Artículos

The Adoption of Solar Photovoltaic Systems in Rural Areas of Brazil

La Adopción de Sistemas Solares Fotovoltaicos en Áreas Rurales de Brasil

Adoção de Sistemas Solares Fotovoltaicos em Áreas Rurais do Brasil

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Abstract: The aim of this study was to categorize the perceptions regarding the benefits and the barriers of solar photovoltaic (PV) systems in rural areas. Responses were collected through a questionnaire, answered by 116 Brazilian farmers. These respondents have farms located in the state of Minas Gerais, which is the Brazilian state with the large installed potency for PV energy. On one hand, the main results indicate that few farmers of the sample already use solar energy at their rural properties; respondents consider environmental issues and cost saving as the main benefits related to solar energy. On the other hand, the majority of the respondents informed that they intend to use PV systems in the future.

Keywords: Photovoltaic Energy, Sustainable Energy, Solar Systems, Rural Electricity.

Resumen: El objetivo de este estudio fue categorizar las percepciones acerca de los beneficios y las barreras de los sistemas solares fotovoltaicos (PV) en áreas rurales. Las respuestas fueron recogidas a través de un cuestionario, respondido por 116 agricultores brasileños. Estos encuestados tienen fincas ubicadas en el estado de Minas Gerais, que es el estado brasileño con la mayor potencia instalada de energía fotovoltaica. Por un lado, los principales resultados indican que pocos agricultores de la muestra ya utilizan energía solar en sus propiedades rurales; los encuestados consideran las cuestiones medioambientales y el ahorro de costes como los principales beneficios relacionados con la energía solar. Por otro lado, la mayoría de los encuestados informaron que tienen la intención de utilizar sistemas fotovoltaicos en el futuro.

Palabras clave: Energía Fotovoltaica, Sostenibilidad Energética, Sistemas Solares, Electrificación Rural.

Resumo: Neste estudo, categorizaram-se as percepções sobre os benefícios e as barreiras dos sistemas solares fotovoltaicos (PV) em áreas rurais. Os dados foram coletados por meio de um questionário, respondido por 116 agricultores brasileiros. Esses respondentes possuem fazendas localizadas no estado de Minas Gerais, que é o estado brasileiro com maior potência instalada de energia fotovoltaica. Por um lado, os principais resultados indicam que poucos agricultores da amostra já utilizam energia solar em suas propriedades rurais; os entrevistados consideram as questões ambientais e a economia de custos como os principais benefícios relacionados à energia solar. Por outro lado, a maioria dos respondentes informou que pretende utilizar sistemas fotovoltaicos no futuro.

Palavras-chave: Energia Fotovoltaica, Energias Sustentáveis, Sistemas Solares, Eletricidade Rural.

1. Introduction

The development and maintenance of a modern society require access to energy (Adoramola, Angelin-Chaab & Paul, 2014; Lima et al., 2017). Since the industrial revolution, the supply of electrical energy is one of the issues that governments must address (Camilo et al., 2017). Therefore, energy plays an important role for sustainable development (Khan, Khan & Binh, 2020) and energy supply must consider efficiency, reliability and environmental issues (Pinto et al., 2016). Renewable sources of energy have gained the attention of researchers and regulators. The demand for this type of energy increased in recent decades, especially in the current days (Khan, Khan & Binh, 2020).

Renewable sources of energy include solar, wind, biomass, geothermal and water (Devabhaktuni et al., 2013; Khoury et al., 2016; Lima et al., 2017). Solar photovoltaic (PV) energy is an extremely promising energy source, especially due to its possibility of being used in different places (Devabhaktuni et al., 2013; Sahoo, 2016; Lima et al., 2017). In addition, “the sun is a major source of inexhaustible free energy (i.e., solar energy) for the planet Earth” (Kabir et al., 2018, p. 894), a factor contributing to the expansion of photovoltaic systems worldwide. Another advantage is the use of non-productive areas to install and generate energy through Solar Panels, which allows the implementation of photovoltaic parks, for example.

A common structure and configuration of electric power systems worldwide involves “large plants located near places with easy access to primary energy resources and connected to a high-voltage meshed transmission network where substations feed radial distribution networks at lower voltages in order to reach final consumers” (Martín-Martinez, Sánchez-Miralles, Rivier, & Calvillo, 2017, p. 850). This traditional configuration (Camilo et al., 2017), known as centralized, does not allow bidirectional energy flows (Bertolini, Buso, & Greco, 2020), one of the main characteristics of a non-centralized structure.

The Distributed Generation (DG): i) allows cogeneration and massive participation of different players and business models in the market; ii) favors the implementation of renewable technologies; iii) helps to serve the electrical energy demands; iv) is associated to the solutions to reduce undesirable effects on the environment (Camilo et al., 2017; Martín-Martinez, Sánchez-Miralles, Rivier, & Calvillo, 2017). In this way, DG represents a “dramatic change” in the traditional configuration of electric power systems, where customers have a more active participation in both consumption and generation sides, allowing downstream and upstream flows, a new concept defined as smart grid (Martín-Martinez, Sánchez-Miralles, Rivier, & Calvillo, 2017). These communicating instruments (smart grids) allow the transmission of data related to the state of a network in real time (Clastres, 2011).

The DG is already regulated in Brazil, through normative resolutions 482 and 517 of ANEEL (ANEEL, 2012a; 2012b). ANEEL resolution 482/2012 allows customers to act as energy generators in their relationship with the distribution company (Camilo et al., 2017). In this way, the year 2012 represents a milestone for the DG in Brazil (Faria Jr. et al, 2017), especially considering that microgeneration should represent an important niche to expand photovoltaic solar energy in the country (Dantas et al., 2017).

Solar panels are nearly maintenance free, highly reliable, and contribute to the goal related to reducing carbon emissions and air pollution emissions (Harder & Gibson, 2011; Elnokaly & Martin, 2014). Such advantages justify the development of policies by governments to encourage the use of this source (Elnokaly & Martin, 2014). After-sales services and equipment quality/durability (Brunet et al., 2018; Garlet et al., 2019) play an important role in the acquisition of photovoltaic systems.

The diffusion of renewable energy sources is a challenge, and in rural areas their effective implementation can be more complex. Clausen and Rudolph (2020, p. 1) note that, "in recent years, rural areas have become significant battlegrounds for the implementation of energy transitions". The gap between urban and rural areas also has an effect at the country level, as the adoption of renewable energy sources considers the entire territory. Therefore, regulators and government need to understand their countries' internal idiosyncrasies at the regional level (including urban/rural differences) in order to develop policies and plan incentives. The dissemination of information related to photovoltaic systems is essential, addressing, for example, the Smart Grid and Off Grid differences, characteristics of distributed generation, the possibility of cost savings, among others. On these initiatives, Garlet et al. (2019, p. 165) comment that: "consumer culture and the lack of adequate knowledge about photovoltaic technology are presented as crucial barriers, indicating the importance of conducting educational campaigns that provide information on the benefits of this energy source."

The PV solar energy has also an important social role. For example, the PV industry in Brazil generated more than 130,000 jobs between 2012 and 2019 (ABSOLAR, 2020). Renewable energy systems usually are expensive (Khoury et al., 2016). Therefore, the absence of financial programs PV installation in rural areas is a factor that mitigates possible negative effect on investment in solar energy.

In Brazil, there are lines of credit created specifically to finance photovoltaic solar energy in rural areas, provided by different financial institutions; however, many rural entrepreneurs may not have access to information related to these lines of credit, which jeopardizes the diffusion of photovoltaic energy in rural areas. In addition, the lack of information related to the technical characteristics of photovoltaic systems, distributed generation and cost-related benefits can mitigate their adoption.

The relevance of clean energy, its role for Brazil and the different scenarios between urban/rural areas motivated the development of this study. The main purpose of this paper is to categorize the perceptions regarding the benefits and the barriers of photovoltaic energy systems by Brazilian farmers. The respondents of the sample are farmers that have farms located in the state of Minas Gerais, which is the Brazilian state with the large installed potency for photovoltaic, accounting for 19.4% (ABSOLAR, 2020). In addition, the agro-industrial sector has an important participation in the economy of Minas Gerais. In 2019, the Gross Domestic Product (GDP) of the agribusiness sector represented 36% of Minas Gerais' GDP (CEPEA, 2020).

Unlike EU countries where some of these barriers involve restructuring incentive policies already implemented for the use of photovoltaic – in some cases due to the high adherence to this technology (Elnokaly & Martin, 2014), in many other countries still there are not many incentives. The absence of incentives creates a potential for expansion of photovoltaic in those localities, especially at their rural areas. There is a great potential to expand photovoltaic energy in Brazil (Garlet et al., 2019); for example, in 2019, the photovoltaics were responsible for less than 2% of the energetic power installed (ANEEL, 2019). Taking into account Brazil's advantages related to solar irradiation, the installed capacity of grid-connected photovoltaics is still underrepresented in the country (Holdermann et al., 2014; Lima et al., 2017).

The penetration of solar energy in developing countries also faces challenges related to infrastructure, operations facilities and maintenance expertise (Khoury et al., 2016). There is a disparity between developed and developing countries regarding strategic investments related to renewable energy sources (Khoury et al., 2016), reinforcing the relevance of analyzing barriers to solar energy development in emerging economies. The disparity also exists between urban and rural areas: "Significant differences have been observed between the preferences of urban and rural communities" (Stigka, Paravantis & Mihalakakou, 2014, p. 105).

The contributions of photovoltaic were also noted by Shahsavari and Akbari (2018, p. 276), who stated that "solar energy technologies will address regional and local environmental issues, reduce poverty, greenhouse gas emissions and increment energy security." From this perspective, Sahoo (2016) observed the relevance of energy for rural development.

It is important to mention that in the context of rural areas there are some specific advantages provided by photovoltaic energy and fundamental for the production process and the quality of life of families in these areas, such as water pumping (Kazem, Al-Waeli, Chaichan, Al-Mamari, & Al-Kabi, 2017; Kumar, Hundal, & Kaur, 2019) and the planting process (Xue, 2017). These arguments reinforce the relevance of this research, which will address the use of photovoltaic energy in the context of rural areas.

Government incentives and policies play an important role for the growth of a particular type of renewable energy source (Carvalho, Wemans, Lima, & Malico, 2011). The development of smart grids is closely linked to market liberalization and requires long term strategies and policies, as it affects the entire market, its players and competition (Bertolini, Buso, & Greco, 2020).

2. Literature Review

Energy is a vital element for the progress of any country; because of this, one of the priorities of developing economies is to ensure energy supply to promote development and economic growth (Raghuwanshi & Arya, 2019). Khoury et al. (2016) have shown that renewable energy sources, such as solar, are highly efficient and a good solution to the energy crisis, which are common in many developing countries, as they generally have renewable resources in abundance.

With the intention of expanding the use of renewable sources of energy, many countries have promoted policies with incentives for their adoption. Sarasa-Maestro, Dufo-López and Bernal-Agustín (2013) analyzed these incentives in the Union European countries. They concluded that the most widely used incentive program is the feed in tariffs, which focuses on manufacturing and installation costs. Other relevant programs identified include green certificates, fiscal support and investment incentives; however, other studies highlight the need for policies that provide confidence to investors and address remaining barriers (Campisi, Morea & Farinelli, 2015).

Regarding solar energy in developing countries, Garlet et al. (2019) analyzed the scenario of the photovoltaic energy sector in southern Brazil, identifying the barriers that compromise the adoption and distribution of this technology in that country. Based on interviews with industry professionals and other related actors, the authors noted that the main obstacles come from technical, economic, social, political and managerial issues (Garlet et al., 2019). Additionally, Carstens and Cunha (2019) addressed the challenges and opportunities for the growth of photovoltaics in Brazil. Among the challenges, they cited the lack of information and dissemination of knowledge about technology, financial constraints and subsidies dedicated to supporting the industry, the limitation of the market in terms of number of companies operating in the sector and low technical professional skills.

According to Garlet et al. (2019), photovoltaic energy systems lose efficiency in Brazil due to the installation of photovoltaic systems, which often occurs without the support of qualified professionals, because, due to their advanced technology, there are few qualified human resources available, thus compromising the proper implementation and maintenance of the systems (Garlet et al., 2019). Brunet et al. (2018) add that in developing countries photovoltaic energy systems are inefficient, because the equipment used is, usually, unreliable and has inadequate support services, since low incomes make it difficult to acquire high-performance equipment.

Similarly, Padmanathan et al. (2019) conducted a survey to identify people's perceptions and acceptance of PV systems in India. Their results indicated that India has similar problems to Brazil, as evidenced by Garlet et al. (2019), regarding barriers to the development and use of photovoltaics, as social, economic, technical and governmental difficulties were also present.

Rodríguez-Urrego and Rodríguez-Urrego (2018) analyzed the state of development and future prospects of photovoltaics in Colombia. They pointed out that although the country has great potential to generate this type of energy, due to its natural characteristics that allow high levels of solar radiation, three main elements limit the development of photovoltaic technology The first concerns institutional policies, which involve standardization, legal barriers and government incentives. Secondly, the limited amount of research in the area aimed at developing technology and increasing efficiency. Finally, it is the low maintenance and monitoring of the systems to ensure their good performance and sustainability (Rodríguez-Urrego & Rodríguez-Urrego, 2018).

In Chile, Haas et al. (2018) also investigated the barriers compromising the development of photovoltaic energy systems. Basically, the main difficulties and barriers identified in the research can be divided into six dimensions, namely: i) economic and financial; ii) market and competition; iii) systems integration; iv) technical; v) legal and regulatory law; and vi) informational. The first dimension, economic and financial, involves the volatility of energy prices and lack of financing. Next is the market barrier, which is related to the immaturity of the solar energy market, causing supplier concentration and inconsistent supply. The low integration of solar energy systems is also a barrier, as it makes it difficult to link supply and demand centers and compromises the overall flexibility of the system. As for the technical problems, they are basically due to the need to map and forecast solar resources, required by Chilean environmental characteristics. The legal dimension addresses regulatory difficulties in terms of obtaining environmental permits, land and power grid concessions. Finally, information restrictions are associated with the low qualification of human resources and social awareness.

When addressing economic barriers, Kowalska-Pyzalska (2018) notes that the financial cost is particularly important, given that people, under normal conditions, are not willing to pay higher prices when cheaper options or substitutes are available on the market. Another point raised by Kowalska-Pyzalska (2018) concerns market structure flaws and competitive imperfections in the sense that a given party has disproportionate market power to charge abusive prices. In addition, the costs required to implement the systems are considered high, limiting their use, especially in the case of developing countries, where a large part of the population is low income and faces financial constraints (Garlet et al., 2019). This understanding was corroborated by Padmanathan et al. (2019), noting that solar energy has not yet reached its anticipated potential in terms of users due to the high cost of implementation.

Sociocultural and behavioral factors also constitute a barrier to the use of photovoltaic systems. According to Kowalska-Pyzalska (2018), consumers do not behave strictly rationally and can make wrong decisions regarding the adoption of photovoltaic systems based on cognitive biases such as resistance to innovation, low trust in energy suppliers, difficulties in identifying the strengths and weaknesses of the technology, among others. Garlet et al. (2019) state that among the sociocultural factors limiting the adoption of solar energy is the lack of sufficient knowledge about the technology. The explanation for this is that people feel insecure about the performance of systems, presenting also afraid of change and reluctant to try something new (Garlet et al., 2019). The authors also found that both business and households are still not concerned about environmental aspects and sustainable development (Garlet et al., 2019).

Regarding the political dimension, the implementation of photovoltaic systems would benefit from government subsidies, due to the high costs of installing technology (Garlet et al., 2019; Padmanathan et al., 2019). Specifically in the case of Brazil, Garlet et al. (2019) state that political instability in the country, derived from aspects such as corruption, policies aimed at private interest over public interest and social inequality, negatively affect the performance of the energy sector, especially with regard to public policies to encourage the industry.

From a sustainable perspective, there is a global need for economically accessible, reliable and sustainable energy sources, as constant carbon emissions from conventional energy sources have generated significant environmental and climate risks (Chu & Majumdar, 2012). In this sense, unlike energy sources that generate high CO2 emissions, such as thermoelectric, photovoltaic power generation has the advantage of not generating any emissions, which brings long-term environmental and economic benefits (Chen & Wei, 2018).

In the view of Breyer et al. (2015), two main trends have stimulated the benefits of photovoltaics in terms of reducing greenhouse gas emissions. The first refers to the reduction of energy repressed demand caused by the emergence of new sources (such as solar) and, consequently, lower emissions from these systems, followed by the reduction of overall electricity generation costs. Even in the case of photovoltaics, whose components are considered expensive, the increase in its competitiveness in recent years is remarkable, both for the reduction of certain costs and for the increase in the costs of other energy sources in relation to aspects that until then were ignored, such as environmental impacts.

Among the benefits generated by photovoltaics, Carstens and Cunha (2019) highlight the economic and social implications derived from the technology. The authors present data showing that for every megawatt of PV installed, on average, 25 jobs are created, both direct and indirect. In this way, Tourkolias and Mirasgedis (2011) found that photovoltaics is the renewable energy source that provides the hightes estimated benefits in terms of employment. This figure is consistent with the Brazilian scenario, since the photovoltaic energy sector has generated an expressive number of jobs in the country (ABSOLAR, 2020).

3. Data and Methods

The main purpose of this study is to categorize the perceptions regarding the benefits and the barriers of photovoltaic energy systems by Brazilian farmers. To do so, it was developed a descriptive study, that can support the identification of characteristics and profiles of individuals, communities or groups (Sampieri, Collado, & Lucio, 2014). In this descriptive study, the measurement was related to aspects of photovoltaic systems (details are presented in the following paragraphs) and responses were collected from farmers.

To collect data, a questionnaire was used and applied to owners of farms located in the state of Minas Gerais. Participants who answered the questionnaire have farms in different cities of the state (a total of 20 different cities). As discussed above, the state of Minas Gerais has the largest installed capacity for photovoltaic energy in Brazil (ABSOLAR, 2020). Moreover, the agribusiness represents an important sector to the economy of the state, representing 36% of Minas Gerais' GDP in the year of 2019 (CEPEA, 2020).

Specifically, the questionnaire addresses the city where the farm is located, the information received about photovoltaics, the availability of the photovoltaic installation, the intention to use photovoltaics, the use of photovoltaics by other farms, the benefits and barriers related to the installation of these resources. It is important to note that questions about the barriers and benefits of PV installation are open, so respondents were asked to provide a textual answer.

The data was collected during the period from December, 2018 to April, 2019 and only farmers answered the questionnaire. Respondents were informed that participation was completely voluntary, anonymous, that answers imply perceptions (so there are not correct or incorrect answers) and that they were free to cancel participation at any time if they were uncomfortable with any questions. It was obtained 116 responses; however, there are some items with missing values. It was not excluded any observation with missing value, since the analysis is based on frequency and all the responses, especially for the open questions, can help the discussion.

It was employed the descriptive statistics to analyze the data. First, all responses were segregated for open questions into categories, according to the benefits and barriers commented by respondents. Barriers related to photovoltaic use were grouped into the following categories: there are no barriers; focus / priority of other investments; technical information / technical consulting; absence of information / absence of knowledge about solar systems; lack of resources / financial constraints; cost and cost/benefit ratio; financial (generic considerations); property size / energy consumption. Benefits related to photovoltaic use were grouped into the following categories: environmental issues / renewable energy source; businesses profitability; energy autonomy; costs savings; financial benefits / financial economics; do not know; do not perceive the benefits; generic considerations. Descriptive statistics related to these categories are available in Appendices A and B.

4. Results

As mentioned above, Minas Gerais is the Brazilian state with the highest installed capacity for photovoltaic energy (ABSOLAR, 2020). In addition, the agro-industrial sector has an important participation in the GDP of the state (the sector represented 36% of the GDP of Minas Gerais, in the year of 2019 - CEPEA, 2020). However, even in a place with great potential for solar energy use, only 10 respondents reported that they already have PV systems on their rural properties. Some of them installed PV systems recently, and other respondents had such systems for more than 5 years. On the one hand, the low percentage of farm owners who already use PV systems on their rural properties is surprising. On the other hand, more than half of the respondents (85) stated that they intend to use (or continue to use) photovoltaic systems in the future. It indicates an expansion scenario for PV systems in rural areas, but many barriers and inhibitors can jeopardize new projects. Lack of adequate information has an important role in this regard.

The majority of the participants (68) of the research stated that they had already received some information about photovoltaic. This result may indicate a positive sign regarding to the dissemination of information related to solar energy in rural areas. On the other hand, some of these 68 participants commented that the absence of information related to photovoltaics also represents a barrier to adopting it. Such disparity suggests that some farms received information about solar energy, but perhaps such information was not enough to support the decision regarding the installation of photovoltaic systems. The implementation of educational campaigns (Garlet et al., 2019) in rural areas can contribute to reducing this lack of information. Another alternative could be to disseminate information about successful cases of implementation of photovoltaic energy in rural areas.

When asked about the use of PV systems on other farms in the region, only 7 respondents reported that they know of other farms in the neighbor that use solar energy. In addition, only 12 respondents reported that they know other farmers who use PV systems. This result is also interesting and suggests that some farmers can use solar energy, but do not necessarily communicate their advantages to other farms if they are not asked to do so.

Some respondents (02) commented on generic benefits related to the use of photovoltaics. They pointed to PV systems as excellent options and good in all aspects. Meanwhile, two other respondents stated that they do not perceive the benefits of solar energy at the moment and another 14 respondents reported that they do not have information about photovoltaic systems to identify their main benefits. This result is consistent with the previous observation about the relevance of adequate information on solar energy in rural areas.

The majority of respondents recognized the financial benefits of PV systems (80). Figure 1 summarizes the main benefits and barriers observed in the data analysis (Figure 1 should be analyzed together with Appendices A and B). Respondents highlighted that cost savings (51) represent the main advantage of PV systems; other farm owners commented on benefits related to reducing expenses and the possibility of increasing the profitability of their business. Other perceptions of advantages were presented by respondents (06), such as energy autonomy.

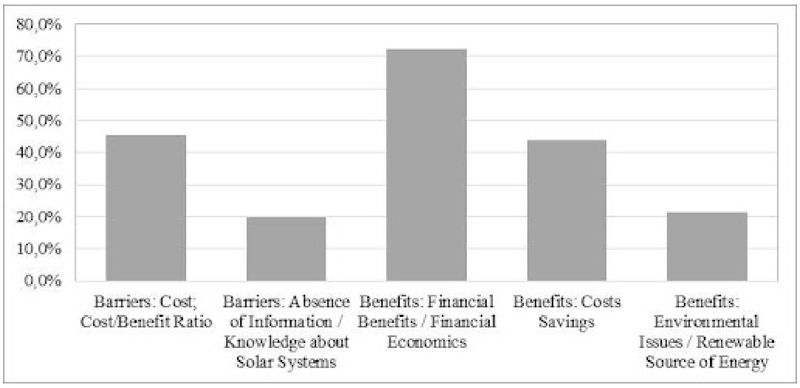

FIGURE 1:
Main Barriers and Benefits observed in the data analysis (in percentage of respondents)
Note: this content should be analyzed together with Appendices A and B of this research.

The environmental benefits of solar energy were highlighted by 25 respondents. They understand that solar energy reduces pollution; preserves the environment; uses natural, renewable and sustainable resources; reduces environmental degradation; and it is a kind of clean energy. This result confirms the positive characteristics related to photovoltaic energy that are usually presented in the literature (Chu & Majumdar, 2012; Breyer et al., 2015; Chen & Wei, 2018) and indicates that, even in a context of low availability of complete information, many farm owners recognize the environmental contributions that come from solar systems.

Regarding barriers to the use photovoltaics, on the one hand, 15 respondents reported that there are no barriers; on the other hand, 12 of these respondents still do not use photovoltaic systems. This result reinforces the relevance of comprehensive information on solar energy among farm owners, as many of them could invest in PV systems. Four farmers reported that there are other priorities for investments. Therefore, other investment alternatives gain priority compared to the photovoltaic installation.

The absence of technical information and technical consulting also represents concerns of two respondents, and this barrier is consistent with studies by Haas et al. (2018), Padmanathan et al. (2019), and Carstens and Cunha (2019). In addition, the absence of specific information related to solar energy represents a barrier for 23 farmers. Therefore, information-related barriers were commented by 25 individuals.

The existence of financial constraints as well as the absence of financial resources were barriers commented by 11 farmers. Concerns related to infrastructure, cost/benefit ratio, installation costs and other costs related to PV systems were commented on by 53 respondents, where some farmers have the perception that PV systems are expensive. Other 07 respondents commented on barriers generically as financial items, but they did not specify them. Therefore, financial-related barriers were mentioned by 69 respondents.

Given finance-related inhibitors and the Kowalska-Pyzalska (2018) study, cost and price concerns may negatively affect additional investments in solar systems, as some people may choose cheaper alternatives with poor quality. Therefore, the low level of quality will represent a characteristic that is not inherent to solar energy, but with the equipment choosing in a context of financial constraint and with low level of information regarding the quality of such equipment.

Barriers related to financial constraints, lack of information, low level of knowledge diffusion, and installation costs are in line with previous research findings, which highlighted obstacles from technical, economic, social, political and managerial perspectives (Hass et al., 2018; Padmanathan et al., 2019; Carstens & Cunha, 2019; Garlet et al., 2019). Concerns related to infrastructure costs become more critical considering a comparison between the results of this paper and the results of Garlet et al. (2019), who commented about the quality and durability of materials and equipment in Brazil. This issue is also commented on by Brunet et al. (2018) in the context of developing countries. Brazilian farmers may be reluctant to invest their financial resources in equipment that they expect to have low durability. In a scenario of financial constraints, other investment options gain priority in this context, which is in line with our results, as some farmers presented other investment priorities in addition to PV systems. Again, information is crucial to expand the use of PV systems.

Many farmers in the study sample reported that they do not have the financial resources to invest in PV systems; therefore, the results of this study are also in line with Hass et al. (2018), who highlighted the lack of funding as a barrier to the development of photovoltaic energy systems. The size of the property was also commented as a barrier (06 responses), but it also has a relationship with the perception of cost/benefit.

The photovoltaic industry plays an important role in job creation in Brazil. Therefore, expanding the use of photovoltaic systems in the country can also contribute to generating more jobs, as is also the case in rural areas. An expansion in power generation will require people capable of cleaning the modules, working with their safety, doing electrical maintenance, cleaning power energy lines in the forest, among others. It also requires trained people to install new equipment, especially in regions where irradiation is high, but rainfall rates are low and create challenges for non-family service providers. These initiatives bring more benefits considering that solar systems can be installed in non-productive areas, allowing the implementation of solar farms. However, this scenario also demands training initiatives and financial opportunities for potential clients.

Previous research also highlights the barriers related to the cost perception of PV systems (Kowalska-Pyzalska, 2018; Garlet et al., 2019; Padmanathan et al., 2019). It is important to note, however, that the price per watt in Brazil has been similar to the price of other developed countries, even with the relatively new market in the country.

This study also reinforces the need for long term policies, implying, for example, financing alternatives to expand the use of the photovoltaic system in rural areas. Government banks could implement initiatives to support the installation of PV systems in rural areas; if these initiatives already exist, banks could disseminate this information to rural entrepreneurs. Many respondents reported that financial constraints represent a barrier to implementing PV in their properties.

5. Conclusion

Photovoltaic energy represents an important alternative, especially in rural areas (Sahoo, 2016), and its potential can be improved in Brazilian farms through the information diffusion. Some benefits can be achieved by farm owners if they better understand the operationalization of PV systems, including: reduction in the costs to food production; new possibilities for irrigation; the use of non-productive areas; the possibility to create solar farms; among others. Educational campaigns (Garlet et al., 2019) should contribute to mitigate the absence of information also in rural areas and increase the adoption of renewable sources of energy among farm owners. Moreover, educational campaigns can contribute to the quality of the information that will be available to people who live in rural areas.

The results are consistent with previous literature (Carstens & Cunha, 2019; Garlet et al., 2019) that highlights lack of information and the need for knowledge dissemination regarding information technologies. Based on previous research (Hass et al., 2018; Carstens & Cunha, 2019), it is considered that training opportunities and incentives to new entrepreneurs to start their business in the sector should expand the adoption of PV systems in rural areas. New entrants in the market could expand competitiveness and facilitate the dissemination of PV in rural areas. The incentives to new research in the area (Rodríguez-Urrego & Rodríguez-Urrego, 2018) can improve this figure too.

The diffusion of solar energy in rural areas also contributes to other variables at the country level, such as the level of employment (Tourkolias & Mirasgedis, 2011; Carstens & Cunha, 2019). Therefore, initiatives to expand the adoption of solar energy also have an effect on social development. The implementation of PV systems may also be related to some behavioral biases (Kowalska-Pyzalska, 2018), as some individuals may prefer to stay with the current system (based on centralized distribution) rather than investing in a new system, even with the potential to save resources and contribute to the environment. This topic can be studied in further research.

This study has some limitations. The first limitation is related to sample composition, since it was used a convenience sample (therefore, results are not necessarily generalizable). Moreover, the tool for data collection may contain some limitations and qualitative studies can expand the results obtained through this research. Future investigations can also consider the possibility of analyzing the determinant factors related to the use of photovoltaic systems in rural areas.

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Appendix A:

Descriptive statistics related to the benefits of PV systems

Benefits	Freq.	%
Environmental Issues / Renewable Source of Energy	25	21.6
Businesses Profitability	2	1.7
Energy Autonomy	6	5.2
Costs Savings	51	44.0
Financial Benefits / Financial Economics	84	72.4
Do not Know	14	12.1
Do not Perceive the Benefits	2	1.7
Generic	2	1.7

Notes: in some cases, the respondent commented more than one advantage.

Appendix B:

Descriptive statistics related to the barriers for the use of PV systems

Barriers	Freq.	%
There are no Barriers	15	12.9
Focus / Priority of Other Investments	4	3.4
Technical Information / Technical Consulting	2	1.7
Absence of Information / Knowledge about Solar Systems	23	19.8
Lack of Resources / Financial Constraints	11	9.5
Cost; Cost/Benefit Ratio	53	45.7
Financial - Generic Considerations	7	6.0
Property size / Low Energy Consumption	6	5.2
Other Barriers	4	3.4

Notes: in some cases, the respondent commented more than one barrier.