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# Economic Feasibility Study of Photovoltaic Panels Installation by PVsyst 6.73 Simulator

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***Abstract*— *The increasing pursuit of industry modernization presenting efficiency gains, productivity and cost reduction raises the discussion about the use of new technologies that promote, simultaneously, business sustainability and productive and economic efficiency for offshore companies, which operates in the Campos Basin, located at the municipality of Macaé, Rio de Janeiro State, Brazil. This paper presents an economic feasibility evaluation to use photovoltaic panels in order to measure the project costs and highlight its benefits; to this end, a local supplier was contacted to estimate a budget. The author ran the PVsyst 6.73 simulator to calculate the energy produced by the photovoltaic system and other parameters. Taking into account the Minimum Attractive Rate (MAR) of 8.3 %, established by the board of directors, the results, by the Simple Payback and Discounted Payback (SPDP); Profitability Index (PI); Return on Investment (ROI); Net Present Value (NPV); and Internal Rate of Return (IRR) methods applied, proved the project is economically feasible and that this company has physical structure to install the equipment. As such, it is possible to have a great medium-and long-term financial economy, contributing to produce clean energy in the country.*

***Keywords*— *Solar Energy; Photovoltaic Panels; Economic Feasibility; PVsyst 6.73 Simulator.***

## I. INTRODUCTION

It is well understood that, with the increasing importance given to sustainability, countries have shown interest in changing their energy matrices, aiming at using renewable and clean energy sources. The demand for energy has been increasing, turning it into a competitive advantage for some companies and countries, allowing the expansion of clean and renewable energy generation, such as solar energy source.

A photovoltaic system for energy generation is composed of a cluster of photovoltaic cells, which aim at capturing solar radiation and converting it into electrical energy. These systems have photovoltaic panels as their main components (Pereira & Oliveira, 2011).

The use of the methods to study the economic feasibility of an investment project aims at establishing whether there is any potential for project implementation. That is, the purpose of this analysis is to answer the following questions: Can the project be developed successfully and achieve the results expected by the investors? Can the project satisfy the investors and generate wealth for the organization? (Abreu Filho et al., 2012). The economic feasibility methods approached by this work were Minimum Attractive Rate (MAR), Return on Investment (ROI), Net Present Value (NPV), Internal Rate of Return (IRR), Profitability Index (PI), and Simple Payback and Discounted Payback (SPDP).

They were selected as their objective is to support and demonstrate the real situation of the economic feasibility. According to Damodaran (2004), the financing of a company comprises all decisions involving financial implications.

In this context, this research aims at approaching seven financial methods to assess the economic feasibility of use of energy generation system installations through photovoltaic panels connected to the grid in a company of Macaé municipality, in Rio de Janeiro State, Brazil.

## II. REVIEW OF LITERATURE

The demand for energy has been increasing worldwide, turning it into a competitive advantage for some companies and countries, allowing the growth of clean and renewable energy generation, such as solar energy source.

As stated by Fernandes and Motta (2014), the photovoltaic system is noticeable with regard to the system sustainability, since it is independent and clean, as the only energy source employed comes from the sun, and the thermoelectric power plant uses part of the energy produced for its own autonomy.

According to them, photovoltaic solar energy is considered one of the main environmentally correct sources in the actual energy matrices. Thus, when a country invests in this type of energy production, the volume of carbon dioxide emitted into the atmosphere is lower and, in turn, less pollution is generated. The calculation of those avoided emissions is of great importance for technology identification and increase in investments and incentives for the sector (Fernandes & Motta, 2014).

The heliothermic or solar thermal energy generation is another way of using solar energy to produce electrical energy, in which solar energy generates thermal energy, and this one, electrical energy. Given the potential for use, it is clear that solar energy is at the center of discussions and definitions of energy policies in several countries, not only the developed ones but also the emerging countries. Its implications are transversal, since the use of solar energy provides some advantages, such as the reduction of fossil fuel use, reduction of greenhouse gas emissions, generation of qualified jobs, technological development, and creation of value and vectors of environmental, social, and economic sustainability (Esposito & Fuchs, 2013).

Solar energy provides many environmental benefits to the world. One of them is the ability to reduce greenhouse gas emissions. Researches conducted by the Associação Brasileira das Empresas de Serviços de Conservação de Energia – ABESCO (Brazilian Association of Energy Conservation Services Companies) in 2016 reveals that residences with photovoltaic systems are able to reduce around 1.3 tons of Carbon Dioxide ($CO_2$) in the atmosphere in one year, once it generates 180 kWh per month. In 25 years, which is the warranty period for photovoltaic modules, this volume can reach around 32 tons.

Nevertheless, the use of this energy source, as well as the others, has negative effects, having as the greatest concern the production and disposal of photovoltaic panels. The exponential growth of photovoltaic energy production will result in a large amount of electronic waste over the next decades and in an increasing demand for resources (energy, water, and chemicals) to produce their modules (Paiano, 2015). As such, it is believed that, by 2035, in accordance with the International Energy Agency (IEA), around one million tons of solar modules may be discarded.

As stated by Pinho and Galdino (2014), photovoltaic modules are produced in automated plants using minimal human intervention. The serial production line in large-scale photovoltaic modules has allowed a relevant fall in prices and ensured the maintenance of high-quality products.

Barbosa (2010) tells that the equipment to use photovoltaic solar energy are as follows:

Solar module –Panels designed to directly convert sunlight into electrical energy, in the form of direct current (DC).

Charge controller – Electronic device that protects batteries from overcharging and excessive discharges, extending its lifetime.

Inverter – Electronic device that converts electrical energy from direct current to alternating current, 127 volts or 220 volts, making it possible to use electrical appliances.

Battery – Used to store energy generated by solar modules to provide energy at night or on rainy days.

Among them, the main responsible for the high costs of system installation is the photovoltaic panel. However, Pinho & Galdino (2014) assert that the module price, which currently represents 50 % of cost of installing a 1 kW photovoltaic system connected to the grid in Brazil, is the main responsible for that price fall, motivated by the relevant increase in the production of photovoltaic modules in Europe, the United States, and, more recently, China.

Photovoltaic systems can be classified into three different categories: isolated, hybrid, and grid-connected category. Off-grid isolated systems do not connect to the electrical grid, since hybrids combine different energy sources, and the ones connected to the on-grid system connect to the electrical grid.

Each model is appropriate for specific goals. Gabardo & Radaskievicz (2013) indicate that isolated systems, usually used in distant areas, are useful for a variety of applications, such as water pumping, fence electrification, light poles and so forth. Most of the time, this is the cheapest way to get electricity in these places. According to them, the energy produced in this system is stored in batteries, ensuring the supply in periods of no sun, or even in gravitational energy form, when water is pumped to tanks in supply systems.

In turn, systems connected to the grid do not need batteries for storage. In accordance with Fernandes & Motta (2014), the energy generated is directly consumed, and its surplus is transferred to the distribution grid, generating profits for the local energy concessionaire. These credits are used in times when there is not production of solar energy, such as at night. The user pays the concessionaire just the difference between the amount consumed and the amount transferred into the electrical grid.

Data given in Figure 1 show a scheme distinguishing the isolated system from the one connected to the grid.

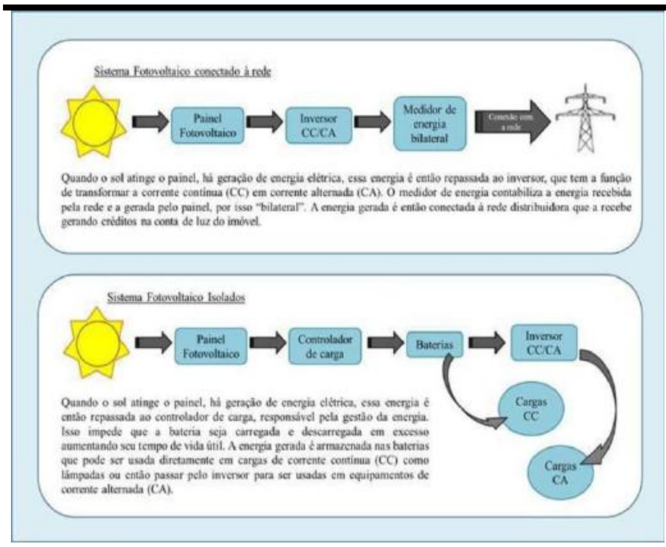


*Fig.1: Example of thermal solar energy use for production of electrical energy*
Source: Machado & Miranda (2015)

By the schemes presented in Figure 1, the installation needs a bilateral power meter in the grid-connected system, as at a given time it may measure the energy transferred into the grid and at another time the energy consumed by the grid.

In Figure 2, data present the connection of a hybrid system in a simple way.

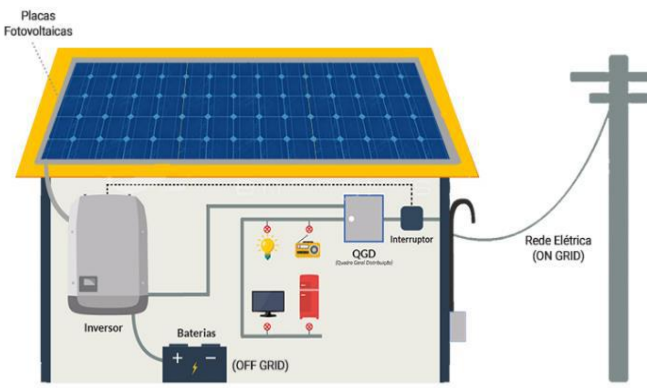


*Fig.2: Example of the hybrid solar system*
Source: ESV solar vida (2018)

In accordance with Figure 2, that hybrid systems are in both batteries and bilateral energy meter, operating as an isolated system when connected to the grid.

In the words of Fernandes & Motta (2014), the most relevant legal framework for the sector of renewable energy generation is the Normative Resolution of the Agência Nacional de Energia Elétrica (482/2012 ANEEL, 2015) (Brazilian Electricity Regulatory Agency – ANEEL), subsequently updated by the Normative Resolution 687/2015 of ANEEL (ANEEL, 2015). According to it, Brazilian consumers can generate their electrical energy from renewable sources and supply the surplus to the distribution grid of their local concessionaire. It consists of distributed micro and mini-generation of electrical energy, innovations that can combine financial economy, social and environmental awareness, and self-sustainability.

Since then, the Brazilian government has stimulated this type of generation in many ways. As stated by the Agência Nacional de Energia Elétrica (ANEEL, 2016), there is already an agreement published by the Conselho Nacional de Política Fazendária – CONFAZ (National Finance Policy Council – CONFAZ), in which, for the states that adhere to this Agreement, the Imposto sobre Circulação de Mercadorias e Serviços – ICMS (State Value Added Tax – ICMS) will be only applied on the difference between the energy consumed and the energy transferred into the concessionary grid.

Lastly, it is highlighted the development of the Programa de Desenvolvimento da Geração Distribuída de Energia Elétrica – ProGD (Distributed Electrical Energy Generation Program – ProGD), implemented by the Ordinance n. 538/2015 of the Ministry of Mines and Energy (MME), with the goal of extending, even more, the actions to stimulate distributed generation, on the basis of renewable resources, such as solar energy.

In conclusion, the high cost of photovoltaic panels is still a key factor to disseminate this technology widely in Brazil. Nevertheless, this cost tends to fall, so as tax incentives and large-scale production are implemented on a national scale.

## III. METHODOLOGY

This work is considered an exploratory research performed by a case study developed in an offshore company at Macaé City, Rio de Janeiro State, Brazil.

As specified by Gil (2008), exploratory research focuses on developing, explaining, and modifying concepts and ideas, considering the development of accurate problems or hypothesis for further studies. They usually cover bibliographic and documentary data, non-standardized interviews and case studies.

This research was based on analyzing the physical feasibility for installation of the solar energy system connected to the grid within the company. For that, a photovoltaic panel installation consulting company and an electrical engineer were contacted to elaborate and dimension the project, assessing its feasibility, having as an initial condition the Minimum Attractive Rate (MAR) of 8.3 %, stipulated by the board of directors.

The annual consumption noted, when studying the accounts of the company, in 2017, was of 371.858 kWh. The solar energy system proposed has an annual production estimated at 156.370 kWh, which is the energy value produced within the first year, meaning annual savings of 42 %. Thus, it is not possible for the company, today, to achieve savings of 100 % through solar energy due to the initial capital invested.

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The simulator run was the PVsyst 6.73, initially developed by the Université de Genève (University of Geneva). The PVsyst AS company currently markets it. It allows the user to operate at different levels of complexity, from an initial representation stage up to a detailed simulation system. It also presents an additional three-dimensional tool, which considers the horizon limitation and objects that may cast shadows.

The program enables to import data from the Meteonorm and TMY2 , which makes it easy to compare simulated values with measured values. Besides, it has a data interface and an irradiation database of 22 locations in Switzerland and 200 locations throughout the world. It has a wide module and inverters database. This program displays the losses of the photovoltaic system and its performance rate. The PVsyst 6.73 simulator is mainly used for Grid-Connected Photovoltaic Systems, such as the study case herein presented.

If the user adds the cost of each component to the existing database, this program can project the cost of energy production in addition to a series of technical parameters provided at the end of the simulation.

The energy produced was calculated by the Meteonorm databank, which is in the PVsyst 6.73, considering irradiation and climatic conditions in the city of Rio de Janeiro.

It is known that Rio de Janeiro City is at 22° 54’ 10” latitude (S) and 43º 12’ 27” longitude (W).

Regarding the application of the simulator, it is of utmost importance to stress the randomness of solar radiation that, as stated by Lorenzo (2002), even when obtaining data on the radiation behavior, it cannot be guaranteed its repetition in the future, as there is an influence of factors, such as climatic changes, increase of greenhouse gas emissions, and so forth. Besides, there are different sources of information for the same location, which differ in terms of content.

The information on Figure 3 shows data used to simulate the energy produced using the PVsyst 6.73 simulator.

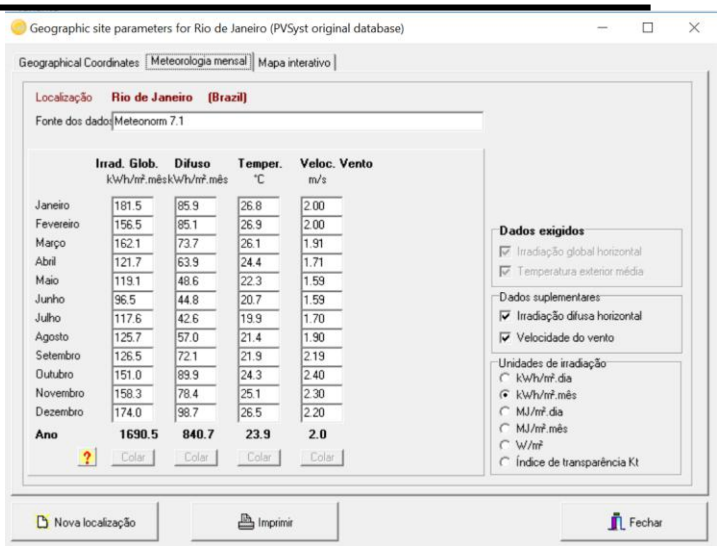
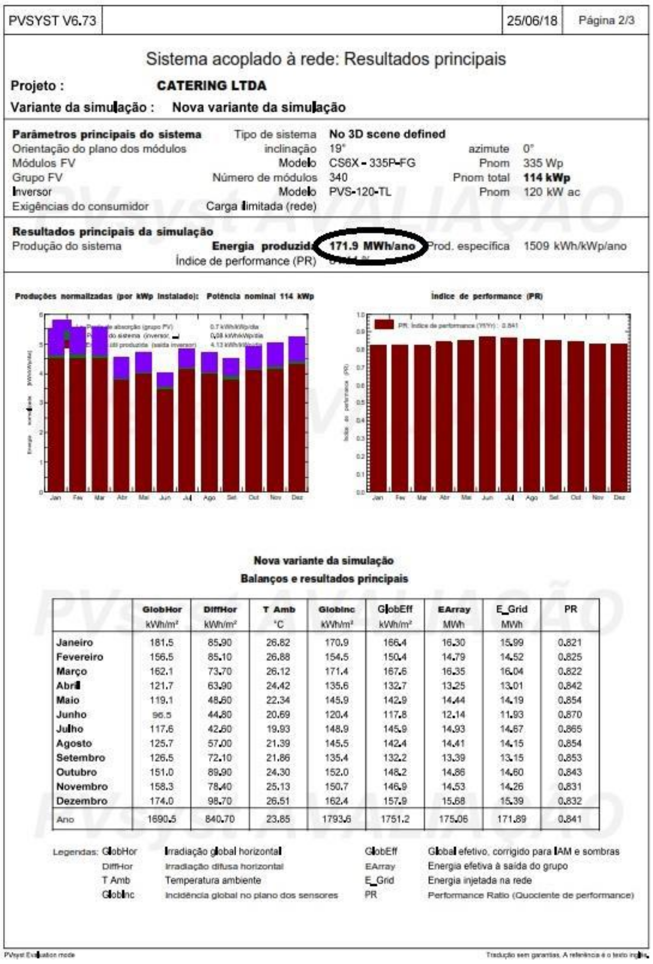



*Fig.3: Data of the simulation with the PVsyst 6.73*

Source: Elaborated by the author (2018)

In the previous Figure, it can be verified the data provided by the Meteonorm 7.1 database concerning the city of Rio de Janeiro, such as direct irradiation, diffuse irradiation, temperature, and wind speed, with their respective annual averages.

Data in Figure 4 show the simulation of energy produced by the solar energy system for the first year.




| | GlobHor kWh/m² | DiffHor kWh/m² | T Amb °C | GlobInc kWh/m² | GlobEff kWh/m² | EArray MWh | E_Grid MWh | PR |
|---|---|---|---|---|---|---|---|---|
| Janeiro | 181.5 | 85.90 | 26.82 | 170.9 | 166.4 | 16.30 | 15.99 | 0.821 |
| Fevereiro | 156.5 | 85.10 | 26.88 | 154.5 | 150.4 | 14.79 | 14.52 | 0.825 |
| Março | 162.1 | 73.70 | 26.12 | 171.4 | 167.6 | 16.35 | 16.04 | 0.822 |
| Abril | 121.7 | 63.90 | 24.42 | 135.6 | 132.7 | 13.25 | 13.01 | 0.842 |
| Maio | 119.1 | 48.60 | 22.34 | 145.9 | 142.9 | 14.44 | 14.19 | 0.854 |
| Junho | 96.5 | 44.80 | 20.69 | 120.4 | 117.8 | 12.14 | 11.93 | 0.870 |
| Julho | 117.6 | 42.60 | 19.93 | 148.9 | 145.9 | 14.93 | 14.67 | 0.865 |
| Agosto | 125.7 | 57.00 | 21.39 | 145.5 | 142.4 | 14.41 | 14.15 | 0.854 |
| Setembro | 126.5 | 72.10 | 21.86 | 135.4 | 132.2 | 13.39 | 13.15 | 0.853 |
| Outubro | 151.0 | 89.90 | 24.30 | 152.0 | 148.2 | 14.86 | 14.60 | 0.843 |
| Novembro | 158.3 | 78.40 | 25.13 | 150.7 | 146.9 | 14.53 | 14.26 | 0.831 |
| Dezembro | 174.0 | 98.70 | 26.51 | 162.4 | 157.9 | 15.68 | 15.39 | 0.832 |
| Ano | 1690.5 | 840.70 | 23.85 | 1793.6 | 1751.2 | 175.06 | 171.89 | 0.841 |

Legendas: GlobHor Irradiação global horizontal; DiffHor Irradiação difusa horizontal; T Amb Temperatura ambiente; GlobInc Incidência global no plano dos sensores; GlobEff Global efetivo, corrigido para IAM e sombras; EArray Energia efetiva à saída do grupo; E_Grid Energia injetada na rede; PR Performance Ratio (Quociente de performance)

PVsyst Evaluation mode — Tradução sem garantias. A referência é o texto inglês.

*Fig.4: Simulation of the energy produced for the first year applying the PVsyst 6.73*

Source: Elaborated by the author (2018)

In Figure 4, it is seen the energy prediction to be produced by the solar energy system in the amount of 171.9 MWh for the first year, in which there are three essential parameters, such as installed power, solar irradiation, and inverter performance.

Since then, a simulation with probabilistic data of climatic conditions, panel performance, and data from the power plants already operating is made. The calculation estimates the best position for the panels, facing north, where the sun sets in the South Hemisphere most of the year.

The inclination of the panels considers the latitude of the city of Macae, Rio de Janeiro State, Brazil. As Rio de Janeiro is at - 22°, the panels must be tilted at 19°, in order not to have losses because of shading.

The value considered for the tariff in the first year was the highest value of the 12 invoices of the company studied in 2017.

This work has as a premise the readjustments of the energy rate from year 1 based on what Miranda states (2014, p. 41):

With regard to the energy tariff, since it depends on the Índice Geral de Preços do Mercado – IGPM (General Price Index – Market) and its readjustment is based on a coefficient called Índice de Reajuste Tarifário – IRT (Tariff Adjustment Index), it can be estimated the variation in values by means of economic studies on the variation of these indexes and factors. Also analyzing statistical studies of energy tariff variation over the last decades, reaching a value of 4.8 % of annual update (Miranda, 2014, p. 41).

It can be noted, by the statement of the researcher, that the electricity tariffs may not be well defined. Its changes can be explained in terms of appropriate policies, government interventions, and different phases of the Brazilian energy sector.

In what concerns maintenance, the photovoltaic system is reliable and of low maintenance. By a well-done installation and a frequent remote monitoring of the system, only a panel cleaning and a thermographic inspection of the electrical boxes are needed.

The power of a photovoltaic generator varies according to the manufacturer; however,

[...] usually, a minimum peak power of 90 % of the nominal power is guaranteed for the 10 to 12 first years of operation, and of 80 % for a period of 20 to 25 years. Nevertheless, there are other ways, like manufacturers, that guarantee, for 5 years, at least 95 % of the nominal power; all through 12 years, at minimum 90 %; throughout 18 years, not less than 85 %; and, during 25 years, at least 80 % (Pinho & Galdino, 2014, p. 132).

For this study, a minimum power of 90 % was used for the first 12 years and a minimum power of 80 %, for further years (13 to 25 years), as described above.

Thus, the multiplication between energy produced and energy tariff results in the revenue of this enterprise. To assess the cash flow, it is necessary to analyze the costs; for that, the maintenance costs and the part insurance are taking into account.

Maintenance cost is the cost of a four-month visit of two employees of a third-party company that provides the service. The cost of each visit is estimated at R$ 1.264,73 , totaling an annual maintenance cost of R$ 3.794,19. How are the adjustments estimated for the following 25 years? The methodology adopted was to use approximate measures to readjust the minimum wage.

The current Brazilian rule for adjustments of a minimum wage was used as a basis. According to Teixeira and Vianna (2013), it corresponds to the variation of the Gross Domestic Product (GDP) plus inflation. The authors still state in footnote 13 that "[…] the adjustments to preserve the purchasing power of the minimum wage will correspond to the variation of the Retail Price Index – RPI (Índice Nacional de Preços ao Consumidor – INPC) […] as a real increase, the % age corresponding to the real growth rate of the Gross Domestic Product – GPD" (p. 41) will be applied.

For this work, the growth forecasts that Teixeira and Vianna (2013) make in the most conservative and probable scenario is used: 2.0 % per year. For the Retail Price Index, it is considered the mean of the indicators between 1995 and 2017: 7.23 %.

In addition, the insurance corresponds to 3 % of the part costs. According to the budget for this research, the cost spent on equipment is R$ 362.160,00, which results in an insurance cost of R$ 10.864,80 for the first year. What about the adjustments for the next years? Some insurance agencies have the General Price Index – Market as a reference indicator for adjustments in Brazil. For this study, it was considered the mean of the General Price Index – Market from 1995 to 2017, which corresponds to 8.36 %, as a proxy for adjustments on the insurance values throughout the period under analysis.

It is worth mentioning that Rio de Janeiro State, by means of the Law no. 7122/2015, exempted the State Value Added Tax (ICMS) on solar energy.

The second step was to assess the economic feasibility proposed by the author in accordance with the Net Present Value (NPV), Discounted Payback, Profitability Index (PI), Return on Investment (ROI), Minimum Attractive Rate (MAR), apart from the budget made by the supplier to calculate the average time of return on investment and the financial economy to be generated.

## IV. CASE STUDY

The company, located in the municipality of Macaé, Rio de Janeiro State, has 250 employees working day and

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night shifts. According to the Serviço Brasileiro de Apoio às Micro e Pequenas Empresas – SEBRAE (Brazilian Micro and Small Business Support Service – SEBRAE) methodology, described by Martins, Leone & Leone (2017), with this number of people employed, the company is considered medium size.

Its structure comprises one auditorium, one laboratory for mechanical testing, one electrical workshop and various administrative sectors. All rooms use air-conditioning systems with a wide range of models and capacities. Besides, it has a large open area around 5500 m² and various light poles with metal vapor lamp installed. Thus, a large amount of energy is demanded to maintain this infrastructure.

Data in Figure 5 indicate one-year consumption in kWh and the corresponding values charged by the concessionaire.

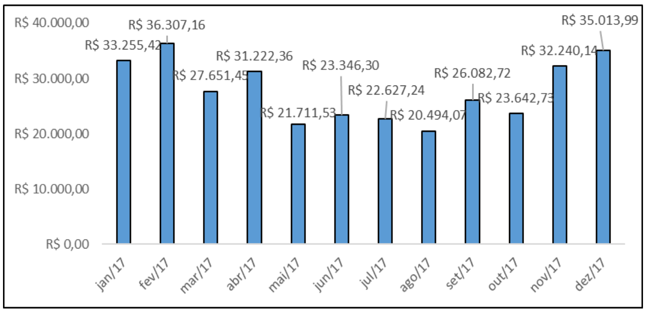


*Fig.5: Consumption history of electrical energy*

Source: Adapted from the PVsyst 6.73 simulator (2018)

From Figure 5, the high energy consumption showed throughout 2017 is evident. It is also noticed in this Figure that the annual costs of electrical energy of the company are R$ 333.595,14. According to the senior administrative management of the company, the budget authorized by the Management, in 2017, to pay and maintain it was of R$1.000.000,00. Therefore, the costs regarding electrical energy represent 33.4 % of the amount spent on the maintenance of the offshore company, a value that compromises the cost of material for new projects and investments. The data given in Table 1 present the estimated budget by the company for installing the system interconnected to the network, totaling R$ 484.106,10.

*Table.1: O Project budget*

| PARTS, ACCESSORIES AND INSTALLATION | |
|---|---|
| Module - Inverter - Structure | R$ 362.160,00 |
| Installation - Project | R$ 121.946,10 |
| Total : | R$ 484.106,10 |

Source: Elaborated by the author (2018)

The data in Table 2 show information about equipment and photovoltaic system data.

*Table.2 : Photovoltaic System Equipment and Data*

| Photovoltaic System | |
|---|---|
| Power (kWp) | 114,00 |
| Number of photovoltaic panels | 340 |
| Minimum area occupied by the system | 664 $m^2$ |
| Number of Investors | 5 |

Source: Elaborated by the author (2018)

According to data in Figure 6, the savings made with solar energy during 2017 are shown.

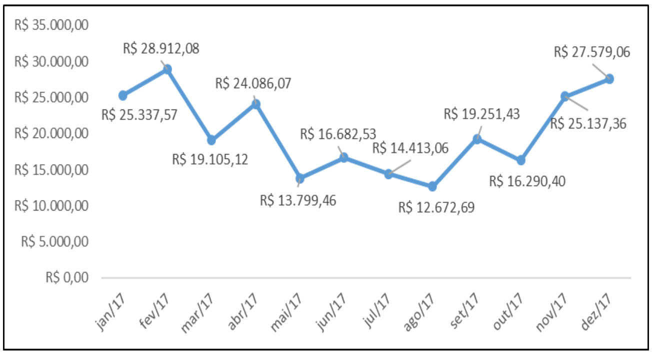


*Fig.1: Savings with solar energy*

Source: Adapted from the PVsyst 6.73 simulator (2018)

It is clear, from Figure 6 that, with the installation of the photovoltaic system, there is a considerable decrease in electricity bills paid in 2017.

As shown in Figure 7, it is noticed the difference in the cost of the entire photovoltaic system without solar energy and the saving generated monthly by solar energy.

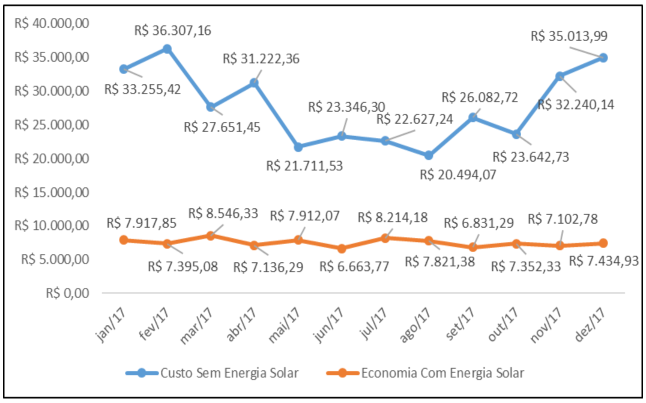


*Fig.7: Cost without solar energy x savings with solar energy*

Source: Adapted from the PVsyst 6.73 simulator (2018)

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It is noted, from Figure 7, that with the installation of the photovoltaic system there is a projected saving of R$ 90.328,28 for the year 2017.

Data in Figure 8 indicate a mean estimate of a monthly saving of R$ 7.527,36.

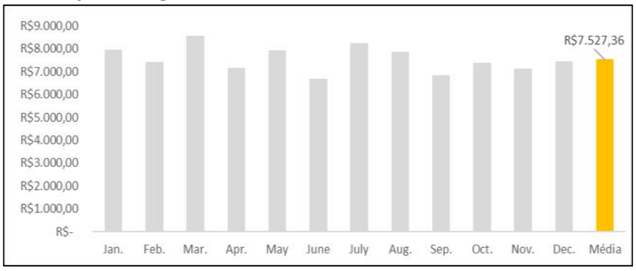


*Fig.8: Estimate of Monthly Savings for 2017*

Source: Adapted from the PVsyst 6.73 simulator (2018)

It can be seen in this Figure the variation of the monthly saving throughout 2017.

## V. ANALYSIS AND DISCUSSION OF RESULTS

Considering the budget provided in Figure 7, the annual saving in electrical energy bills, for 2017, was estimated at R$ 90.328,28. This way, Figure 9 and Table 3 were prepared, which indicate the mean time of return on investment and the savings generated with the project over a 25-years period.

| YEAR | ENERGY PRODUCED | ELECTRIC TARIFF | REVENUE FROM ELECTRIC POWER PRODUCED | ANNUAL MAINTENANCE | ANNUAL INSURANCE | CASH FLOW | ACCUMULATED CASH FLOW |
|---|---|---|---|---|---|---|---|
| 0 | 0,00 | 0,0000 | R$ 0,00 | R$ 0,00 | R$ 0,00 | -R$ 484.106,10 | |
| 1 | 154.710,00 | 0,5777 | R$ 89.375,97 | R$ 3.794,19 | R$ 10.864,80 | R$ 74.716,98 | - R$ 409.389,12 |
| 2 | 153.317,61 | 0,6068 | R$ 93.035,59 | R$ 4.144,46 | R$ 11.855,67 | R$ 77.035,46 | - R$ 332.483,42 |
| 3 | 151.937,75 | 0,6374 | R$ 96.845,06 | R$ 4.527,07 | R$ 12.936,91 | R$ 79.381,09 | - R$ 253.364,29 |
| 4 | 150.570,31 | 0,6695 | R$ 100.810,52 | R$ 4.944,99 | R$ 14.116,75 | R$ 81.748,78 | - R$ 172.011,20 |
| 5 | 149.215,18 | 0,7033 | R$ 104.938,35 | R$ 5.401,50 | R$ 15.404,20 | R$ 84.132,65 | - R$ 88.408,45 |
| 6 | 147.872,24 | 0,7387 | R$ 109.235,20 | R$ 5.900,15 | R$ 16.809,06 | R$ 86.525,98 | - R$ 2.545,82 |
| 7 | 146.541,39 | 0,7759 | R$ 113.707,98 | R$ 6.444,84 | R$ 18.342,05 | R$ 88.921,09 | R$ 85.580,71 |
| 8 | 145.222,52 | 0,8151 | R$ 118.363,92 | R$ 7.039,81 | R$ 20.014,85 | R$ 91.309,26 | R$ 175.968,11 |
| 9 | 143.915,52 | 0,8561 | R$ 123.210,49 | R$ 7.689,71 | R$ 21.840,20 | R$ 93.680,59 | R$ 268.605,45 |
| 10 | 142.620,28 | 0,8993 | R$ 128.255,52 | R$ 8.399,60 | R$ 23.832,03 | R$ 96.023,89 | R$ 363.472,89 |
| 11 | 141.336,69 | 0,9446 | R$ 133.507,12 | R$ 9.175,03 | R$ 26.005,51 | R$ 98.326,58 | R$ 460.540,59 |
| 12 | 140.064,66 | 0,9922 | R$ 138.973,76 | R$ 10.022,05 | R$ 28.377,21 | R$ 100.574,50 | R$559.767,56 |
| 13 | 138.944,15 | 1,0422 | R$ 144.810,21 | R$ 10.947,26 | R$ 30.965,21 | R$ 102.897,74 | R$ 661.242,38 |
| 14 | 137.832,59 | 1,0947 | R$ 150.891,78 | R$ 11.957,88 | R$ 33.789,24 | R$ 105.144,66 | R$ 764.908,81 |
| 15 | 136.729,93 | 1,1499 | R$ 157.228,75 | R$ 13.061,80 | R$ 36.870,82 | R$ 107.296,13 | R$ 870.695,81 |
| 16 | 135.636,09 | 1,2079 | R$ 163.831,85 | R$ 14.267,63 | R$ 40.233,43 | R$ 109.330,79 | R$ 978.515,88 |
| 17 | 134.551,01 | 1,2688 | R$ 170.712,26 | R$ 15.584,78 | R$ 43.902,72 | R$ 111.224,76 | R$ 1.088.263,19 |
| 18 | 133.474,60 | 1,3327 | R$ 177.881,63 | R$ 17.023,53 | R$ 47.906,65 | R$ 112.951,46 | R$ 1.199.811,60 |
| 19 | 132.406,80 | 1,3999 | R$ 185.352,09 | R$ 18.595,09 | R$ 52.275,74 | R$ 114.481,26 | R$ 1.313.012,44 |
| 20 | 131.347,55 | 1,4704 | R$ 193.136,29 | R$ 20.311,74 | R$ 57.043,28 | R$ 115.781,26 | R$ 1.427.692,11 |
| 21 | 130.296,77 | 1,5445 | R$ 201.247,39 | R$ 22.186,87 | R$ 62.245,63 | R$ 116.814,89 | R$ 1.543.649,41 |
| 22 | 129.254,39 | 1,6224 | R$ 209.699,14 | R$ 24.235,10 | R$ 67.922,43 | R$ 117.541,60 | R$ 1.660.652,67 |
| 23 | 128.220,36 | 1,7041 | R$ 218.505,83 | R$ 26.472,43 | R$ 74.116,96 | R$ 117.916,45 | R$ 1.778.436,59 |
| 24 | 127.194,59 | 1,7900 | R$227.682,38 | R$ 28.916,29 | R$ 80.876,43 | R$ 117.889,66 | R$ 1.896.698,78 |
| 25 | 126.177,04 | 1,8802 | R$ 237.244,31 | R$ 31.585,77 | R$ 88.252,36 | R$ 117.406,19 | R$ 2.015.095,98 |

*Fig.9: Investment and Costs Analysis over 25 Years*

Source: Elaborated by the author (2018)

The data in Figure 9 display the values referring to the analysis of investment and costs during 25 years, separated annually, based on the following topics: Produced Energy; Electric Tariff; Revenue from Produced Energy; Annual Insurance; Cash Flow; and Accumulated Cash Flow .

The study presents a covered area of approximately 3.000 m². It was considered that a large part of this area could be used for installation of photovoltaic panels, as it was already covered with tiles having a suitable slope, making its installation easier. Regarding the project made by the electrical engineering, it is only needed a roof of 664 m², which corresponds to the installation of 340 panels.

The data given in Figure 10 illustrate the increase in the return on investment estimated in approximately six years, using the Simple Payback method. At the end of 25 years of warranty of the photovoltaic panels, the savings generated to the company under study is of R$ 2.015.095,98.

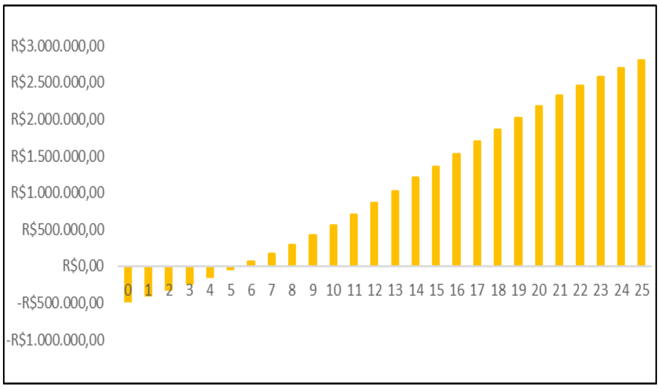


*Fig.10: Time of Return on Investment*

Source: Adapted from the PVsyst 6.73 simulator (2018)

From the data reported in Table 3, it was calculated the PI, which resulted in 1.99 %, higher than 1, being, thus, a favorable characteristic for the project. The ROI and the Net Present Value (NPV) were also calculated, resulting in 516.25 % and R$ 438.835,34, respectively, which is also a positive and relevant factor for the decision making of the board of directors. As mentioned before, the MAR was 8.3 % and the IRR corresponded to 17.1 % per year, higher than the MAR. The data provided in Table 3 show these results.

*Table.3: Results about Economic Indicators*

| Economic Indicators | Results |
|---|---|
| Profitability Index | 1.99 % |
| Return on Investment | 516.25% |
| Net Present Value | R$438.835,3 |
| Minimum Attractive Rate | 8.30% |
| Internal Rate of Return | 17.51% p.y |
| Simple Payback | 6 years e ½ month |
| Discounted Payback | 8 years and 5 months |

Source: Elaborated by the author (2018)

On the basis of the results achieved by the economic feasibility provided, it can be stated that the project is viable, since it offers great financial savings in the medium and long term, presenting itself as one of the solutions for the reduction in the maintenance costs of the oil company, and contributes to the generation of clean energy, with no emission of carbon dioxide ($CO_2$).

## VI. CONCLUSION

The solar energy generation system has been widely disseminated worldwide. In Brazil, after ANEEL resolution 482/2012, the photovoltaic system became largely used in residences, industries, and different organizations, with the possibility of offsetting electric generation credit.

This work aimed at assessing the possible implementation of a photovoltaic system in an offshore company in the municipality of Macaé, Rio de Janeiro State, Brazil. As observed, the company has the structural capacity to accommodate the system, and the investment will be returned in approximately six years, providing great savings in a medium and long term.

The return on investment rates was observed to be inconsistent considering the return on investment time less than or equal to five years.

Therefore, the feasibility of using photovoltaic panels is regarded as positive, providing not only financial benefits, but also contributing to sustainability, given that solar energy does not use fossil fuel, does not emit carbon dioxide into the atmosphere, and contributes to the maintenance of hydropower reservoirs, thus conserving national water resources.

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