PHOTOVOLTAIC ENERGY: PERCEPTION OF PRODUCERS/CONSUMERS REGARDING THE ADOPTION OF ENERGY IN A CITY IN THE SOUTH OF THE STATE OF PARÁ

1.INTRODUCTION

The transition to a cleaner energy matrix is urgent in the face of climate change and natural resource scarcity. In this scenario, photovoltaic solar energy is a strategic alternative, especially in regions with high solar radiation potential. Despite its potential, the adoption of this technology remains limited by factors such as high initial costs, lack of technical information, bureaucratic obstacles, and the absence of financial incentives. In contrast, benefits such as savings on energy bills, increased property values, energy autonomy, and environmental contributions reinforce their economic, social, and environmental relevance.

Energy sustainability has gained prominence on the global stage because of the growing demand for cleaner and renewable energy sources. In this context, photovoltaic solar energy presents itself as a promising option, particularly in areas with high solar radiation potential, such as cities in the southern region of Pará. However, the adoption of this technology depends not only on technical and economic conditions, but also on how consumers perceive it in relation to its benefits, challenges, and effects on the environment.

It is a fact that the adoption of residential photovoltaic systems by the population contributes to the country's clean energy production, as well as sustainable practices in its production. Thus, this research seeks data that enable an understanding of the factors (economic, environmental, or social) that are leading people to increasingly use this technology. Photovoltaic solar energy has been considered a strategic option to diversify Brazil's energy matrix and reduce environmental damage in response to the growing demand for cleaner and more sustainable energy sources (Brito, 2023). The weather conditions in cities in the southeast of Pará are highly conducive to solar power generation, with high levels of radiation throughout most of the year. Despite this potential, the adoption of photovoltaic systems remains limited, raising questions about how consumers view this technology and what obstacles prevent its implementation.

The decision to invest in solar panels is not determined solely by technical and financial aspects but also by how consumers understand their advantages and challenges (Payel et al., 2023). Factors such as high initial costs, lack of understanding of how the system works, doubts about the durability of the equipment, and lack of accessible financial incentives can negatively affect the intention to adopt. Conversely, factors such as lower energy bills, increased property value, and contribution to the environment can encourage this choice. Understanding this perception is essential for developing strategies that promote the adoption of sustainable technologies in the area.

2.THEORETICAL FOUNDATION

Increased awareness of climate change, depletion of natural resources, and growing demand for energy have fueled discussions on energy sustainability. In this sense, the implementation of photovoltaic solar panels has been considered a practical and strategic alternative to diversify Brazil's electricity matrix, reduce greenhouse gas emissions, and encourage the use of clean and renewable sources.

The oil crisis of the 1970s served as an important starting point for discussions on the need for alternative energy sources, as stated by Godinho et al. (2022). From that moment on, mainly as

a result of the 2001 water crisis, Brazil began to promote policies that prioritized sustainable sources, such as photovoltaic solar energy, which is considered inexhaustible from a human perspective (Mahmoud, 1990 apud Godinho et al., 2022).

In addition to reducing environmental impacts, photovoltaic solar energy can meet the needs of remote areas, encourage energy self-sufficiency, and boost local economic growth in developing countries. Brito et al. (2023) point out that, after repeated shocks in the electricity sector, this form of energy has become strategic, benefiting from technological progress, cost reductions, and policies such as ANEEL Normative Resolution 482 (2012), which allowed for distributed micro and mini generation. Although there are benefits, consumer perception remains a crucial factor in the adoption of this technology. According to Alves and Silva (2021), although companies in the sector understand the concept of sustainability, there are weaknesses in relationships throughout the supply chain, which can impact consumer confidence. This demonstrates that sustainability transcends technical aspects, encompassing communication, accessibility, and awareness.

The study conducted by Oliveira (2023) highlights that solar energy is no longer a promise for the future but a current necessity, especially considering the environmental damage caused by non-renewable sources. She emphasizes that, despite the initial investment in the installation of solar panels, it still represents an obstacle for many consumers. The long-term advantages, such as reduced energy bills, minimal maintenance, and long system life, are favorable aspects that affect perception and purchasing choices. Another important aspect is the environmental impact that has been avoided. According to Godinho et al. (2022), between 2015 and 2021, there was a considerable decrease in carbon dioxide emissions related to energy production, a direct consequence of the growth of solar energy in the electricity matrix. During this period, the replacement of fossil fuels with solar energy prevented the emission of tons of CO_2, contributing to the UN's 2030 Agenda for Sustainable Development Goals. This is especially relevant for SDG 7, which refers to clean and affordable energy sources.Despite this promising scenario, challenges remain. Brito et al. (2023) indicated that the economic viability of solar systems is influenced by factors such as climate and regional tariffs. However, in other regions, it may be less viable, which directly affects consumer perceptions of the cost-benefit of the investment.

Energy sustainability is a principle that concerns the constant supply of energy in a safe, effective manner with minimal environmental impact. According to Alves and Silva (2020), "sustainability and sustainable development are related to economic development that does not harm nature and future generations," which means that energy must be considered a resource to be exploited responsibly and with a long-term vision. This principle is also linked to the Triple Bottom Line concept, which deals with three interdependent dimensions: economic, social, and environmental (Elkington, 2002).

In this scenario, solar energy is a promising option. It is a clean, renewable, and abundant resource. Ribeiro (2008) emphasized that solar energy is becoming increasingly important "due to the need to use new renewable energy sources," especially considering the predominance of non-renewable sources that intensify environmental management. Energy production using solar panels can be achieved through two fundamental processes: thermoconversion and photoconversion.

The adoption of solar panels by consumers involves various factors. Undoubtedly, environmental concerns are an important motivation, but they are not the only one. According to Teixeira et al. (2011), "the motivation lies in demonstrating the technical and economic strategy of implementing the system," particularly when considering long-term investment. According to Alves and Silva (2020), sustainable practices are being progressively integrated into supply chains,

driven by public policies and government incentives that seek to consolidate external institutional structures focused on sustainability. It is important to note that high initial costs, considered the most critical barrier in emerging economies (Payel et al., 2023), are exacerbated by the lack of accessible credit lines.

In Duranay's (2023) study on fault detection in solar energy systems, a detailed analysis of the effectiveness of a hybrid approach was presented. This approach integrates the Efficient Net-B0 convolutional neural network model with the neighborhood component analysis (NCA) feature selection technique and Support Vector Machine (SVM) classifier. This combination of deep learning and machine learning techniques has enabled the optimization of the defect detection process, achieving a remarkable accuracy of 93.93% in identifying 12 different types of faults in photovoltaic panels, based on thermal images obtained by drones. In this scenario, the use of thermal images provides a strategic advantage by enabling the remote, agile, and reliable inspection of extensive solar generation areas, thereby reducing the demand for manual intervention.

In assessing the technical and economic feasibility of photovoltaic systems, Guimarães, Guimarães, Nascimento (2025) provide solid evidence that adopting this technology can reduce operating costs by up to 77.5%. The average payback period ranges from 4 to 7 years, depending on climatic conditions and user consumption patterns. The authors highlight that consumers with high continuous energy consumption represent a particularly favorable scenario for the adoption of solar energy, as they can reduce costs and increase their energy autonomy. In view of the aforementioned demands, economic expansion, often driven by automation, combined with increasing urbanization, has intensified the need for more robust energy sources. In a scenario marked by global climate challenges, it is imperative to seek sustainable energy solutions that meet the contemporary demands for consumption and environmental preservation.

Despite the significant solar potential, access to quality energy at affordable prices remains an obstacle for a significant part of the population. In several urban and rural areas of the municipality, the high costs of electricity charged by utilities have sparked growing interest in more viable and sustainable energy alternatives (Teixeira et al., 2011; Godinho, 2022; Guimarães, Guimarães, and Nascimento, 2025). Solar panels have emerged as an interesting alternative, although the initial cost remains an obstacle for many residents. Thus, several consumers are driven to become not only users but also producers of energy, due to two factors: the abundance of sunshine throughout most of the year and dissatisfaction with high electricity prices. For these residents, adopting solar technology means a chance for energy independence and household savings, although a lack of technical knowledge and financial support may delay this choice.

In contrast, consumers view solar energy as a means of achieving energy independence, reducing long-term electricity costs, and increasing property values. However, obstacles prevent the expansion of this technology. High initial costs, bureaucracy in connecting to the electricity grid, and lack of technical information are among the main obstacles. Teixeira et al. (2011) pointed out that although technical feasibility has been demonstrated in contexts such as the city of Belo Horizonte, the implementation of the hybrid system (utility + solar) still faces economic and structural obstacles.

However, there are considerable advantages. In addition to saving on electricity bills, the use of solar panels contributes to reducing the carbon footprint, encourages the decentralized use of energy, and alleviates pressure on public grids, especially during peak hours. According to CRESESB (2006), this is one of the technologies that has progressed the most in recent decades, both in terms of efficiency and specifications for residential installations.

However, this transition is not uniform. While some social groups have greater purchasing power and easier access to financing, others face structural and educational difficulties that prevent them from adopting more sustainable alternatives. Therefore, understanding consumer perceptions must consider not only technical and economic aspects but also distinct social, cultural, and educational realities. Thus, analyzing consumer behavior in this context allows us to understand the local challenges of consolidating a cleaner and more democratic energy matrix. This reinforces the importance of public policies aimed at energy inclusion and initiatives that value the use of renewable sources in an accessible and fair manner for the entire population, especially in regions with high solar potential.

Therefore, consumers' perceptions of solar panel use encompass several dimensions: financial, environmental, social, and institutional. The creation of a sustainable energy culture in Brazil, especially in cities in the interior of the states, requires greater access to information, government incentives, investment in research, and a transformation of the collective mindset regarding energy production, consumption, and valuation.

3.METHODOLOGY

This is a mixed-methods study because, according to Creswell et al. (2021), it seeks to explain phenomena in greater depth and clarity by combining quantitative methods (numbers) with qualitative methods (questionnaires, interviews, observations) in the same study to better understand the phenomenon. Thus, the elements that influence the decision of producers/consumers in a city located in southern Pará regarding the implementation of photovoltaic energy systems in their homes were assessed. In addition, we sought to understand the producers' and consumers' perceptions of their contributions to sustainable energy practices and the challenges they face. Producers/consumers are some of the subjects of this research, that is, people who have installed photovoltaic energy systems in their homes, to produce clean energy and use it in their homes.

The data collection procedure was a *survey-type* study with convenience sampling. It is characterized by the collection of data from individuals who are easily accessible to the researcher, without the need for random selection or probabilistic criteria. This is because it seeks to obtain information directly (BABBIE, 1999) from producers/consumers, using structured instruments. The objective was to measure opinions and behaviors related to the adoption of photovoltaic energy systems. The aim is to obtain a comprehensive view of the phenomenon under investigation, enrich the analysis, and broaden the understanding of the factors that influence the decision to invest in solar energy.

Questionnaires and interviews with producers and consumers were used to collect data. Thus, this study was organized into two stages. First, data collection was carried out, beginning with interviews with some companies that sell solar energy generation systems to understand whether there is significant growth in the adoption of sustainable energy in the municipality. Subsequently, a questionnaire was administered to producers/consumers to collect information on the implementation of photovoltaic energy systems, seeking to identify aspects such as economic access to the technology, ease of implementation in their homes, and perception of the financial return obtained after installation.

4.ANALYSIS AND RESULTS

Regarding the implementation of photovoltaic energy systems, the research provides a better understanding and perspective of producers/consumers of photovoltaic solar energy.

Table 01 - Statement of producer/consumer perception regarding the implementation of photovoltaic solar energy in their homes

Analysis	Producer/consumer	Number
Knowledge of the technology	Superficial knowledge of technology	50%
	Technical mastery of the technology	20%
	No understanding	30%
Motivating factor for implementing	Implemented technology for economic reasons—reduction in electricity	70%
	Implemented for economic and environmental reasons	30%
Challenges faced in implementing	High initial cost for installation	60%
	Lack of information about credit lines	40%

Source: authors, 2025

Approximately 50% of consumers have only superficial knowledge of how the systems work, possessing only basic concepts of energy generation, components, and installation. However, only 20% have a more advanced technical understanding, covering issues related to efficiency, maintenance, and connection to the electrical grid.

In terms of perceived benefits, approximately 70% of respondents associated solar energy with lower electricity bills, highlighting the economic aspect as the main motivator. However, only 30% explicitly recognized its contribution to environmental sustainability and reduced carbon emissions, revealing a limited view of technology's potential.

In terms of barriers, more than 60% of participants cited the high initial installation cost as the main obstacle, while approximately 40% mentioned the lack of information about credit lines, tax benefits, and return on investment.

Regarding the growth of photovoltaic solar energy in the municipality, from the perspective of companies that sell and install solar panels in homes:

Companies point to a certain discrepancy between the intentions and actions of future consumers/producers, i.e., among all those who seek out the company, approximately 75% express interest in adopting solar energy in the future, of which 30% seek specific information or request quotes. This demonstrates a mismatch between the intention and implementation. Finally, they point out that approximately 80% of consumers show little or no knowledge of public policies and regulations related to solar energy, such as incentive programs or energy compensation systems. This result reinforces the need for greater information dissemination, more accessible support policies, and awareness-raising actions that encourage the democratization of photovoltaic energy.

5 CONCLUSIONS

The analysis of producers' and consumers' perceptions of photovoltaic systems shows that solar energy is widely valued, especially for its economic benefits, with emphasis on the significant reduction in electricity costs. However, a significant portion of the population still has limited knowledge of the technical and environmental aspects related to this technology, highlighting the urgent need for actions aimed at raising awareness and disseminating accessible and informative information.

Among the main obstacles identified are the high initial installation cost, scarcity of information on financing options and tax incentives, and lack of clarity regarding public policies

aimed at promoting solar energy. Simultaneously, the survey revealed considerable interest in the future adoption of this technology, although this intention does not always materialize, highlighting a gap between desire and practical implementation.

Given this context, it can be concluded that photovoltaic solar energy has high potential for expansion, provided that effective incentive strategies are implemented, combined with transparent disclosure of data on costs, benefits, and economic viability. Democratizing access to solar energy not only promotes energy autonomy for consumers but also contributes significantly to boosting sustainable development in the region.

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