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Applied Economic Engineering To Solar Energy Projects

Alcides Feitosa Neto[1], Cleilson Coutinho Da Silva[2],
Rickardo Léo Ramos Gomes[3]

[1](Bachelor's Degree In Economics From Unifor, Specialist In Mba In Renewable Energy Management – Farias Brito University Center/Euvaldo Lodi Institute (Fbuni/Iel), Specialist In Executive Mba In Financial Management From Unifor, Master's Degree In Economics From The Federal University Of Ceará)
[2](Bachelor's Degree In Pedagogy – State University Of Vale Do Acaraú (Uva); Bachelor's Degree In Physics – Federal University Of Ceará (Ufc); Specialist In Physics Teaching – Federal University Of Ceará (Ufc); Specialist In Mba In Renewable Energy Management – Farias Brito University Center/Euvaldo Lodi Institute (Fbuni/Iel); Master's Degree In Science And Mathematics Teaching – Federal Institute Of Education, Science, And Technology (Ifce)) [3](Professor Of The Methodology Of Scientific Work Discipline (Advisor) – Euvaldo Lodi Institute; Fbuni; Ph.D. In Biological Sciences - Ficl; M.Sc. In Crop Science - Federal University Of Ceará; Specialist In Science Teaching Methods - Uece; B.Sc. In Agronomy - Ufc; Licentiate In Natural Sciences, Mathematics, And Their Technologies - Uva; Additional Training Courses In People Management, Project Management, Education, Leadership, Auditing, And Health At: Harvard; Idb; Fiocruz; Johns Hopkins University (Jhbsph); International Consultant For Scientific Laboratories At The World Bank. Scientific Consultant)

Abstract:
Background: *The search for the use of electrical energy through renewable sources is experiencing significant expansion, particularly at a time when social policies are being implemented with a focus on climate conditions. Solar energy stands out as a renewable energy source with costs that are more accessible than conventional energy sources. Photovoltaic panels for commercial use represent a smart strategy for many companies seeking energy efficiency, cost savings, and sustainability. These systems offer benefits that range from reductions in operational expenses to contributions toward corporate social responsibility goals.*
Materials and Methods: *To conduct this study, two research methods were used: bibliographic research and documentary research. The qualitative approach employed in this article enabled a detailed investment analysis of the elements related to economic engineering applied to solar energy projects. Techniques for economic and financial viability were presented, including Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period.*
Results: *The findings of the research demonstrated that solar energy is a viable and strategic option for economic growth in Ceará. Considering that Ceará ranks fifth in Brazil for its capacity to generate solar energy, solar power represents a promising investment alternative for the state. The study highlighted the economic and environmental advantages of utilizing solar energy.*
Conclusion: *The research clearly shows that solar energy not only contributes to economic growth but also plays a crucial role in environmental conservation in Ceará. Achieving the objectives reinforces the importance of government policies focused on expanding clean energy sources. These policies will ensure that the benefits of solar energy extend beyond the current scenario, fostering a more sustainable and inclusive future.*
Keywords: *Investment Analysis; Cost Savings; Energy Efficiency; Solar Energy.*

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I. Introduction

Over the centuries, the transformations in temperature and climate have accelerated significantly. The constant use of fossil fuels (coal, oil, and gas) has been a major driver of climate change, being one of the primary causes of global warming. In the early 1990s, society began to pay greater attention to the warming of planet Earth as a new global issue. This scientific fact—the increase in the Earth's temperature—was named global warming and was addressed by international organizations such as the United Nations (UN).

It is necessary to carry out an energy transition toward a low-carbon economy to prevent the climatic disasters caused by global warming. According to the Copernicus Climate Change Service of the European Union, 2023 was the hottest year on record for the planet. In Brazil, according to the National Institute of Meteorology (INMET), the average temperature in 2023 was 24.92°C, making it the hottest year in the historical series.

The continuous increase in global demand for electricity, combined with a growth in industrial production, has generated a considerable volume of gas emissions. As a result, there is a clear need for the use of clean energy. Renewable or clean energy can come from sources such as solar, wind, hydropower, geothermal,

and biomass. These energy sources contribute less to the greenhouse effect, do not cause acid rain, and release fewer polluting gases. This article aims to present solar energy as an investment alternative for businesses and its impacts on economic and financial viability.

The qualitative approach employed in the preparation of this article enabled a detailed analysis of the elements related to economic engineering applied to solar energy projects. To collect information, two research methods were used: bibliographic research and documentary research.

The overall objective of the article is to present the importance of solar energy as an investment alternative in the state of Ceará, considering that this state ranks fifth in the country for its capacity to generate solar energy. The specific objectives are as follows: to show that sustainable and economic development is possible by reducing environmental risks, promoting social inclusion, and increasing productivity through the use of solar energy; to demonstrate the economic and financial viability by exploring the techniques of Net Present Value (NPV), Internal Rate of Return (IRR), and Payback.

This article is structured into four sections. The first section is the introduction, in which the research objectives are explained. The second section is dedicated to the methodology. In the third section, a theoretical foundation is developed, where a discussion is held among authors who address the same topic covered here. In the fourth and final section, the final considerations are presented.

II. Material And Methods

The qualitative approach employed in the development of this article facilitated a detailed analysis of the elements related to economic engineering applied to solar energy projects. To gather information, two research methods were utilized: bibliographic research and documentary research. The bibliographic study involved an analysis of the available literature on the fundamentals of economic engineering and its application in the solar energy sector, aiming to understand the most effective practices and the obstacles encountered. This methodology is crucial for establishing a robust theoretical framework, as emphasized by authors such as Gitman (2024), who highlight the relevance of financial management in project evaluation[1].

The documentary analysis was conducted using documents produced by ABSOLAR (Brazilian Association of Solar Energy), which provide pertinent data on policies, guidelines, and case studies in the field of solar energy in Brazil. The use of this type of study is essential for obtaining updated and accurate information, reflecting the reality of the sector and allowing for a critical assessment of the available information[2]). The combination of these two methodologies offers a comprehensive understanding of the subject, enabling the identification of gaps in the literature and areas requiring further research. According to Wernke (2018), cost assessment in energy projects is crucial for establishing financial viability and sustainability in this domain[3].

The most relevant authors contributing to the advancement of this study include Silva and Lins (2014), who discussed cost management and its importance in decision-making[2]; Wernke (2018), who highlighted cost and price analysis within the Brazilian context[3]; and Gitman (2024), whose principles of financial management serve as a theoretical foundation for the economic analysis of projects[1]. These references were essential for underpinning the discussions proposed in this article, emphasizing the progress of knowledge in the field of economic engineering focused on solar energy. This approach aims not only to aid academic understanding of the topic but also to provide practical support for industry professionals, encouraging a synergy between theory and practice in executing sustainable projects.

III. Literature Review

The aforementioned article was divided into three subtopics. The first subtopic discussed the costs of energy and their impacts on companies. The second subtopic addressed the scenario of photovoltaic energy in Brazil and its importance in reducing environmental impacts. The third and final subtopic covered the main techniques for analyzing investment projects.

Energy Costs

Electricity is one of the primary inputs for the development of industrial activities and society as a whole. In recent decades, the continuous increase in energy tariffs has directly affected the competitiveness and sustainability of companies. A significant factor influencing competitiveness is cost control, as production costs have a direct impact on the final price of products, reducing profit margins and the company's reinvestment capacity.

In the national context, the photovoltaic solar source is expected to generate over 300,000 new jobs in 2023, according to the Brazilian Association of Photovoltaic Solar Energy, with investments generated by the sector potentially exceeding R$ 50 billion in the coming year, including large-scale plants and small systems on rooftops, facades, and land. Despite Brazil being a country rich in hydric resources, uncertainties remain regarding water availability for future energy production. Even if uncertainties about sufficient water availability for energy generation in the future are confirmed, it is considered a renewable and inexhaustible source.

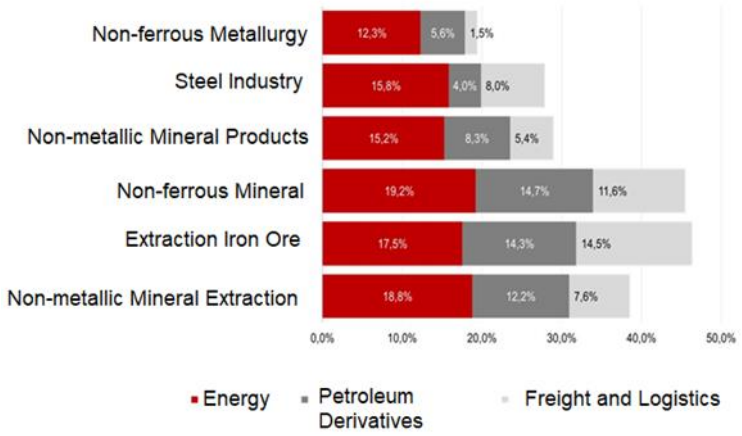
It is well known that current energy sources not only cause significant pollution but also drastically affect nature due to the consumption of finite natural resources, leading to undesirable environmental impacts. It is evident that renewable energy is essential for sustainable development. According to Silva and Araújo (2022), there is significant concern regarding pollutant emissions resulting from the combustion of fossil fuels for electricity generation, such as oil, natural gas, and coal[16].

Regarding the definition of costs, Wernke (2018) states that they can be characterized as expenditures incurred to manufacture a product or provide a service. According to Silva and Lins (2014), costs represent an investment in an asset that will be used during manufacturing, undergoing a transformation process until it becomes a finished product or service rendered[3].

Commissioned by ABRACE Energia, a technical study by Ex Ante Consultoria Econômica outlines the increase and rising costs of electricity. The study reveals that between 2000 and 2022, the unit cost of electricity for Brazilian industry increased by 1154%. During the same period, industrial prices rose by 585%, while the Broad Consumer Price Index (IPCA) accumulated a variation of 291%. As observed, this substantial increase surpasses inflation during the same period.

According to the analysis, reversing the trend of rising energy costs could have substantial effects on the Brazilian economy. The projection indicates that GDP growth could jump from an average of 1.9% per year to 3.7% per year over the next ten years, with a more pronounced impact between 2028 and 2033. This reality is not exclusive to any specific segment of the economy. Graph 1 below presents the percentage of energy produced according to economic segment.

Graph 1 – Energy Produced



Source: IBGE. Prepared by: Ex Ante Economic Consulting 2022

As we can observe, between 12% and 20% of the costs in industrial production are allocated to energy, which directly impacts the product price.

Solar Energy Landscape

The Sun is a primary and abundant source of energy on our planet. According to Pinho and Galdino (2014), solar radiation, in addition to being inexhaustible, holds immense potential for utilization through capture systems and conversion into other forms of energy[5]. Solar energy is considered clean and renewable, as it does not emit gases or negatively impact the environment. Furthermore, the direct impacts are mitigated since solar panels are recycled at the end of their useful life. The Sun has been one of the most important energy sources, utilized for millions of years as a source of heat and for generating electricity. Solar energy is produced by capturing solar radiation, being regarded as 100% clean and generating no waste for the environment, while utilizing what is available in nature.

Photovoltaic solar energy can be defined as the conversion of sunlight into electrical current; the term "photovoltaic" originates from Greek, with "phos" meaning "light" and "volt" referring to electrical tension. The photovoltaic effect was first observed in 1839 by Edmund Becquerel and currently consists of a potential difference between two semiconductors with different electrical properties due to light incidence at the junction [6].

The renewable energy sector is increasingly promising in Brazil, generating employment and income for the population. Among various sources, solar energy has positively impacted the entire production chain and consequently the economy. Electricity expenditures represent nearly 40% of a business's operational costs, affecting the final price of products/services and reducing the competitiveness of companies/industries. The

Brazilian energy matrix comprises the set of sources used for generating all energy consumed within the national territory. It consists of 55.2% non-renewable sources and 44.8% renewable sources.

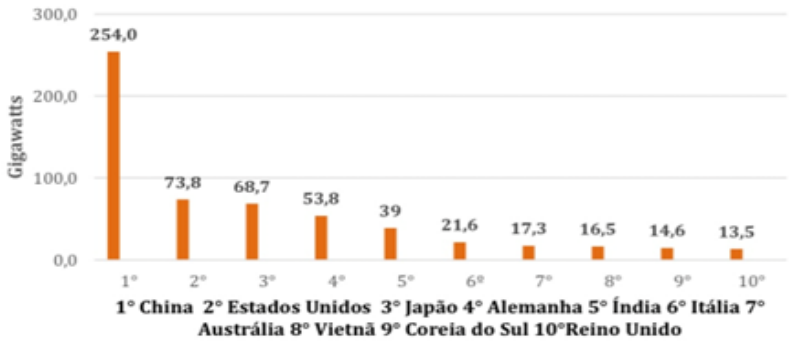
A significant advantage of the Brazilian energy matrix is its high proportion of renewable sources, making it one of the cleanest in the world. In 2020, demand for solar energy surged in Brazil, leading to historic growth in photovoltaic systems, which reached 90.77% of total installed systems in 2018, according to data from the National Electric Energy Agency (ANEEL). Pereira et al. (2017) state that Brazil's electrical matrix is highly renewable because a large portion of Brazilian electricity comes from hydroelectric plants, with considerable growth in wind and solar energy production[7]. Countries are increasingly concerned about global warming and its impacts on populations. Ribeiro (2012) identifies a current challenge: reducing dependence on fossil sources, which are excessively aggressive and consist of finite natural resources[8].

A low-cost energy generation alternative is photovoltaic solar energy. This technology consists of panels that allow local energy production by capturing sunlight. This type of energy becomes even more valuable for Brazilians due to new ANEEL regulations that permit exchanging energy produced by panels for credits in kWh on electricity bills. One of the main advantages of installing solar energy systems is the decentralization of electricity production in Brazil. The ability to generate electricity at one's own residence provides greater independence for consumers, eliminating reliance on distribution costs and high government charges [9].

Among the primary advantages of renewable energies are their availability and accessibility due to their abundant and inexhaustible nature. Additionally, they are fewer polluting sources that generate fewer environmental impacts compared to traditionally used energies. Another factor pertains to the declining implementation costs associated with renewable energies over recent years. Consequently, photovoltaic solar projects have become more feasible in rural, residential, and industrial properties. One sector that can benefit from these new forms of energy is hospitality. Implementing such systems in accommodations can be an excellent strategy for reducing costs. For hotel enterprises, energy represents one of the main variable costs. These expenses increase during peak seasons, raising the cost of generated electricity. Therefore, cutting or reducing energy costs has become one of the most viable alternatives.

According to Alves (2021), there are numerous applications for solar energy derived from sunlight. Direct generation (photovoltaic solar energy) and indirect generation (heliothermal energy, converting solar irradiation into heat for electricity generation) can be highlighted, along with thermal solar energy (generating heat to warm fluids as well as drying and industrial heating)[10].

Graph 2: Countries Leading in Photovoltaic Energy Production



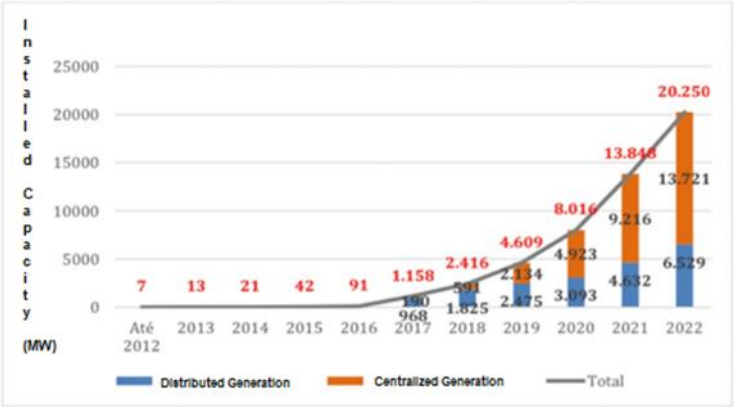
Source: IRENA (2022)

Graph 02 presents the ten countries leading solar energy production globally, with China occupying the top position on the list of solar energy producers, boasting approximately 254 GW of installed capacity, followed by the United States and Japan, with production figures of 73.8 GW and 68.7 GW, respectively. A survey conducted by Bloomberg New Finance (BNEF) indicates that the Brazilian distributed generation market totaled USD 13 billion in 2022; this technology is projected to become the largest source of electricity generation in the country by 2050.

According to ABSOLAR (Brazilian Association of Photovoltaic Solar Energy), Brazil added approximately 5.7 gigawatts (GW) of capacity from solar generation plants in 2021, considering both self-generation systems in residences and businesses as well as large-scale projects connected to the National Interconnected System (SIN).

In terms of this volume, Brazil ranked behind China, which added 52.9 GW, the United States with 19.9 GW added, and India with an expansion of 10.3 GW. Regarding total solar generation capacity among countries, Brazil moved up one position in the global ranking to 13th place. According to ABSOLAR, the country concluded last year with over 13.6 GW of operational solar power.

Graph 03 – Evolution of Photovoltaic Solar Energy in Brazil



Source: ANEEL/ABSOLAR (2022)[2]

We can observe in Graph 03 the exponential growth of solar energy in Brazil from 2012 to 2022. According to data from the National Electric Energy Agency (Aneel), Ceará is the 5th state in the country with the largest solar energy generation capacity, currently reaching 5.4 GW. Since 2012, self-generation of solar energy has brought Ceará more than R$ 2.5 billion in investments, the creation of over 14,000 jobs, and more than R$ 636.7 million in public revenue.

These factors make solar energy investment increasingly promising, reducing the payback period of capital applied. In the public sector, the state, as an active economic agent, launched the *Renda do Sol* Project in 2023. This program aims to implement Distributed Generation photovoltaic systems for low-income families and small rural producers.

Economic Engineering and Investment Analysis Techniques in Projects

According to Pilão and Humell (2004, p. 79), "Economic Engineering is a set of techniques that allows for scientific comparison between the results of decision-making regarding different alternatives[11]." In this comparison, the differences that distinguish the alternatives should be expressed, as much as possible, in quantitative terms. Economic engineering employs financial mathematics tools to evaluate projects concerning costs, risks, and investments, aligning them to a common timeframe due to the time value of money. Among these tools, the most commonly used are Net Present Value (NPV), Internal Rate of Return (IRR), and Payback, all calculated based on the project's Cash Flow (CF).

According to Nogueira (2013), controlling the precise timing of cash inflows and outflows throughout the project lifecycle is essential for evaluating any type of investment alternative. For this purpose, cash flow is utilized. The cash flow diagram consists of a horizontal line representing time or capitalization periods and vertical vectors representing inflows if the arrows are above the line or outflows if they are below[12].

As noted by Samanez (2009), the process of identifying, analyzing, and selecting investments in projects is referred to as capital budgeting. This process involves utilizing highly refined economic logics and ultimately forms a portfolio of acceptable projects that will collectively or individually yield economic returns consistent with the company's long-term goals while contributing to value generation[13].

The primary techniques addressed in this research will include: Net Present Value (NPV), Internal Rate of Return (IRR), and Payback. For Wernke (2018), Net Present Value, also known by some authors simply as Present Value, is a mathematical concept that indicates the current value of future capital, discounted at a given rate of compound interest over its respective term[3].

Net Present Value

NPV brings future values of Cash Flow generated by the project over its useful life into present terms. "In theory, if the company has no budgetary constraints, analysis through Net Present Value leads to the optimal solution"[13]. The calculation of NPV is given by Equation 1.

$$VPL = -Io + \sum_{t=1}^{n} \frac{FC_t}{(1+i)^t} \qquad (1)$$

Where I_0 is the initial investment, CF_t is the cash flow value in period *t*, and *i* is the required return rate for the project. Regarding the analysis of the indicator, if the result is positive (NPV > 0), the project is considered economically viable. When choosing between investments, the project with the highest value of the indicator will be the best option in economic terms.

Internal Rate of Return (IRR)

Investment analysis is an important tool that encompasses various techniques for comparing analyzed results to assist in scientific decision-making. Moreover, investment analyses can be applied both for comparison and for selecting the best investment alternative among two or more options.

According to Nogueira (2013), the Internal Rate of Return (IRR) is the interest rate that equates the present values of inflows to the present values of outflows in a cash flow stream. In other words, when applied in the previous formula, IRR results in an NPV = 0[12].

The calculation of this indicator is given by Equation 2.

$$VPL = -Io + \sum_{t=1}^{n} \frac{(1 + TIR)^t}{FC_t} = 0 \qquad (2)$$

For Gitman (2024), the Internal Rate of Return (IRR) is the discount rate that equates the present value of cash inflows to the initial investment associated with a project[1].

Payback

Lastly, we have Payback, which is a method used to identify the time required to recover the initial investment[14]. It can be calculated in two ways. The first method does not discount future values to the present and is referred to as Simple Payback. The second method, known as Discounted Payback, brings future values to the present using a discount rate. According to Ross, Westerfield, and Jordan (2000, p. 218), "Payback is the period required for an investment to generate sufficient cash flows to recover its initial cost[15]."

IV. Conclusion

The research highlighted that the energy transition is a fundamental process for building a sustainable future, impacting both production processes in companies and consumption patterns. This shift will involve moving from fossil and non-renewable sources to clean and renewable sources, ultimately reducing greenhouse gas emissions.

As observed, solar energy stands out as one of the primary renewable sources. Solar energy is clean, emits no pollutants during its use, and has a lower environmental impact compared to other energy sources. Solar energy has the potential to provide electricity to remote communities, contributing to regional development and economic growth at a lower cost than conventional energies, benefiting both companies and consumers by reducing electricity expenses, optimizing costs, and consequently lowering final prices for consumers.

The study fully achieved all established objectives, as evidenced by the development of the topics discussed in the theoretical framework. The evaluation of energy costs underscored the increasing competitiveness of solar energy compared to conventional sources, confirming its financial viability.

The situation of solar energy in Ceará was analyzed, highlighting its significant production potential and confirming that the state ranks fifth nationally in installed capacity. Furthermore, the investigation into economic engineering methodologies and investment evaluations—such as Net Present Value (NPV), Internal Rate of Return (IRR), and Payback—confirmed the financial viability of solar energy projects, making them an attractive option for investors.

The study also revealed that solar energy can contribute to sustainable economic development by reducing environmental hazards, promoting social inclusion, and enhancing productivity. The information presented indicates that solar energy can significantly impact reducing energy costs, benefiting both businesses and consumers while assisting in environmental preservation and sustainable economic development.

However, it is suggested that future studies intensify the evaluation of the socioeconomic effects of solar energy, particularly in isolated communities, as well as assess the effectiveness of government policies and tax incentives in promoting this energy source in Brazil. It would also be beneficial to explore the role of solar energy in combination with other renewable sources to optimize energy efficiency. In summary, this text clearly demonstrated that solar energy is a viable and strategic option for both economic growth and environmental

conservation in Ceará. Achieving established goals underscores the importance of government policies focused on expanding this clean energy source, ensuring that the benefits of using solar energy extend beyond the current scenario, fostering a more sustainable and inclusive future.

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