Comparative Analysis Of Economic Feasibility For Energy Efficiency: Dimensioning A Photovoltaic System In A Confection In Municipality Of Dona Euzebia (Mg)

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***Abstract* — *Energy efficiency is a topic that is very much in Brazil, due to water problems. Therefore, we chose to do the analysis proposed in this paper to emphasize the importance of rational use of energy. The objective of the present work is to generate a comparative study between the costs for the implementation of a Photovoltaic Power Generation System in a confection located in the city of Dona Euzebia, Minas Gerais. Two Energy Efficiency projects were carried out to propose savings in the reduction of electricity and to verify which is the most economically viable project for the company under study. For the analysis of the economic and financial viability of the projects, the simple payback, the net present value (VPL), and the internal rate of return were analyzed (TIR). With the proposal of saving in the reduction of electric energy, Project 2 should be implemented in the confection, because the cost of the initial investment and the return time of this investment are smaller than Project 1. The results revealed that the project of the implementation of Photovoltaic solar energy as an alternative for cost reduction and energy diversification is feasible for the analyzed confection, considering the projected dice.*

Keywords: *Confection, Energy Efficiency, Photovoltaic Energy, Project; Viability;*

I. INTRODUCTION

Electricity is known to be essential to serve the entire population of a country, so it must be generated on a large scale. According to Dutra et al. (2013), the use of non-renewable sources is the predominant one recently, in order to produce all the energy. According to the same authors, the use of non-renewable sources can cause major impacts on the environment.

According to the National Electric Energy Agency - ANNEL (2019), most of the electricity generated in Brazil comes from hydroelectric and thermoelectric plants, which account for 88.47% of production. Currently photovoltaic plants produce 1.26% of the energy generated.

In this context, environmental concern grows on a global scale. Faced with climate change, energy efficiency emerges as an instrument for the reduction of greenhouse gases and ozone-depleting gases. Today, energy efficiency may be one of the most economical and sustainable forms of energy in Brazil, and with the increase of this efficiency, some programs have been created to promote the efficient use of electricity, namely the National Program for Conservation of Energy. Electricity (PROCEL) and the Energy Efficiency Program (PEE).

According to Bermann (2008), renewable energy sources are classified into biomass, wind, geothermal, hydraulic and solar. For the International Renewable Energy Agency - IRENA (2019), renewable energy will make up about 85% of the global energy matrix by 2050, with emphasis on solar and wind generation.

In Brazil, photovoltaic energy, also known as solar, stands out for being a renewable energy source. This alternative energy has great potential for growth and investment. For Dutra et al. (2013), solar energy stands out among the renewable energy sources, as it is an inexhaustible source, besides being renewable and autonomous, thus, it does not pollute the environment, besides offering great reliability and reducing consumption costs by long term.

From this perspective, photovoltaic solar energy has been an alternative for renewable, clean, and environmentally friendly generation of electricity. As a result, electricity is being replaced by photovoltaic solar energy due to higher tariffs on the electricity bill. As a way of reducing costs and not harming the environment, many homes, businesses and industries are investing in photovoltaic solar energy. According to the National Electric Energy Agency - ANNEL (2017), it is estimated that more than 800,000 commercial and residential consumers will adopt solar photovoltaic microgeneration by 2024.

Given the facts mentioned, the objective of this paper is to generate a comparative study between the costs for the implementation of a Photovoltaic Power Generation System in the company under study.

Thus, 2 Energy Efficiency projects will be presented in order to propose savings in the reduction of electricity and to verify which is the most economically viable project to be implemented in the confection. Project 1 will have a total investment of R$ 37,300.20 and the return time for this investment will be 2.9 years. Project 2 will have a total investment of R $ 34,731.08 and a payback time of 2.7 years. Thus, it can be concluded that Project 2 is economically viable, since the initial investment and the return time are smaller when compared to Project 1.

II. LITERATURE REVIEW

A. Energy efficiency

Energy efficiency is the method of accomplishing more using less energy. According to the Brazilian Association of Energy Conservation Service Companies ABESCO (2019), this means using energy efficiently.

According to the Energy Research Company (2019), energy efficiency means generating more electricity using less natural resources, or doing the same things by consuming less energy. It is related to rational use, with the least possible waste of energy sources.

According to Busse (2010), the advantages and benefits of energy efficiency are directly related to higher energy availability, because with energy saving it is possible to avoid waste, obtain more resources, and protect the environment.

The adoption of energy efficiency techniques and programs is increasingly recognized as the most cost effective option in the short and medium term to meet the energy needs of economic growth and to minimize the impact of global climate change. It is particularly important in developing countries that are experiencing great economic growth. (LIMAYED D.; LIMAYE E., 2011, p.133-144).

B. Photovoltaic Power Generation

Photovoltaic Power Generation is based on the direct conversion of solar radiation into electrical energy. According to Rosa (2007), the photovoltaic generation system is composed of photovoltaic panels, a voltage regulator, as well as a storage system and an inverter that converts direct current to alternating current. For the author, the photovoltaic panel performs a generator function itself, besides being composed of photovoltaic cells built from semiconductors, which, after receiving sunlight on their surface, produce electrical voltage at their terminals.

The Photovoltaic Power Generation System is simple to install, so it is not necessary to make major adaptations in homes and industries to perform the installation of this system.

C. Investment analysis

According to Veras (2011), the investment analysis is based on the study of alternatives between two or more investments to choose the best one, and also on the criticism of a single investment in order to judge whether it is of interest or not. For the authors Rezende and Oliveira (2008), the analysis of an investment seeks to ascertain whether or not the project is viable to be implemented, thus making a comparison using the methods and parameters of analysis that associates own costs and revenues to the project.

a) Payback

Payback time, which is known as payback, is a method of investment analysis in which the time required to recover the capital invested in a given project is verified. Gitman (2011) states that payback is the time required for a company to recover its initial investment in a project by calculating it based on its cash inflows.

For Weise (2013), it is necessary for the investor to assess the risk over the time it will take to recover the capital invested in this project. The author further defines that this investment analysis method has two different application methodologies, namely: Payback Simples and Payback Discounted. In this context, Lima et al. (2008) explains that the simple payback does not take into consideration the cost of capital in the period, whereas the discounted payback considers the real value of money over time

b) VPL (Net Present Value)

According to Boeira (2014), the Net Present Value (VPL) method is very important and easy to calculate. According to the same author, it is one of the most used tools to verify investment proposals. According to the author Wakamatsu (2012), VPL is applied when we want to buy cash flow, that is, the profit of a given investment. Therefore, in a defined period, cash flow is accounted for, making the necessary reparations of the cost of capital and subtracting from this value the initial investment.

c) Internal Rate of Return (TIR)

According to Muller (2003), the Internal Rate of Return (TIR) is equivalent to a discount rate that compares the real value of future revenues with the real value of future project costs, ie the project rate of return. For the authors Pilão and Hummel (2003), the TIR method is the one that allows the return on investment to be found in percentage terms. According to the same author, finding the TIR of an investment is the same as finding its maximum power, the exact percentage of return that the investment offers.

III. METHODOLOGY

This study was conducted through bibliographic searches, scientific articles, monographs available on academic google and specific websites, in order to obtain a theoretical basis regarding the contents covered and the methods to be used.

The method used for the research in question was the case study. According to Mendes and Mendes (2006), the case study is a method adopted to verify the data that was studied, seeking to analyze the decisions made, the reason for certain actions and the results.

The paper presents a case study carried out in a confection located in the city of Dona Euzebia, in Minas Gerais. The company that is the object of study operates in the production of garment manufacturing of women's clothing and works for major brands throughout Brazil.

For the preparation of the present work, site visits were made in order to survey all existing electrical equipment in the confection, and from there it was possible to analyze and describe the projects characterizing them as a descriptive study. According to Prodanov and Freitas (2013), the descriptive study records and describes the observed acts, reporting the particularities of some population and determining relationships between the variables.

Research is applied as it provides knowledge for practical application. It is classified as the approach as quantitative, in which from the collection and analysis of data obtained quantifiable results. Thus, 2 Energy Efficiency Projects were prepared to verify which is the most economically viable project for the confection. The sizing of the photovoltaic systems was carried out by the company Efficax Efficiency Energy that works in the field of photovoltaic solar energy.

Energy Efficiency Project1:
Step 1: Design of a Photovoltaic Power Generation System to meet the total consumption of making with inefficient electrical equipment.
Step 2: Calculation of costs and financial viability of the project
Energy Efficiency Project 2:
Step 1: Conduct an energy diagnosis to reduce energy consumption by identifying inefficient equipment that can be replaced.
Step 2: Design of new efficient electrical equipment and calculation of expected savings (improvements)
Step 3: Design of a Photovoltaic Power Generation System to meet the remaining consumption of the company.
Step 4: Calculation of costs and financial viability of the project.

After the data collection, it was possible to verify that the means that consume electric energy in the confection are: illumination, climatization, refrigeration, motors and heating. For this purpose, a form was used for each item mentioned in order to record the technical characteristics, quantity and operating scheme of each electrical equipment.

The work in question aims to evaluate two projects and by comparing their economic and financial viability, it will be possible to identify which is the most suitable for implementation in the confection, aiming to reduce the consumption of electricity, and of course operating costs, with the best return on investments to be made. For the analysis of the economic and financial viability of the projects, the simple payback, the net present value (VPL) and the internal rate of return (TIR) were calculated and analyzed. The demonstration of the collected data and development of the formulas were performed in Excel 2010 software.

IV. RESULTS

In this session will be presented the premises of each project

Table 1 - Monthly Consumption

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Consumption (kWh)	*957*	*1.664*	*1.320*	*1.575*	*1.343*	*1.366*	*1.339*	*1.291*	*1.463*	*1.496*	*1.403*	*1.636*	***16.853***

Source: Author.

A. Project 1

Project 1 aims to meet the current consumption of sewing with inefficient electrical equipment.

The Photovoltaic Generation System was designed to meet the unit in which it will be installed, with a two-phase supply at 220/127 V, with an average consumption of 1,404 kWh per month, totaling 16,853 kWh per year. The assumption was made to reduce the availability cost of 50 kWh per month, corresponding to the minimum for customers with two-phase connection, which is charged to the electricity bill.

Table 2 shows the dimensioning of Project 1, which has an installed power of 11.39kWp (kilowatts-peak) and is composed of 34 335 Wp (Watt-peak) solar modules, 2 5,000W inverters. (Watts), which was budgeted in the amount of R $ 37,300.20.

Table 2 - Photovoltaic System Dimensioning - Project 1.

SYSTEM SIZING	
Photovoltaic Modules	Fabricante: Jinko Solar
Maximum power of module	335Wp
Amount	34
Inverter Rated Power (W)	5.000
Maximum Inverter Power (W)	6.500
Number of Inverters	2

Source: Author.

This Photovoltaic System will be able to generate an average monthly energy of approximately 1,372 kWh / month and a total of 16,469 kWh / year.

Consumption, after the availability of 50 kWh, and the average energy generated by the system, monthly and accumulated, are presented in Table 3 below.

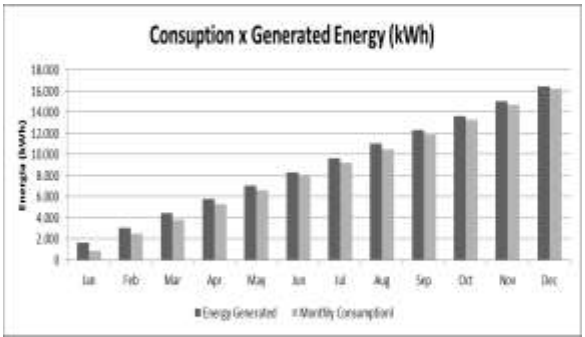
Table 3 - Consumption and Generation (monthly and accumulated)

	Monthly Energy (kWh)		Accumulated Energy (kWh)	
Month	**Consumption (kWh)**	**Generation (kWh)**	**Consumption (kWh)**	**Generation (kWh)**
January	907	1.617	907	1.617
February	1.614	1.419	2.521	3.036
March	1.270	1.396	3.791	4.432
April	1.525	1.325	5.316	5.757
May	1.293	1.319	6.609	7.075
June	1.316	1.201	7.925	8.277
July	1.289	1.377	9.214	9.653
August	1.241	1.405	10.455	11.059
September	1.413	1.223	11.868	12.282
October	1.446	1.363	13.314	13.644
November	1.353	1.361	14.667	15.005
December	1.586	1.464	16.253	16.469
Total	**16.253**	**16.469**	**16.253**	**16.469**

Source: Author.

It can be observed that the total value of annual generation (16,469 kWh) is higher than the annual energy consumption (16,253 kWh). Given this, it is possible to conclude that the energy generated by the Photovoltaic System will be able to meet the consumption of confection, which can also be seen through Graph 1, which shows the energy balance between the energy consumed and the energy generated.

Graph 1 - Consumption x Accumulated Generated Energy(KWh).



Source: Author.

The total cost of Project 1 is R$ 37,300.20, and will be able to provide an annual savings of 16,469 kWh. Knowing that the price of electricity is R$ 0.7848 / kWh, which will result in R$ 12,924.87 / year. The project has a service life of 25 years, which is the warranty time given by the manufacturer of the photovoltaic modules.

Subsequently, the simple payback was calculated to verify the return time of the investment, the net present value (VPL), considering a discount rate of 8% per year, and the internal rate of return (TIR). The following equation was used to calculate the simple payback. [Simple Payback = Investment Amount ($) / Savings ($)]. VPL and TIR calculations were performed in an Excel spreadsheet.

The project's payback time is 02 years and 09 months. The viability of the project has a VPL of R$ 143,606.83 and an internal rate of return (TIR) of 46.1%, as can be seen from the data in Table 4, presented below.

Table 4 - Consumption and Generation (monthly and accumulated)

Source: Author.

Initial investment	**Annual Savings**	***Simple Payback (years)***	**VPL (R$)**	**TIR (%)**
R$ 37.300,20	R$ 12.924,87	2,9	143.606,83	46,1%

A- Project 2

Aiming to reduce the consumption of electric energy to enable the sizing of a smaller Photovoltaic Generation System, in the second project, it was proposed to replace some inefficient electrical equipment with efficient low consumption, through an energy diagnosis performed in the confection facilities.

Replacement of 9 110 W tubular fluorescent lamps with 40 W tubular LED lamps, 4 40 W fluorescent tubes with 18 W tubular LED lamps, 1 280 liter refrigerator for another 261 liter A Procel, and 1 345-liter refrigerator for another 300-liter refrigerator with Procel A seal.

The estimated cost of replacing the equipment is R $ 3,683.60, providing an average monthly savings of 269.6 kWh, totaling 3,235kWh / year, according to Table 5, extracted from Energy Diagnostics.

Table 5 - Savings from replacing inefficient equipment.

System	Current Consumption (kWh / year)	Expected Consumption (kWh / year)	Economy (kWh / year)	Economy (%)
Lighting	3.786	1.287	2.499	66,0
Cooling	1.445	709	736	50,9
Total	**5.231**	**1.996**	**3.235**	**116,9**

Source: Author.

Thus, the new average monthly consumption of apparel would be reduced to 1,135 kWh, totaling 13,618 kWh annually, without lowering the availability cost factor.

A new photovoltaic generation system was designed to meet this consumption, keeping the same assumptions adopted in Project 1.

Table 6 shows the dimensioning of Project 2, which has an installed power of 9.045kWp (kilowatts-peak) and consists of 27 335 Wp (Watt-peak) solar modules, 2 inverters, one of 5000W (Watt-peak) and another of 3000W (Watt-peak), which was budgeted in the amount of R $ 31,047.48.

Table 6 - Photovoltaic System Dimensioning - Project 2.

SYSTEM SIZING	
Photovoltaic Modules	Manufacturer: Jinko Solar
Maximum power of module	335Wp
Amount	27
Inverter Rated Power (W)	5.000 e 3.000
Maximum Inverter Power (W)	6.500 e 3.900
Number of Inverters	2

Source: Author.

This system will be able to generate an average monthly energy of approximately 1,089 kWh / month and a total of 13,068 kWh / year.

Consumption, after the availability of 50 kWh, and the average energy generated by the system, monthly and accumulated are presented in Table 7.

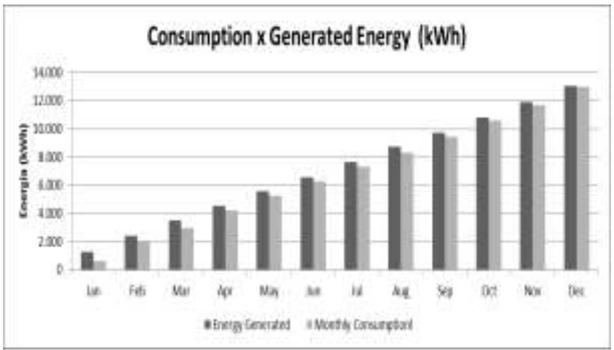
Table 7 - Consumption and Generation (monthly and accumulated).

Monthly Energy (kWh)			**Accumulated Energy (kWh)**	
Month	**Consumption (kWh)**	**Month**	**Consumption (kWh)**	**Month**
January	638	1.283	638	1.283
February	1.345	1.126	1.983	2.409
March	1.001	1.107	2.984	3.516
April	1.256	1.052	4.240	4.568
May	1.024	1.046	5.264	5.614
June	1.047	953	6.311	6.567
July	1.020	1.093	7.331	7.660
August	972	1.115	8.303	8.775
September	1.144	971	9.447	9.746
October	1.177	1.081	10.624	10.827
November	1.084	1.080	11.708	11.907
December	1.310	1.161	13.018	13.068
Total	**13.018**	**13.068**	**13.018**	**13.068**

Source: Author.

Based on the data in Table 5 and Graph 2, it is possible to observe the relationship between the energy generated and the energy consumed through the energy balance. From this, it is possible to conclude that the energy generated by the system (13,068 kWh / year) will be able to meet the consumption of clothing (13,018 kWh / year).

Graph 2 - Consumption x Accumulated Generated Energy (KWh).



Source: Author.

The total cost of Project 2 is R$ 3,683.60 to replace inefficient equipment plus R$ 31,047.48 for installation of the photovoltaic generation system, totaling R$ 34,731.08 and will be able to provide annual savings of 13,068 kWh due to the system. photovoltaic system, and 3,235 kWh / year due to the replacement of inefficient equipment, totaling 16,303 kWh / year, which with the price of electricity of R$ 0.7848 / kWh will result in R$ 12,794.59 / year.

The project has a service life of 25 years for the photovoltaic system, 10 years for the refrigerators and 9 years for the lamps.

The return on investment for this project is 2.7 years, with a VPL of R$ 144,352.44 and an TIR of 48.5%, as can be seen in Table 8.

Table 8 - Payback Simple / VPL / TIR.

Initial investment	**Annual Savings**	***Simple Payback (years)***	**VPL (R$)**	**TIR (%)**
R$ 34.731,08	R$ 12.794,59	2,7	R$ 144.352,44	48,5%

Source: Author.

V. CONCLUSION

Energy efficiency is a topic that has been much discussed today. For, besides bringing benefits from a financial point of view, it is also very important for the preservation of the environment.

Given this, the study aimed to analyze the economic and financial viability of photovoltaic solar energy as an alternative to reduce costs in a confection located in the city of Dona Euzebia, Minas Gerais.

Thus, a descriptive and applied research was conducted through a case study, and later a comparative study. To analyze the economic and financial viability of the projects, the simple payback, the net present value and the internal rate of return were calculated and analyzed.

Project 1's total investment will be $ 37,300.20 and the payback time of 2.9 years, while Project 2 will have an investment of $ 34,731.08 and the payback time of 2.7 years. comparative analysis, it can be seen that Project 2 is more economically viable, because the cost of the initial investment and the return time for this investment are shorter than Project 1. With the proposed savings in electricity reduction, Project 2 should be implemented in the company under study.

Due to the facts mentioned, it is concluded that, besides reducing costs and presenting economic and financial viability for the analyzed confection, solar energy, one of the most important among the renewable energy sources, will also generate invaluable benefits for the environment.

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