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Factors Associated with the Use of Solar Energy in Urban Households - Case Study: Municipality of São José Dos Campos

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ABSTRACT

The increased demand for electricity and greenhouse gas emissions resulting from the current energy matrix reinforces the need to expand the use of renewable energy. The conversion of solar energy into electrical energy is the fastest growing worldwide and Brazil has a potential greater than that of developed countries that use it on a large scale. However, it is observed that decentralized generation with the use of photovoltaic panels, in households, occurs at a slower pace than in other countries. We studied a case of the municipality of São José dos Campos, a city with a high human development index in the state of São Paulo, seeking to understand the relevant factors that affect the expansion of installation and use of solar energy. We developed the case study from the collection of information with actors in the process, namely, the government and residents of four neighborhoods in the city. Among the research results, the importance of public guidance for the expansion of the use of technology stand out; the recognition of the use of solar energy, especially in neighborhoods where there are already similar facilities and in those with high purchasing power. It was also found that cultural barriers to the appropriation of technology can be overcome by referential learning and by raising the awareness of the population on environmental issues.

Keywords: Renewable Energy, Distributed Generation, Solar Energy, Photovoltaic Panels
JEL Classifications: Q2, Q4, O13, Q42.

1. INTRODUCTION

The intense urbanization seen in most countries in recent decades indicates that by 2050, more than 70% of the estimated 9.7 billion people in the world at the time will reside in cities (United Nation, 2019). The population increase in urban areas intensifies and concentrates the demand for resources and the environmental impacts resulting from anthropogenic activities as point out by Cortinovis and Geneletti (2020).

Among the main resources demanded for economic development and human well-being is energy, whose per capita consumption is currently associated with the economic, cultural, and environmental conditions of countries. According to Ahmad and Zhang (2020), world data on energy demand show that population growth and continuous technological development have stimulated human consumption of energy in recent decades. Considering the expected population growth, the increase in population density in cities, the need for the current universal access to energy and the promising scenario of technological development in the coming decades, it is necessary to state that studies related to energy sources are still required. Currently, more than 60% of the world's energy matrix comes from fossil resources that are known to be responsible for the emission of atmospheric pollutants that cause the greenhouse effect (GHG). However, in the current decade there is also a rapid reduction in anthropogenic GHG emissions resulting from the establishment of global transition policies for the use of clean energy (ESMAP, 2018).

The search for an increase in energy generation, with the reduction of harmful gas emissions to the environment, presents an opportunity for inserting renewable energies, as indicated by Kammen and Sunter (2016). In this context, it is worth mentioning the European regulation (European Commission, 2014) that established a goal of gradual transition of its energy matrix to renewable sources by the year 2030, reaching 27%. If this target is achieved, it is believed that the region could have a 28% reduction in CO_2 emissions when compared to 2015. In numbers, this means a migration from 304 to 219 g of CO_2 emitted per kWh, according to IRENA (2018).

The natural resources available in South and Central America provided differentiated conditions in these territories because, as shown in Figure 1, in these regions the energy matrices are mostly renewable, mainly due to the hydroelectric potential.

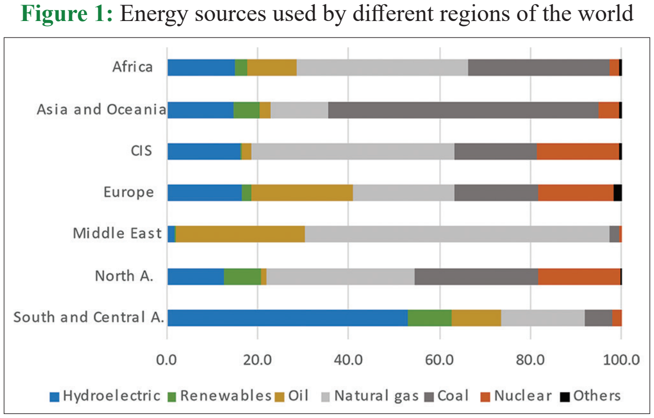
According to IRENA (2018), solar and wind energy are the renewable sources with the highest growth expectation, such that solar energy is expected to grow an eighth of its current percentage, totaling 6% of the energy matrix worldwide. In 2018, both contributed together with more than 60% of the installed capacity.

Compared with other energy sources, solar energy is the technology with the fastest growth rate, accounting for more and more countries that have more than 1 GW installed, as shown in REN21 (2019). The total installed photovoltaic energy capacity in the world in 2018 was 509.3 GW and by 2023, according Solarpower Europe (2019) this value is expected to exceed 1 TW. Asia and Oceania have the highest concentration of installed capacity, led mainly by China, which is the world leader in this sector with 175.13 GW.

The expansion of solar energy can be divided into two major sectors, large-scale or centralized production and decentralized. The centralized production sector corresponds to large solar power plants and photovoltaic farms, while the decentralized one comprises generation in homes, businesses, businesses, and transport. In addition to the environmental benefits of decentralized solar energy generation, economic and political benefits are also reported to countries in IRENA (2018).

According Kammen and Sunter (2016), about 75% of all energy in the world is consumed in cities. Thus, the generation located within the urban perimeter becomes even more attractive since it can avoid energy losses with large transmission lines, in addition to reducing expenses with them. Urban areas often have considerable potential to overcome this barrier, as they have a high density of roofs, and this tends to increase even more with urbanization predicted by several studies (Castellanos et al., 2017).

Figure 1: Energy sources used by different regions of the world



Photovoltaic panels installed in buildings will tend to have a significant increase in the share of the amount of electricity generated in all continents, reaching a share of 29-35% in the photovoltaic market, as indicated in Solarpower Europe (2019). According Wiginton et al. (2010), this growth is directly related to the government's role in developing measures that encourage the use of solar energy in households in their cities. Despite the growth in the use of solar energy in homes, industries and government buildings still have a greater share in the total installed capacity in the high-end sector, as indicated in REN21 (2019).

Currently, the largest market for residential solar panels is Australia, where more than 2 million homes have the equipment installed, equivalent to 1 in every 5 homes in the country. According REN21 (2019), the country totaled about 1.8 GW. Another example is the state of California, which made the use of photovoltaic panels mandatory in new built homes, according to Solarpower Europe (2019). One of the important factors in the growth of this market is the drop in the cost of modules, which, in Europe, in 2016 was 80% in value compared to 2010, as indicated by IRENA (2018).

Case studies on the deployment of solar energy in urban areas showed that these programs, by including social participation, ensured sustainability and technological appropriation (Lobaccaro et al., 2019). According to Hai et al. (2017), the positive perception of people in relation to the use of solar energy, associated with environmental issues, does not always lead them to adopt systems for reasons generally associated with the absence of adequate information about costs, legislation, and government incentives. Meanwhile, Sovacool and Griffiths (2020) indicated that the cultural barriers to the implementation of solar systems in homes were identified in five different developing countries and showed that the absence of information related to the implementation and operation of the technology leads to significant distortions that minimize efficiency or make its use unfeasible. The study also reports that cultural non-acceptance, vandalism, and theft can prevent the use of photovoltaic panels. Table 1 presents the main perceptions verified in case studies conducted with urban dwellers on the theme.

As can be seen, the generation of photovoltaic solar energy still faces some barriers for implementation in urban regions to be effective as an alternative energy generation. Such barriers can include factors such as users' lack of knowledge about alternative energy sources, lack of knowledge about the generation of electricity from the use of photovoltaic panels, or even the lack of available space for installation (Schwartz et al., 2017; Acaravci and Ozturk, 2012).

1.1. Study Area

As observed in international experiences, Brazil continues to experience a rapid increase in the installed capacity of photovoltaic

Table 1: Perceptions of urban dwellers about the use of renewable energy sources

Local	Perceptions
Xangai, China (Vand et al., 2019)	Income level is the main factor associated with the propensity to use renewable energy
Nikaia, Greece (Ntanos et al., 2018)	Limiting factors for use: high installation cost and lack of information to interested parties
Sweden (Azizi et al., 2019)	Groups from different socioeconomic conditions have different perceptions of the benefits and barriers of using solar energy
Bahrain, Middle East (Alsabbagh, 2019)	Verification of popular interest in the implementation of photovoltaic panels Barriers associated with cost, small areas available for deployment, the lack of technical information, concern with systems maintenance and security
Australia (Hampton and Eckermann, 2013)	Social learning as a driver for the expansion of use and costs as a limiting factor
Africa	
Nigeria (Oyedepo, 2012; Barau et al., 2020)	Solar energy as an opportunity to use clean energy Users report technical and maintenance problems: the malfunction of panels and inverters reduced charge retention and low battery life Barriers associated with the construction pattern of homes
Others (Opiyo, 2019; Naidoo and Munien, 2020)	The neighborhood influences the expansion of photovoltaic technology Approval of use and perception of improved quality of life in low-income communities Negative perceptions related to negative experiences and/or technical difficulties in use

panels, installing more than 1GW in 2018, including 390.2 MW in the decentralized sector, according to Solarpower Europe (2019). This growth to the existence of regulatory policies that allow the injection of energy produced by photovoltaic panels into the local energy network, as in Monojero et al. (2018). However, highlight that the policies employed in Brazil are still simplistic compared to those of other countries, such as the United States, China and Germany, which have legislation covering points that are not observed in national regulations, such as: Discounts, investments, technologies of research and environmental education, as mentioned by Pinto et al. (2016).

Another essential factor for the growth of this alternative in Brazil is its enormous potential in terms of solar irradiation compared to other countries. According to Behrang et al. (2010), Brazil has 90% of its territory with average annual solar irradiation above 4 kWh/m^2. Compared to European countries Brazil has an average annual solar irradiation up to 3 times greater than countries like Germany, France, and Spain (Tiba, 2000).

Despite its potential, solar energy still has little significant participation in the Brazilian energy matrix. However, in recent times, hydroelectric generation has been compromised by facing a water crisis in many regions of the national territory and the consequent decrease in reservoir levels. According to Pinto et al. (2016) natural gas, imported by the country, is also considered quite vulnerable to political and diplomatic crises. Therefore, solar energy stands out as a good alternative to increase the country's energy security and stability.

The Office of Energy Research, EPE (2019) stipulated that by 2027 the country's goal is to reach a total of 18.4 GW of installed capacity. In 2018, the country had 2.34 GW of total capacity, and is projected to increase to 10.15 GW in 2023. Also in 2018, photovoltaic energy was responsible for the generation of 3.46 GWh, which corresponds to approximately 0.6% of all energy generated in the country. However, when looking at micro and mini distributed generation, solar energy dominates the national share with more than 60%.

Currently in Brazil there are 187,707 distributed photovoltaic generation units, corresponding to a power of MW. Consumer units (UCs) are distributed throughout the entire national territory, but the southeast and south regions present the highest concentration, with 42.9% and 25.5%, respectively. The units together present a power of 2.17 GW, which is also distributed throughout the territory in a concentrated manner in the Southeast and South regions. The 2.17 GW of distributed generation in the country comes from the commercial, residential, rural, and industrial sectors, in percentages of 40%; 39%; 11% and 10%, respectively (ANEEL, 2021).

The state of São Paulo is the second state with the largest use of residential photovoltaic solar energy in the country, surpassing the mark of 124 thousand homes with solar panels. The city of São José dos Campos, with 171,480 households, ranks 11th in number of residential systems installed and registered with panels installed in 0.19% of homes (ANEEL, 2021). These 335 units add up to a power of 1.21 MW, which corresponds to approximately 1% of the state power. It is in the context of the existence of potential and regulatory policy, this case study on decentralized generation in Brazilian urban residences was conducted in the municipality of São José dos Campos, to identify the strengths and weaknesses identified by urban residents for the installation and use of solar energy.

2. MATERIALS AND METHODS

This work is a case study with quali-quantitative analysis, as discussed by Bogdan and Biklen (1982), whose subjects include the government and residents of different neighborhoods in the city of São José dos Campos. Regarding the qualitative approach, the instrument for constituting the data was an interview with a representative of the government. The quantitative aspect reflects the result of a survey conducted with residents of neighborhoods in this municipality.

In the development of this work, we started from the premise that the economic aspect is the main factor that contributes for Brazil not to be among the largest producers of solar energy in the world. Thus, we sought to understand the other aspects of the triple bottom line, which interfere in the incorporation of technologies that promote sustainable energy generation.

The perceptions of residents of neighborhoods in the city of São José dos Campos were obtained through direct interviews supported by structured questionnaires with questions that included: Environmental aspects, knowledge about solar energy; socioeconomic and environmental aspects. We started from the premise that these aspects can be correlated, and that, when analyzed in an integrated way, they can provide a better understanding of the use or nonuse of solar energy. Neighborhoods with greater economic, social and environmental diversity were chosen.

To ensure greater heterogeneity in the definition of neighborhoods covered by the research, the results of the Municipal Human Development Index (IDHM) made available by the local government were used. The IDHM is an adaptation of the HDI elaborated by the Economic Research Institute (IPEA) and by the United Nations Development Program (UNDP). Composed of the same three dimensions of the Global HDI - longevity, education, and income - the IDHM goes beyond the following: it adapts the global methodology to the Brazilian context and the availability of national indicators. Although they measure the same phenomena, the indicators considered establishing this index are more suitable for evaluating the development of Brazilian cities and metropolitan regions. The classification, according to the IDHM, has the following categories: Low, medium, high, and very high.

The neighborhoods were chosen through the analysis of the published IDHM values for the 67 sections called Urban Development Units (UDH), existing in the studied municipality. Since no HDU was identified in the city with an IDHM classified as low, it was decided to choose the HDU with the lowest value, namely, the IDHM = 0.694, which corresponds to the "Railroad Station" grouping, which includes the Vila Terezinha neighborhood. Two other HDUs were also chosen, one with a high IDHM value (Jardim Satélite) and another with a very high IDHM (Aquarius), as shown in Table 2. Additionally, a fourth neighborhood was chosen, also with medium IDHM, whose homes were sold through a government housing subsidy program where, by decision of the local public administration, solar collectors were installed in all housing units.

Notably, that the neighborhoods chosen for this study, shown in Figure 2, have similar environmental elements, namely: Existence of selective collection and afforestation in the form of small parks or green areas.

From the data on the occupation of each neighborhood, the number of interviews to be carried out was determined so that the survey had a statistical confidence level of 90%. Therefore, interviews were conducted in 68 housing units in each of the neighborhoods.

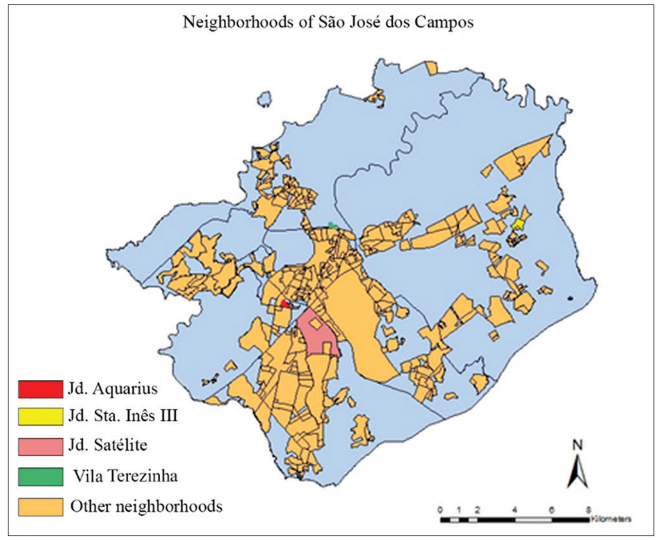
Based on questionnaire responses, some quantitative indicators were created to establish the probability of installing solar energy by the residents of the neighborhoods visited. Therefore, it was necessary to establish some criteria that would classify the interviewees as prone to the installation of solar energy, either for heating water or for transformation into electrical energy, according to the responses verified in the questionnaires. The questions considered in this classification were about knowledge about what solar energy is, knowledge about the use of this energy for heating water as well as for generating electricity.

Table 2: IDHM of the HDUs chosen for the study

Neighborhoods	IDHM
Aquarius	0.952
Jardim Satélite	0.775
Vila Terezinha	0.694
Jardim Santa Inês III – Conj. Habitacional	0.633

Adapted from Municipality of São José dos Campos - City Hall Website.
IDHM: Municipal Human Development Index

Figure 2: Location of the neighborhoods under study, in the municipality of São José dos Campos (own elaboration using ArcGis and shapefiles available on São José dos Campos-City Hall website)



In addition to these questions, it was established that for an interviewee to be considered a potential installer, they should have manifested themselves without knowing where the equipment was purchased and claiming that they did not have the resources to do so. The choice of these two alternatives is justified by the fact that, within your group, it is the alternatives that can change since not knowing where to buy the equipment can be solved with access to information, and the claim of not having resources, many often due to the lack of knowledge of the real value of the panels. This means that there are residents who claim not to have resources but have an income that is sufficient for the installation of the panels. Considering this possibility, the interviewees' income was also included as a cutoff criterion. The criteria are shown in Table 3.

Thus, with the inclusion of these filters, it was obtained, in addition to information on the number of houses that already had panels installed (Q_i), the number of houses prone to a future installation (Q_pi). With these data it was possible to calculate then the probability of installing solar energy (P_ies), defined by the sum of the number of houses with panels already installed with the number of houses prone to installation, divided by the total of respondents (T), according to Equation 1.

$$P_{ies} = \frac{Q_i + Q_{pi}}{T} \quad (1)$$

Table 3: Adopted criteria

Collector type	Knowledge about solar energy	Knowledge about water heater	Photovoltaic knowledge	Reason for not using	Monthly income
Water heating	Yes	Yes	Yes and no	Don't know where to buy Has no resources	Above 3 minimum wages
Photovoltaic	Yes	Yes	Yes	Don't know where to buy Has no resources	Above 5 minimum wages

Table 4: Residents profile with highest tendency to install solar water heating panels

Neighborhoods	Age	Schooling	Monthly income	Number of residents
Jardim Aquarius	61 or +	Complete higher education	14 or +	5
Jardim Satelite	41-50	Complete higher education.	9-13	4
Vila Terezinha	-	-	-	-
Jardim Santa Inês III	31-40	Incomplete high school	3-4	5

Source: Own elaboration

Table 5: Residents profile with highest tendency to install photovoltaic panels

Neighborhoods	Age	Schooling	Monthly income	Number of residents
Jardim aquarius	51-60	Complete higher education	14 or +	4
Jardim satelite	-	-	-	-
Vila terezinha	-	-	-	-
Jardim santa Inês III	-	-	-	-

Table 6: Tendency for installing water heating panels by residents who practice selective waste collection

Neighborhoods	Selective waste collection	No selective waste collection
Jardim aquarius	2.06	0.00
Jardim satelite	0.32	0.00
Vila terezinha	0.00	0.00
Jardim santa Inês III	16.50	0.13

Table 7: Tendency for installing photovoltaic panels by residents who practice selective waste collection

Neighborhoods	Selective waste collection	No selective waste collection
Jardim Aquarius	0.12	0.00
Jardim Satelite	0.00	0.00
Vila Terezinha	0.00	0.00
Jardim Santa Inês III	0.00	0.00

Then, the tendency to install solar energy (C_ies), defined by Equation 2, was calculated.

$$C_{ies} = Q_{pi} \, x \, P_{ies} \quad (2)$$

Subsequently, it was decided to analyze how the residents' environmental awareness could affect their susceptibilities to the installation of solar energy panels. For this, the issue of selective collection practice was considered an additional filter.

The same equations were applied this time in two parts, one for residents who practice selective collection and another for residents who do not practice collection, for all neighborhoods in the sample.

To validate and discuss the results verified with the residents, we also contacted the government to understand, from the viewpoint of municipal management, what elements could contribute to the distribution, incentive and implementation of photovoltaic systems, both from a residential and commercial point of view. Initiatives associated with the protection of the environment, as well as local laws that can serve as a basis for the dissemination of the use of renewable energies are important attitudes toward ensuring access and consumption of energy generated in a sustainable manner. The semi-structured interview was carried out in the second half of 2020, with the municipal secretary of sustainability.

3. RESULTS

3.1. Tendency for Installing Water Heating Panels

Considering previous results, it was possible to determine the profile of residents with the highest tendency to install solar water heating panels, according to Table 4.

3.2. Tendency for the Installation of Photovoltaic Panels

Similarly, according to the results above, it was possible to determine the profile of residents with the highest tendency to install photovoltaic panels, according to Table 5.

3.3. Selective Waste Collection

The values of the tendency for installing water heating panels were calculated using the filter of residents who practice selective waste collection and are shown in Table 6.

The same calculation was performed for photovoltaic panels, according to Table 7.

3.4. Interview Results

According to the Municipal Secretary of Urbanism and Environment, the main projects related to the environment in development can be classified as: One-off projects- environmental reforestation initiatives, rural sanitation, creation of UCs (creation of the UC for comprehensive urban protection of the saws); Partnership with the public water and sewage company

Table 8: Tendency for installing water heating panels (C_{ies}) - Jardim Santa Inês III

Indicators	C_{ies}
Age	
18-24	2.5
25-30	6.0
31-40	15.0
41-50	1.0
51-60	0.0
61 or +	0.0
Schooling	
Incomplete elementary school	0.0
Complete primary education	0.48
Incomplete high school	17.0
Complete high school	14.0
Incomplete higher education	2.0
Complete higher education	2.0
Monthly income	
None	0.0
Until 2 min	2.5
3-4	25.2
5-8	0.0
9-13	0.0
14 or +	0.0
Number of residents	
1	0.0
2	0.0
3	0.0
4	10.88
5	13.0
6 or +	7.0

Table 9: Tendency for installing water heating panels (C_{ies}) - Jardim Aquarius

Indicators	C_{ies}
Age	
18-24	0.0
25-30	0.0
31-40	0.0
41-50	0.0
51-60	0.32
61 or +	4.9
Schooling	
Incomplete elementary school	0.0
Complete primary education	0.0
Incomplete high school	0.0
Complete high school	0.0
Incomplete higher education	0.0
Complete higher education	3.64
Monthly income	
None	0.0
Until 2 min	0.0
3-4	0.0
5-8	0.0
9-13	0.97
14 or +	1.2
Number of residents	
1	0.0
2	0.0
3	0.0
4	0.2
5	5.6
6 or +	0.0

Table 10: Tendency for installing water heating panels (C_{ies}) - Jardim Satélite

Indicators	C_{ies}
Age	
18-24	0.0
25-30	0.0
31-40	0.0
41-50	0.2
51-60	0.0
61 or +	0.0
Schooling	
Incomplete elementary school	0.0
Complete primary education	0.0
Incomplete high school	0.0
Complete high school	0.0
Incomplete higher education	0.0
Complete higher education	0.8
Monthly income	
None	0.0
Until 2 min	0.0
3-4	0.0
5-8	0.0
9-13	0.21
14 or +	0.0
Number of residents	
1	0.0
2	0.0
3	0.0
4	0.33
5	0.11
6 or +	0.0

Table 11: Tendency for installing water heating panels (C_{ies}) - Vila Terezinha

Indicators	C_{ies}
Age	
18-24	0.0
25-30	0.0
31-40	0.0
41-50	0.0
51-60	0.0
61 or +	0.0
Schooling	
Incomplete elementary school	0.0
Complete primary education	0.0
Incomplete high school	0.0
Complete high school	0.0
Incomplete higher education	0.0
Complete higher education	0.0
Monthly income	
None	0.0
Until 2 min	0.0
3-4	0.0
5-8	0.0
9-13	0.0
14 or +	0.0
Number of residents	
1	0.0
2	0.0
3	0.0
4	0.0
5	0.0
6 or +	0.0

(Cetesb), in order to reduce the "debt" that the city has regarding compensatory measures; Building projects with innovations in sustainable construction, including photovoltaic panels, which score as a decrease in the local fees of construction, and finally

Table 12: Tendency for installing photovoltaic panels (C_{ies}) - Jardim Aquarius

Indicators	C_{ies}
Age	
18-24	0.0
25-30	0.0
31-40	0.0
41-50	0.0
51-60	0.2
61 or +	0.0
Schooling	
Incomplete elementary school	0.0
Complete primary education	0.0
Incomplete high school	0.0
Complete high school	0.0
Incomplete higher education	0.0
Complete higher education	0.24
Monthly income	
None	0.0
Until 2 min	0.0
3-4	0.0
5-8	0.0
9-13	0.0
14 or +	0.24
Number of residents	
1	0.0
2	0.0
3	0.0
4	0.3
5	0.0
6 or +	0.0

Table 13: Tendency for installing photovoltaic panels (C_{ies}) - Jardim Satélite

Indicators	C_{ies}
Age	
18-24	0.0
25-30	0.0
31-40	0.0
41-50	0.0
51-60	0.0
61 or +	0.0
Schooling	
Incomplete elementary school	0.0
Complete primary education	0.0
Incomplete high school	0.0
Complete high school	0.0
Incomplete higher education	0.0
Complete higher education	0.0
Monthly income	
None	0.0
Until 2 min	0.0
3-4	0.0
5-8	0.0
9-13	0.0
14 or +	0.0
Number of residents	
1	0.0
2	0.0
3	0.0
4	0.0
5	0.0
6 or +	0.0

on Biomass: Use the products generated by the city (collection of leaves and organic matter generated in the city and transformation into energy) either by reducing or commercializing to companies that use.

Table 14: Tendency for installing photovoltaic panels (C_{ies}) - Vila Terezinha

Indicators	C_{ies}
Age	
18-24	0.0
25-30	0.0
31-40	0.0
41-50	0.0
51-60	0.0
61 or +	0.0
Schooling	
Incomplete elementary school	0.0
Complete primary education	0.0
Incomplete high school	0.0
Complete high school	0.0
Incomplete higher education	0.0
Complete higher education	0.0
Monthly income	
None	0.0
Until 2 min	0.0
3-4	0.0
5-8	0.0
9-13	0.0
14 or +	0.0
Number of residents	
1	0.0
2	0.0
3	0.0
4	0.0
5	0.0
6 or +	0.0

Most of the remarkable environmental education projects conducted by the government in the city, under the coordination of the Secretariat, are related to urban agriculture: Vegetable gardens and composting plants in schools (more than 50 public schools already have vegetable gardens), urban native orchards, which consists of the planting of native fruit trees in public areas (17 already implanted with 40 seedlings). The idea is to add this with some exercise/walking place, generating an approximation of the population with the theme. Another project is the rescue of the springs: 35 already restored, in public actions of the city hall, in partnership with a public university.

Concerning to the use of solar energy there are municipal initiatives based on law that generates discounts on the urban tax for residents who occupy 85% of the roofs with photovoltaic cells. Simultaneously, there are projects in development by the local government for public buildings (such as the city hall building) to use renewable energy. The main challenge for next year, especially in terms of energy, waste, education is the internal assimilation of all secretaries about what the city should do about climate change and how to negotiate it with the city's productive sector.

4. DISCUSSION

As for the installation of panels for water heating, it was noted that the greatest tendency is for residents of the Jardim Santa Inês

Table 15: Tendency for installing photovoltaic panels (C_{ies}) - Jardim Santa Inês III

Indicators	C_{ies}
Age	
18-24	0.0
25-30	0.0
31-40	0.0
41-50	0.0
51-60	0.0
61 or +	0.0
Schooling	
Incomplete elementary school	0.0
Complete primary education	0.0
Incomplete high school	0.0
Complete high school	0.0
Incomplete higher education	0.0
Complete higher education	0.0
Monthly income	
None	0.0
Until 2 min	0.0
3-4	0.0
5-8	0.0
9-13	0.0
14 or +	0.0
Number of residents	
1	0.0
2	0.0
3	0.0
4	0.0
5	0.0
6 or +	0.0

III neighborhood (Table 8). Despite not having high levels of concentration of income or education, the potential in this case can be justified by the fact that the indicator considers the number of homes with panels installed in the neighborhood and in Jardim Santa Inês III has a large amount already installed, because of the public decision to implement them in the construction phase of these houses that come from government programs. This result differs from Vand et al. (2019) regarding income, however, reaffirms the findings of Hampton and Eckermann (2013) who report the influence of the neighborhood for the social recognition of technology and the importance of social learning for its expansion of use.

The Jardim Aquarius and Jardim Satélite neighborhoods were in second and third place, respectively (Tables 9 and 10). The potential of these neighborhoods can be justified given that in both, most residents have enough income to make them potential. This result is convergent with Vand et al. (2019). Notably, positive perception does not always lead to the implementation of adequate solutions and in this case, government awareness and incentives should be applied, as mentioned by Hai et al. (2017). Finally, the Vila Terezinha neighborhood did not present significant values for this indicator (Table 11), and the low performance can be justified by the fact that a large part of the residents of the neighborhood does not have enough income to pass through the potential filters, and because they do not have basic knowledge about what solar energy is and how it can be used, therefore, potential installers cannot yet be considered (Ntanos et al., 2018).

Regarding the installation of photovoltaic panels, there is only the Jardim Aquarius neighborhood tendency values (Table 12). The absence of numbers for other neighborhoods in this item is directly related to the small number of residents that were considered as potential, that is, few residents managed to pass through the filters, and, thus, the neighborhood ended up with a null value (Tables 13-15). For Jardim Aquarius, the high concentration of income in the neighborhood is a factor that helps to increase the result, given that this is the neighborhood with the highest income in the sample. Notable, despite this potential, the number of units installed in that neighborhood is low and that this fact may be associated with the lack of appropriation of technology or the absence of adequate information and incentives (Lobaccaro et al., 2019; Sovacool and Griffiths, 2020).

As water heating panels have a lower price than photovoltaic panels, the number of residents in the city with the potential to install them is consequently also greater, a fact that is observed by the greater distribution of potential throughout the neighborhoods under study, while residents with the potential to install photovoltaic panels are concentrated only in a restricted part of the sample. According to Alsabbagh (2019) this shows that the economic barrier is also a relevant issue in the studied area.

When the selective collection indicator was considered when calculating the tendency to install, it was clear that residents who practice selective collection have a significantly greater propensity than those who do not, a fact that may suggest an important correlation between the environmental concerns of residents related to waste, with an inclination to install renewable energy sources. This shows that the population's sensitivity to other environmental issues can contribute to breaking the cultural barrier related to the implementation of individualized solar systems as seen in Sovacool and Griffiths (2020), where energy generation occurs centrally, and distribution is conducted by means of a government concession.

Thus, having a cluster of residents who were not considered potential does not mean that they cannot install any panel, only that there are other profiles with characteristics that make them more prone to this.

Finally, analyzing the profile clusters of residents with greater propensity to install solar panels, a significant diversity can be noticed between the neighborhoods, a fact that further reinforces the need to understand the unique characteristics of each neighborhood at the time of decision making on how to act in relation to solar energy in each of them, since a profile of residents that is potential for installation in one neighborhood, is not necessarily potential in another neighborhood. In addition to the socioeconomic diversity, mentioned by Azizi (2019), the results of this research show that other cultural factors influence the difference in technology appropriation for the studied neighborhoods.

5. CONCLUSION

According to the results obtained, it is possible to conclude that there is potential for the use of solar energy in the municipality of São José dos Campos, especially in places where there is knowledge of the technologies available for this purpose and in those with greater socioeconomic potential.

It was also possible to verify that water heating panels are more viable for employment in the municipality than photovoltaic panels, and that this is associated with the population's income. The results also suggest that the use of photovoltaic panels is more favorable in the group of people between 51 and 60 years old, with a high level of education and salaries.

From the results presented above, it is also possible to infer that the absence of clear public policies with tax incentives, the lack of knowledge about the characteristics of the panels, advantages, and relevance of their use, as well as the low degree of environmental commitment of society are important factors that contribute to the use of this type of energy has not yet expanded and consolidated in the municipality. Additionally, public actions must be taken considering the characteristics of each neighborhood, to obtain the greatest effectiveness.

An important point to note is that since some specific questions were not asked in the questionnaire, the classification of potential residents may have been less accurate than the ideal, which may interfere with the results.

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