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# Solar Energy: Profile and Analysis of Rural Producers' Satisfaction in the Municipality of Três Passos, Rio Grande do Sul

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## ABSTRACT

Electricity is an essential and necessary resource for every human being. In Brazil, hydroelectric power plants are an option for energy production, but they generate environmental impacts, in addition to flooding large areas; therefore, it is necessary to seek less aggressive alternatives. Solar energy emerges as an alternative, as it generates a lower negative environmental impact. Thus, the objective of this study was to assess the profile and satisfaction of rural producers in the municipality of Três Passos, Rio Grande do Sul, with the solar energy generation system. Ten rural producers in the municipality were interviewed using a qualitative-quantitative questionnaire. The results showed that most producers are older (over 40 years old), are family farmers (up to 20 ha), and own their own land. Furthermore, the rural producers interviewed are very satisfied with the installed solar energy generation system, mainly due to the reduction in electricity bill costs, and indicate that they would make the investment again. The study concludes that solar energy is a viable source of power, with a high degree of satisfaction among rural producers, as it allows for cost reductions on the property.

**Keywords:** family farming; electricity; renewable energy.

## Introduction

Electricity is an indispensable and essential resource for every human being. In Brazil, the total installed energy production capacity in rural areas was 397.3 MWp as of 2020, corresponding to 14% of the country's total installed capacity; it is possible to infer an upward trend in rural areas due to the mechanization of agricultural activities (Dutra et al. 2022). However, current production systems generate numerous negative environmental impacts, which has driven the adoption of alternative systems to meet the high demand for electricity in the country (Brancher et al. 2025).

As an alternative, renewable energy sources have emerged, which generate less negative environmental impact, serve as a source of growth, development, and economic sustainability, and benefit the environment; in Brazil, hydroelectric plants are an option; although renewable, their installation and operation generate significant environmental impacts, in addition to large flooded areas, making it necessary, therefore, to seek methods that are less harmful to the environment (Ferreira et al. 2018; Brancher et al. 2025).

Among many systems, photovoltaic solar energy can meet the energy needs of rural producers by powering automated systems; it can also reduce the property's electricity bill and even generate electricity where there is no distribution grid (Claca et al. 2021).



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In order to establish regulations and laws to govern the sector, in 2012, the National Electric Energy Agency (ANEEL 2012) issued Normative Resolution No. 482, which aimed to “establish the general conditions for the access of microgeneration and minigeneration to electricity distribution systems and the energy compensation system.”

Therefore, this resolution enabled the use of energy exchange systems, where consumers are permitted to acquire grid-connected photovoltaic generators. Thus, it is possible for the installation at the consumer's site to offset energy with the local power distribution grid depending on the demand used on the property (ANEEL 2012).

## Theoretical Framework

### *Environmental Impacts of Unrestrained Energy Consumption*

Electricity consumption in Brazil is shaped by large-scale energy production, which results in significant environmental consequences. Energy generated by hydroelectric plants remains of paramount importance worldwide. However, these plants entail high costs in various areas, including environmental, social, and economic impacts. Among the environmental impacts caused by hydroelectric plants are: alteration of the hydrological regime; compromised water quality, which hinders the decomposition of tailings and effluents; siltation of reservoirs, deforestation, removal of riparian vegetation, greenhouse gas emissions, overpressure on the soil and subsoil due to the weight of the dammed water, public health issues, including the proliferation of vectors transmitting endemic diseases, etc. (Silva et al. 2025).

Global threats to the environment, the lack of human care and interest in these issues in general, and the various studies and facts highlighting ecosystem problems are some of the factors driving the search for strategies to conserve and preserve life and the ecosystem. These factors highlight the current neglect evident in the relationship between humans and the environment. Therefore, obstacles and factors that influence the evolution of humanity in conjunction with the ecosystem persist (Tatagiba 2023; Brancher et al. 2025).

When compared to electricity generated from fossil fuels, such as coal, renewable energy is an effective tool in the fight against global warming. In this regard, it is worth highlighting the local specificity of where energy production can be developed, reducing dependence on large energy producers, and promoting job creation and economic development (Brancher et al. 2025). Furthermore, it is considered a key tool in reducing greenhouse gas emissions and combating global warming (Tatagiba 2023).

### *Renewable Energy*

Renewable energy is a type of energy generated through natural processes, which are naturally replenished or regenerated through human intervention. Thus, it produces energy, and among the main types of renewable energy are wind, hydro, biomass, and solar energy (Corrêa et al. 2020).

The use of renewable energy aims to preserve and maintain the environment so that future generations can enjoy the same space without it being harmed. Electricity, generated by sunlight, is a form of energy that can be replenished, causes little harm to nature, and does not deplete the raw materials we so desperately need (Brancher et al. 2025).

### *The Benefits of Using Solar Energy*

Traditionally, Brazil has relied heavily on hydroelectric power for electricity generation; however, as a result of energy crises, particularly the 2001 “blackout,” numerous efforts are underway to diversify the energy mix. According to the National Energy Balance Summary Report (BEN 2025), the domestic energy supply from hydroelectric plants in 2023 was 37.90%, but it decreased by 1.7% compared to 2024 figures, reaching 37.3%. Solar energy, on the other hand, rose from 5.4% to 7.2% during the same period, representing a 33.2% increase.

Despite its current modest share in the energy mix, solar energy has high growth potential in the country. It is important to note that, even though it represents a small share in absolute terms, solar energy has great potential for expansion and development, given the favorable sunlight conditions across the country. Germany, which has half of Brazil's solar energy potential, derives 12% of its energy mix from solar power; moreover, this percentage was virtually nonexistent a decade ago, becoming possible thanks to the decline in the cost of this energy, which fell by 89% over 10 years (BEN 2018).

One of the main advantages of using solar energy, according to Dassi (2015), is decentralization, as it is possible to generate energy at home; however, few studies have been conducted to date to understand potential



obstacles and challenges of the system. Given the above, studies on this topic are highly relevant for assessing the evolution and level of satisfaction with energy production systems in the Northwest region of Rio Grande do Sul.

### ***The benefits and challenges of using solar energy in rural areas***

According to Silva et al. (2026), access to energy is a fundamental element for the social, economic, and productive development of rural communities, especially in regions characterized by infrastructure limitations and inequalities in energy supply. In this context, solar energy emerges as an excellent alternative.

According to Franscisco et al. (2024), photovoltaic energy allows rural communities to access electricity in a reliable and affordable manner, overcoming the limitations of the electrical infrastructure; this drives local economic development. Furthermore, according to the authors, solar energy reduces dependence on fossil fuels, contributing to climate change mitigation and environmental preservation (Franscisco et al. 2024).

The technical and economic viability of these systems still raises doubts among producers. To address certain concerns, Kruger et al. (2023) analyzed the economic and financial viability of photovoltaic solar energy as a cost-reduction alternative on a rural property in Santa Catarina through exploratory research conducted at a poultry farm located in the western part of the state; the authors concluded that the implementation of solar photovoltaic energy as an alternative for cost reduction and energy diversification was feasible during the study period.

Furthermore, Silva et al. (2026) analyzed the main sources of renewable energy used in rural communities, as well as the challenges, barriers, and prospects associated with their adoption. The results indicate that solar photovoltaic energy, biomass, biogas, and small-scale wind energy are among the main sources used in rural communities, due to their adaptability to local conditions and their potential for energy self-sufficiency.

However, according to Silva et al. (2026), some obstacles are significant, such as high initial implementation costs, limited access to credit, a lack of technical training, regulatory barriers, and the discontinuity of public policies. Despite these barriers, the authors observed positive prospects for the expansion of renewable energy in rural areas, driven by technological advances, cost reductions, strengthened incentive policies, and growing environmental awareness.

Given the numerous uncertainties, potential benefits, technical and economic feasibility, and challenges of implementing solar energy systems, this study aimed to assess the profile and satisfaction of rural producers in the municipality of Três Passos, Rio Grande do Sul, with solar energy generation systems.

### **Materials and Methods**

Três Passos is a Brazilian municipality located in the northwestern region of the state of Rio Grande do Sul. It has a population of approximately 25,692 inhabitants, and its economy is based on agriculture, livestock, and commerce. The municipality is known for being a major hub for grain production, particularly soybeans, corn, and wheat. Additionally, the region is a producer of milk and meat, with a focus on pork and poultry production (IBGE 2025).

The methodology used to conduct this research involved a literature review and field research to clearly achieve the research objectives.

To obtain information regarding the profile of farmers and the adoption of solar energy generation systems, theoretical data was collected through a literature review of academic articles. Subsequently, field research was conducted to gather additional information aimed at fulfilling the objectives of this study.

Field data collection was conducted using a qualitative-quantitative questionnaire administered to residents of the districts of Três Passos (Três Passos, Alto Erval Novo, Bela Vista, Floresta, Padre Gonzales, and Santo Antônio) who have solar power generation systems. The interview was conducted with two residents from each district living in the rural area of the municipality of Três Passos, who decided to invest in and begin using this method of energy production in conjunction with the rural property's production system.

Prior to the research, the interviewees were informed about the study's content and, after agreeing, signed the informed consent form. Subsequently, the interview proceeded with questions covering both open-ended and closed-ended topics such as: education level, age, gender, property size, activities carried out on the property, time since installation of the solar power generation system, reason for installation, need for a loan, financing, or personal funds for installation, number of panels, average reduction in the energy bill, benefits of the system, environmental impact of the solar power generation system, satisfaction, among others.



After data collection, a comparative analysis was conducted of the scenarios experienced before and after the implementation of the solar power generation system. The results obtained were tabulated, presented in figures and tables, and discussed.

## Results and Discussion

In this study, interviews were conducted with ten families residing in rural districts of the municipality of Três Passos. Two families were randomly selected per district, provided they had a solar power generation system installed.

During the field research in the rural districts of the municipality of Três Passos, it was noticeable that the majority of owners were older, with 60% of respondents aged 40 or older, while the remainder were aged 30–40 and 20–30, each group accounting for 20% (Figure 1).

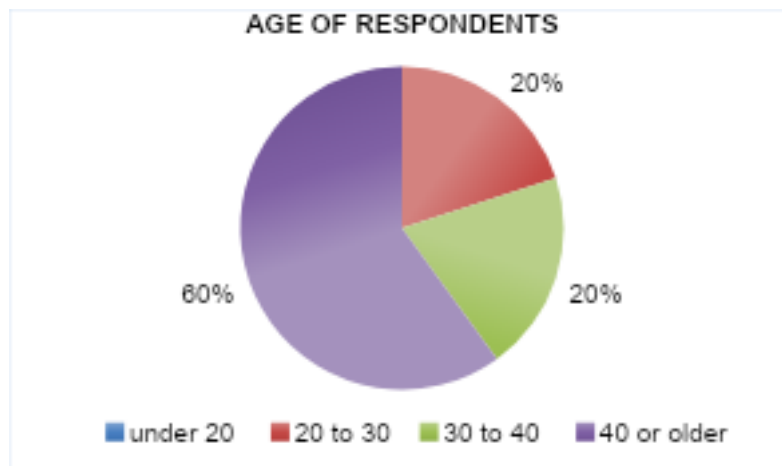


Figure 1 - Age group of rural producers with installed solar power generation systems interviewed in the municipality of Três Passos/RS. Source: Prepared by the authors (2025).

The older age of the rural population is not unique to the municipality under study but is generally observed in various locations across southern Brazil, as inferred by Ostwald et al. (2022).

Other studies indicate that this phenomenon can be explained by the vulnerability of family farmers, especially due to the scarcity of natural, physical, human, social, and financial resources, which result in rural exodus among young farmers (Aquino; Gazolla; Schneider 2018).

In the present study, all respondents own their own land and can be classified as family farmers, as they have an area of less than four fiscal modules, that is, less than 20 ha.

When analyzing the respondents' sources of income, dairy production, grain production, and pig farming stand out (23.1%), followed by other activities with a frequency of 7.7% (Figure 2) (data include duplicates, as many properties engage in more than one activity).

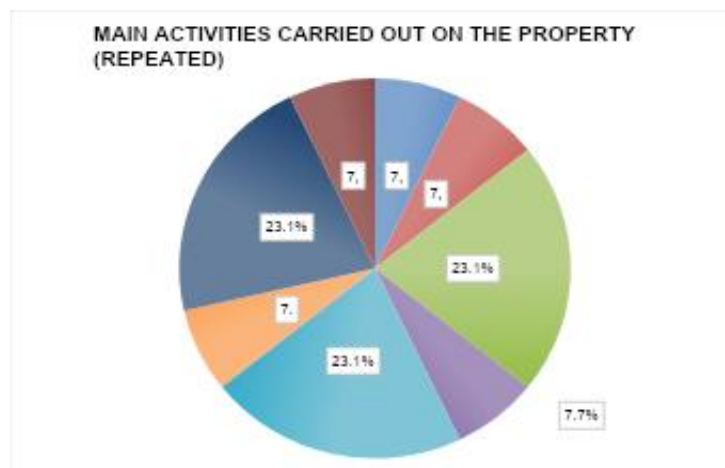


Figure 2 - Main activities carried out on the farms by the rural producers interviewed in the municipality of Três Passos, Rio Grande do Sul. Source: Prepared by the authors (2025).



The data obtained regarding production and livestock systems on the farms under study corroborate other studies that suggest that the northwestern region of the state of Rio Grande do Sul is characterized, in terms of grain production, as a producer of soybeans, corn, and wheat. These three grains play a fundamental role in the diet of millions of Brazilians. Soybeans are traditionally used in the production of vegetable oil and animal feed; however, their nutritional potential and ability to help reduce the risk of chronic and degenerative diseases have increased their consumption (EMBRAPA 2010).

Corn is used as the primary energy source in the formulation of diets for poultry and swine in Brazil, comprising up to 80% of these diets (EMBRAPA 2011). In human food, currently, only about 5% of Brazilian production is destined for this purpose, and even then, indirectly, as part of other products. For wheat, cultivars have been developed for various uses, such as the production of bread, pasta, crackers, and cookies, as well as varieties intended for animal feed, whether in the form of grains or preserved forage (EMBRAPA 2023). Therefore, the focus on grains is associated with their multiple uses.

Pig farming in Brazil is predominantly carried out on small rural farms. Approximately 81.7% of pigs are raised on farms of up to 100 hectares. This activity is present on 46.5% of the 5.8 million farms in the country, typically employing family labor and serving as an important source of income and social stability (IBGE 2025). Similarly, milk production is noteworthy in the northwestern region of the state (Braum et al. 2024).

When asked about the duration of solar energy system use on their properties, it becomes evident that these systems are relatively recent (Figure 3), where it is observed that the oldest systems were installed about five years ago (four respondents), while the others are even more recent.

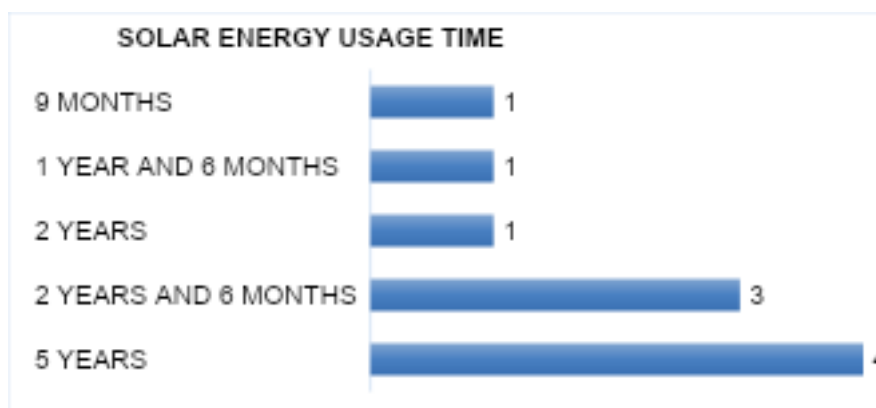


Figure 3 - Duration of solar energy system use by rural producers interviewed in the municipality of Três Passos, Rio Grande do Sul. Source: Prepared by the authors (2025).

Energy derived from fossil fuels played a major role during the 20th century, especially with the emergence of gasoline- and diesel-powered automobiles. Later, in the 1970s, the oil crisis highlighted the need for alternative energy sources (Losekann & Hallack 2017), making it a relatively recent development in society.

The market for solar energy installations has grown significantly over the past decade, especially in the last three years, with substantial annual increases exceeding 50 GWp per year (BEN 2025).

In recent years, with growing global concern over the environmental impacts caused by the use of non-renewable energy and the side effects of the greenhouse effect, renewable energy has become a priority on the international agenda and in Brazil. Thus, there has been a greater adoption of alternative energy sources, such as wind and solar power, with the latter deserving special mention (Losekann & Hallack 2017).

In this study, when investigating the reason that led producers to acquire this production system, all interviewees stated that the main objective is to reduce the property's electricity bill. This can be explained, in part, by the National Compensation System, since the financial return on investment is related to the price the consumer would pay for energy if they consumed it from the grid. Thus, the return is greater for those who pay higher rates (Losekann & Hallack 2017).

According to data from the National Energy Balance (BEN 2025) on the profile of those interested in installing distributed solar energy, there is a concentration of high-income individuals whose monthly electricity bill exceeds R\$ 200.00 (75% of those requesting quotes) and who own the properties (85% of those requesting quotes).

When respondents were asked about the source of funds for implementing the system, the results are presented in Figure 4, where 40% used financing; 30% reported that the purchase was made with their own



funds; 20% through loans; and 10% via a combination of financing and their own funds—that is, part of the investment amount came from their own funds and part was financed.

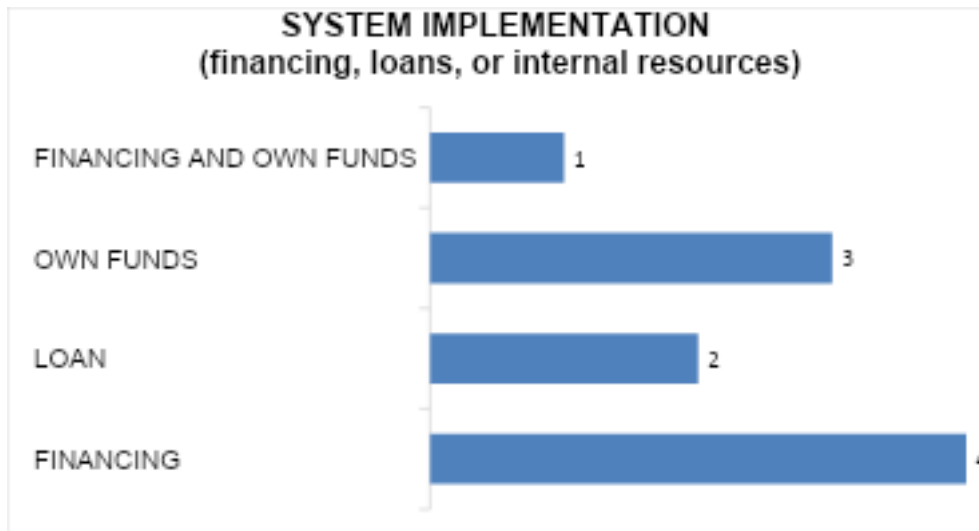


Figure 4 - Source of funds for the implementation of the solar energy system by rural producers interviewed in the municipality of Três Passos, Rio Grande do Sul. Source: Prepared by the authors (2025).

The respondents reported some difficulties, such as: 10% of the respondents stated they had encountered problems installing the system (“Difficulty finding qualified personnel for installation”), and 10% stated they had needed to perform maintenance on the system due to technical installation issues.

Regarding the environmental impact of adopting this system, controversial results emerged, with 50% of respondents reporting that using this system makes it possible to produce clean energy, which is beneficial for the environment. Meanwhile, 10% reported a negative impact, stating that the production of panels will be harmful when the time comes to dispose of them, and another 40% did not know how to respond.

Although they have a long life cycle, photovoltaic cells eventually reach the end of their useful life. Since most contain silicon in their composition, there is currently a strong warning about the need for proper disposal, raising a major question regarding the environmental impact of this waste. In addition to silicon, photovoltaic cells also contain glass, aluminum, and semiconductor material, which have an efficient recycling rate of 97% in the production of new silicon-free panels (Ferreira et al. 2018).

The recycling of photovoltaic panels is still ineffective, focusing primarily on the reuse of semiconductor materials. It is of utmost importance to invest in new research and technologies to recycle all the material from the panels and reduce the costs of the process.

The disposal of this material and the need for recycling open the door to a new market, which, according to some authors, could generate billions of dollars. It is estimated that by 2050, China will have 13.5 million tons of photovoltaic waste. This issue demands urgent attention, while there is still time to prevent the accumulation of tons of panels awaiting recycling and a solution (Esposito & Fuchs 2013).

For solar energy to be considered entirely clean, it is essential to ensure that photovoltaic panels are properly recycled and disposed of. Currently, companies that supply photovoltaic panels are responsible for their final disposal, but there is still a problem of improper disposal and low recycling rates for their components (Oliveira et al. 2017).

Improper disposal can contaminate the soil and cause health problems due to the release of toxic substances, thus requiring a special disposal process associated with recycling (Coelho & Serra 2018). It is also important to consider waste and the possibility of recycling materials that could be reused in new panels or in the composition of other products (Dias 2015).

Regarding the number of solar panels installed and the financial return on investment, results vary widely, as each property has a different number of panels as well as specific costs. In general, the responses indicated a cost reduction of 70% to 100% of the excess amounts, with a monthly reduction of up to R\$3,500.00, as reported by the producer with the highest number of panels (Table 1).



Table 1 - Number of solar panels on the property and time (years) required to recoup the investment.

Interviewee	Number of panels	Payback period (years)
1	18	3
2	18	3
3	20	3.5
4	20	4
5	26	4
6	30	5
7	40	5
8	46	6
9	64	7
10	85	10

Source: Prepared by the authors (2025).

When assessing producer satisfaction, 80% reported being very satisfied and 20% satisfied with the system. When asked if they would recommend adopting this type of system, all respondents reported that they would recommend it to other producers and would purchase it again at current prices. Some statements were transcribed and can be viewed below:

“I’m satisfied, and I hope more families can install it.”

“It’s a worthwhile investment.”

### Final Considerations

The ten producers interviewed in the municipality who installed the solar power generation system are older in age, are family farmers, and own their own land.

The use of solar power generation systems as a source of energy is highly valuable for application on different properties and in various production systems.

- Monthly energy costs can be significantly reduced.
- The project’s economic viability is positive, with a return on investment expected within a few years.
- Producers’ satisfaction with the solar power generation system is high.

Therefore, in addition to being a highly efficient energy source, solar energy is clean, as it is a renewable and inexhaustible resource and causes minimal environmental damage if waste and panels are properly recycled.

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