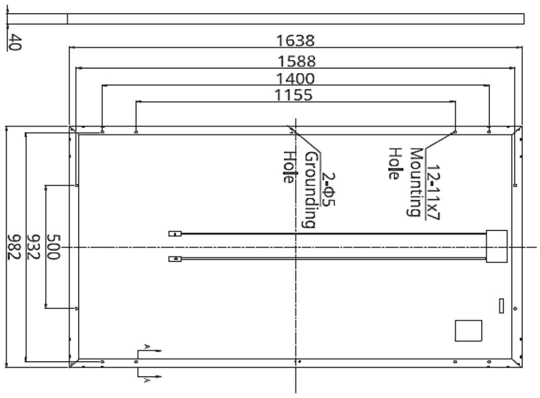
Geographic latitude of the location	**Determined inclination angle**
0º a 10º	a = 10º
11º a 20º	a = latitude
21º a 30º	a = latitude + 5º
31º a 40º	a = latitude + 10º
41º or more	a = latitude + 15º

Source: Villalva and Gazoli (2012).

Table 1 - Angle of inclination

Thus, following the data in Table 2 regarding the angle of inclination, considering that the latitude of the city of Rio de Janeiro is 22 °, the value used is with latitudes between 21 and 30 and the angle of inclination is obtained by latitude + 5 °, resulting in a = 27 °. With this information, the project is continued and the photovoltaic module is determined.

Photovoltaic Module: The dimensioning of the solar system implies the choice of a module, the type considered as determined was the Canadian CSI CS6K-270P, it has a maximum rated power of 270W, with dimensions of 1638 x 982 x 40mm, having an area of 1.61 m² (Figure 2), and the reason for his choice was because it originated from a poly-crystalline material, with a yield of 16.79%, in addition to the fact that this manufacturer has one of the most affordable prices in the Brazilian market.



Source: Canadian Solar (2018).

Figure 1 - Geometric and dimensional detail of the CSI CS6K-270P module.

With the module determined, it is possible to calculate, based on your data, the number of modules that will be needed to supply the company's energy consumption, as shown by the calculations below.

$$NUMBER\ OF\ MODULES = \frac{3562\ W}{270\ W}$$
$$NUMBER\ OF\ MODULES = 13{,}19 \sim 14\ modules$$
$$TOTAL\ PLATES\ AREA = 13{,}19 * 1{,}61\ m^2$$
$$TOTAL\ PLATES\ AREA = 21{,}24\ m^2$$

Then, it is possible to have an area of 21.24 m² to result in the supply of the initially determined power of 3.562 kW, and a total of 14 modules will be used to supply your energy demand.

Sizing: With the geographic data and from the chosen solar module, it is possible to perform the sizing of the photovoltaic system, following the guidelines of Rosa and Santos (2016), it is possible to obtain the energy produced daily per module and the total power to be installed through the system.

First, the energy produced by the equation was found:

$$Em = A * \eta * Es$$

Where: is the energy produced daily by the module in kWh / day; is the area of the module determined in m²; is the efficiency of the module in decimal; it is the sunstroke of the determined place.$EmA\eta Es$

Reproducing the values obtained so far in the equation it is possible to arrive at the result:

$$Em = 1{,}61 * 0{,}1679 * 5{,}07$$
$$Em = 1{,}37\ kWh/dia$$

Therefore, from the data obtained and presented in the previous topics and solving the calculation, the daily energy production is 1.37 kWh / day.

The power of the system can be determined by the following equation:

$$Pt = Nm * Pm$$

Where: is the total power of the system to be installed in kW; is the number of modules used; is the power of a module in kW.$PtNmPm$

Reproducing the values obtained so far in the equation it is possible to arrive at the result:

$$Pt = 14 * 0{,}27$$
$$Pt = 3{,}78\ kW$$

Thus, based on the module manufacturer's specifications, the total system power is 3.78 kW.Pt

Therefore, it is possible to observe in Table 3 the main data obtained in the design of the photovoltaic system.

Description	Results
Solar radiation from Rio de Janeiro	5,07 kWh/m²day
Installation angle of the plates	27°
Photovoltaic Module	Canadian CSI CS6K-270P
Module power	270 W
System efficiency	16,79%
Energy produced daily by each module	1,37 kWh/day
Total system power	3,78 kW

Source: Own Author (2020).

Table2 - Data of the dimensioned photovoltaic system.

In addition to the calculations performed and the determination of the parameters related to the project, it is necessary to detail some equipment that is essential for the operation of the photovoltaic system such as the inverter and the support structure.

Inverter: The inverter was chosen based on the determination of the power of the photovoltaic system, being 3.78 kW. Thus, from the options presented by the company WEG, being one of the strongest companies nationally in the market for electronic products for power generation and transmission, the SIW 600 ST020-44 solar inverter was chosen, which supports up to 5 kW. Figure 3 shows the chosen model.

Source: WEG (2018).

Figure 2 - SIW600 inverter model.

Supporting Structure of Photovoltaic Plates: The structure to support the solar panels is also relevant in its determination, even though it is a disregarded factor in making a budget, its cost is considerable for the project in question. Therefore, contact was made with a company specialized in this type of structure, Sonnen Energies, and the support for plates was indicated, which is shown in Figure 4.

Source: Sonnen Energies (2017).

Figure 3 - Support structure for solar panels.

With the developed project it is possible to present the question of the budget and costs of the developed project and thus analyze the return time so that it is paid for.

BUDGET AND PROJECT COST ANALYSIS

Having collected all the information regarding the system, contact was made with the companies or third parties regarding the equipment provided for the budget and cost survey of the entire photovoltaic system. A third party responsible for selling the products of the Canadian Solar company, presented the costs for installing the system based on the dimensioning and the determined module, even presenting the auxiliary equipment necessary for its installation. Table 4 illustrates the data received.

Material	Unit price	Amount	Total price
Canadian Solar 60 Cells 270Wp Poly-SI	R$ 486,61	14	R$ 6.812,54
Female / Male Connectors	R$ 12,55	4	R$ 50,20
Cable 6mm, 1000V	R$ 3,22	240	R$ 772,80
Schneider 1000DC 25A Photovoltaic Circuit Breaker	R$ 319,00	1	R$ 319,00
Surge Protector DPS 40 KA 275C Steck	R$ 120,90	1	R$ 120,90
DPS Schneider PRD-DC40r 1000PV Photovoltaic	R$ 569,00	2	R$ 1.138,00
Flexible Cable 10mm 100m 750 V SIL	R$ 416,90	2	R$ 833,80
Total			**R$ 10.047,24**

Source: Canadian Solar (2018)

Table3 - Budget for the photovoltaic system.

Making contact with the company WEG, it was possible to obtain the costs related to the inverter raised for application in the energy system, according to the company, the cost of the inverter with a capacity of 5 kW, being the SIW 600 ST020-44 model , is R $ 4,765.52.

The company responsible for the support structure for the photovoltaic plate system, also presented costs related to materials and services, with a total value of material and labor of R $ 6,104.17.

Therefore, adding all the necessary components for the proposal presented, the entire project will have a total cost of R $ 20,916.96.

Payback: Payback is the period necessary to obtain the return on investment made on a given project, therefore, in this case study, it will be presented together with the budget raised the time it takes to obtain the costs spent on the project of the photovoltaic system for an area of 21.24 m² of solar panels.

To determine the payback, it is necessary to determine some prior information. First, it is necessary to obtain the value of the electricity tariff according to the energy distributor and according to the current legislation, following the regulations of ANEEL (National Electric Energy Agency) updated in 2019, the tariff referred to in question is R $ 0.56 / kWh.

Following the calculation of the payback, it is also necessary to survey the monthly energy generation of the dimensioned electrical system. Bearing in mind that 1.37 kWh / day is generated by each module and having 14 modules, the system presented is responsible for generating 575.4 kWh / month.

With the previous data, it is then possible to determine the return on investment in the project, the payback for this case according to Solar (2016), will be based on the following equation:

$$Payback\ [months] = \frac{Investment\ (R\$)}{Generated\ Energy\ \left(\frac{kWh}{mes}\right) x\ Fare\ amount\ (\frac{R\$}{kWh})}$$

$$Payback\ [months] = \frac{20916{,}96\ (R\$)}{575{,}4\ \left(\frac{kWh}{month}\right) x\ 0{,}56\ (\frac{R\$}{kWh})}$$

$$Payback\ [meses] = 64{,}9\ months \sim 5\ years\ e\ 5\ months$$

Therefore, using the presented equation, the return time for investment in the photovoltaic system for an area of 21.24 m², generating 3.78 kW of power, is 65 months or 5 years and 5 months.

According to Câmara (2011), photovoltaic plates have a durability of 20 to 25 years, and it becomes a viable alternative in the long term, depending on the case in question (CÂMARA, 2011). Thus, based on the return time of the payment of the solar energy project it becomes viable.

CONCLUSION

The case study for demonstration of the solar system was applied to the city of Rio de Janeiro - RJ, the purpose of the survey was to determine a renewable energy system that can be used and that makes possible the supply of self-sustainable energy for a given time. company concerned. Thus, considering an area of 21.24 m², a system was determined to meet the energy consumption needs of the proposed company, which is at least 3.562 kW of power.

Firstly, the method of development of the solar energy project had as a process the use of bibliography and regulated standards for survey and analysis of data and documents related to geographic information and insolation of the city in question, where based on these factors the dimensioning was carried out , and thus arrive at the conclusion that under the conditions it was possible to generate a total of 1.37 kWh / day for each solar module, having a total of 14 modules, generating a power of 3.78 kW. With the calculated photovoltaic system, it was possible to determine the inverter based on the manufacturer's data and also the bearing structure of the plates.

Therefore, from all the detailed and designated components, the total cost of expenses was assessed to make the initial objective of the research possible, the total amount is R $ 20,916.96. And with the necessary budget for investment in the detailed solar energy project, there was a payback of 5 years and 5 months, which is the period necessary for the solar system to be able to pay for itself. From the evaluated information, it appears that the feasibility of a project of this dimension for a company with the energy demand initially assessed at 684 kWh is feasible and can be applied, considering that its useful life of 25 years, in addition to which brings many economic benefits through the application of sustainable practices.

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