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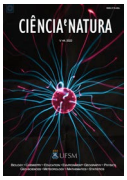

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Environment

Energy efficiency project: analysis of the installation of photovoltaic panels at the Curitiba City Hall

Projeto de eficiência energética: analise da instalação de painéis fotovoltaicos na sede da prefeitura de Curitiba

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ABSTRACT

Brazil stands out for the use of renewable energy sources in its energy matrix. Even so, it suffers from the risks of collapse and depletion of resources, as occurred in the beginning of the 21st century. In view of this, there is a need to promote growth in the use of other less polluting energy sources, such as photovoltaic solar energy. Some factors contribute to the growth in the use of this technology, such as: scarce rains, constant increases in electricity tariffs, tax exemption and expansion of credit lines that guarantee resources for the best use of abundant solar radiation. In this context, this study aimed to analyze the feasibility of implementing the solar energy generation system, from the installation of photovoltaic panels, in the Curitiba (Brazil) City Hall, seeking to encourage the expansion of access to photovoltaic energy, as a way to reduce spending on electricity, preserving the environment and maximizing the municipality's energy efficiency. This is an exploratory study, developed based on data obtained from secondary sources, which provided a new approach to the subject and which enabled the significant achievement of positive results, including the financial one.

Keywords: Renewable energy sources; Photovoltaic solar energy; Energy efficiency

RESUMO

O Brasil se destaca pela utilização de fontes de energia renovável na sua matriz energética. Mesmo assim, sofre com os riscos de colapso e esgotamento de recursos, como o ocorrido no início do século XXI. Em vista disto, surge a necessidade de promover o crescimento na utilização de outras fontes de energia menos poluentes, dentre elas a energia solar fotovoltaica. Alguns fatores contribuem para o crescimento do uso dessa tecnologia, tais como: chuvas escassas, aumentos constantes das tarifas de energia elétrica, isenção de impostos e ampliação de linhas de créditos que garantem recursos para o melhor aproveitamento da radiação solar abundante. Neste contexto, o presente artigo objetivou analisar a

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viabilidade da implantação do sistema de geração de energia solar, a partir da instalação de painéis fotovoltaicos, na sede administrativa da prefeitura de Curitiba (PR), buscando incentivar a ampliação no acesso à energia fotovoltaica, como forma de reduzir os gastos com energia elétrica, preservar o meio ambiente e maximizar a eficiência energética do município. Trata-se de um estudo de caráter exploratório, desenvolvido com base em dados obtidos de fontes secundárias, que proporcionou uma nova abordagem a respeito do tema e possibilitou o alcance significativo de resultados positivos, inclusive o financeiro.

Keywords: Fontes renováveis de energia; Energia solar fotovoltaica; Eficiência energética

1 INTRODUCTION

Brazil has great potential for energy generation, with regard to the availability of natural resources, solar incidence rate and territorial areas suitable for the development of renewable energy sources (SANTOS, 2019). According to the 2020 energy balance, developed by the EPE (Energy Research Company), renewable energy sources represent 83% of the domestic electricity supply in Brazil, resulting from the sum of national production plus imports (EPE, 2020). Despite this, the country suffers from a serious energy crisis, caused by the lack of investments in the sector, limitation in technological development processes and the creation of incentives that prioritize the generation and distribution of electricity from the use of renewable sources (ALTOÉ *et al.*, 2017).

According Kruse (2017), the electricity sector is responsible for a considerable part of the emission of gases and other pollutants that interfere with air quality, and it is still a growing problem for the Brazilian energy hub. In this context, the constant demand for energy and the dependence on the use of non-renewable energy sources, causes energy insecurity and requires drastic changes in the country, making it necessary to develop other sources that are not limited and that allow maintaining the structure whether rural or, mainly urban, ensuring the development of activities without harming the environment and the population's quality of life (SILVA *et al.*, 2019).

The feasibility of energy production from renewable sources, such as: solar, wind, water, biomass, geothermal, among others, has been guided by several

researches and studies, as they are considered inexhaustible reserves, offer energy security to society, help in reducing environmental impacts and promoting growth in the number of jobs and in the country's level of economic and social development (TOLMASQUIM, 2016).

According Freitas and Dathein (2013)

> The expansion of the use of renewable sources in the energy matrix contributes to achieving better levels of development, which is verified by the variations in the level of sustainability that occur with the increased use of these energies.

In this sense, the present study was developed based on the following research problem: What is the participation of the Curitiba City Hall in environmental preservation, from the use of renewable energy sources?

According to the Brazilian Association of Photovoltaic Solar Energy, photovoltaic energy represents only 1.6% of the Brazilian electrical matrix (ABSOLAR, 2021). The main objective of this work was to encourage the expansion of access to the source of photovoltaic solar energy, based on the analysis and investigation of the incentives used to transform Curitiba City Hall into a source of solar energy for the municipality.

With this in mind, the energy efficiency project proposed by the city of Curitiba was analyzed, from January 2017 to December 2020, in order to identify and spread the benefits achieved after the installation of photovoltaic panels at Palácio 29 de Março (Curitiba City Hall), aiming to encourage the expansion of the use of the photovoltaic solar system in this region.

The choice of this theme is justified due to the need to disseminate the improvements generated by adherence to the energy efficiency process, which allow expanding the growth of the renewable energy sector, aiming at universalizing access to electricity, avoiding future supply problems, reducing environmental impacts of the project's area of influence, in addition to demonstrating the reduction in electricity costs and ensuring the sustainable development of the municipality.

In this scenario, this study initially presented a brief description about the concepts about the process of generating photovoltaic solar energy. Next, the main fiscal and political incentives created to stimulate the growth of this process. Finally, an analysis of the benefits achieved by Curitiba City Hall with the adhesion to the Curitiba Mais Energia Program was carried out, demonstrating the need to promote awareness among municipal representatives regarding the expansion in the use of renewable energy sources, as a way to improve the economic development and increase the energy efficiency of their regions.

2 LITERATURE REVISION

This study is based on three foundations: In item 2.1, the basic considerations of photovoltaic solar energy were discussed; item 2.2 discussed incentives for the generation of photovoltaic solar energy; and, in 2.3, the Curitiba Mais Energia Program and the process of installing photovoltaic panels at the Curitiba City Hall were discussed.

2.1 Solar photovoltaic energy

Electricity generation can be conceptualized in two ways: centralized generation and distributed generation. Centralized generation is related to the conventional way of obtaining electricity, predominantly the use of generating plants, such as hydroelectric plants, which produce energy and send it to consumers through transmission networks (TOLMASQUIM, 2016).

On the other hand, distributed generation, according ANEEL (National Electric Energy Agency) is that performed through the installation of small generators, mainly from renewable energy sources, located close to consumption centers or even in the consumer unit itself , such as: houses, shopping centers and companies, which are connected to the public electricity network (ANEEL, 2016).

According ANEEL (2016), the renewable sources that can be used by consumers to generate their own energy are: solar, wind, biomass and water. Of those mentioned, the one with the greatest ease of use in Brazil is photovoltaic solar energy, as it is generated from the direct conversion of solar radiation into electricity, through the use of photovoltaic panels (CRESESB, 2006). According Silva (2015), photovoltaic panels are formed by a set of photovoltaic cells and can be interconnected in order to allow the assembly of modular arrangements that, together, can increase the capacity for generating electricity.

According Santos *et al.* (2013),

> Photovoltaic modules work as collectors, which absorb solar radiation and transform it into electricity through a process known as the photovoltaic effect - a phenomenon presented by certain materials exposed to light that generate electricity.

Thus, the greater the solar radiation on the solar plates, the greater the amount of electrical energy produced. Despite this, for a long time, investment in photovoltaic solar energy was considered unfeasible due to the high cost of purchasing and installing solar panels. However, in recent years, due to the considerable increase in tariffs and taxes levied on the conventional electricity bill, there has been a change in this scenario, allowing photovoltaic solar energy to compete economically with other sources (NAKABAYASHI, 2014).

The use of photovoltaic systems for electricity generation in Brazil was allowed from 1994, with the creation of PRODEEM (Program for the Development of Energy in States and Municipalities), established by Decree of December 27, 1994 (BRASIL, 1994), with the objective of enabling the installation of micro energy systems in isolated and needy communities, without access to the electric network, aiming to support the fulfillment of their basic social needs.

Years later, in April 2012, ANEEL instituted Normative Resolution No. 482 - REN 482/2012 (ANEEL, 2012), updated by ANEEL Normative Resolution No. 687, of November 24, 2015 - REN 687/2015 (ANEEL, 2015), which represented a great advance on the part of public policies in relation to stimulating the growth of

energy production from renewable sources, as through these the conditions of access of micro-generation and mini-generation to electric energy distribution systems were defined, which can be established as follows (ANEEL, 2015):

> Micro-generation: Electric energy generating system from renewable sources, with installed power less than or equal to 75 kW (kilowatts).
>
> Mini-generation: Electric energy generator system, with installed power greater than 75 kW and less than or equal to 3 MW (for hydro sources) and less than or equal to 5 MW for other renewable sources (Solar, wind, biomass and qualified cogeneration).

The REN 482/2012 (ANEEL, 2012) also established the electric energy compensation system, it is a procedure in which consumers-generators that meet the criteria of micro or mini generation, can inject excess energy generation into the grid. distributor, which will be registered as a credit in kWh, and can be used within a period of up to 60 months, which has brought benefits to consumers in seasonal periods, when energy generation is reduced

Therefore, since the normative acts were created in 2012, the interest of consumers in generating their own energy has grown, which allowed an increase in the participation of distributed energy generation in the national energy balance (MONTEIRO and SILVEIRA, 2018).

According Nakabayashi (2014), currently, the cost of photovoltaic solar energy basically depends on the following factors: available solar irradiation, performance and cost of photovoltaic systems. Consequently, the investment in photovoltaic energy generating panels has grown and become attractive, because unlike other renewable sources that require great planning and space to be installed, photovoltaic solar energy offers a silent operation without emission of pollutants, and can be easily installed in homes, commercial buildings or businesses.

Nakabayashi (2014) still says that:

> It is only a matter of time for tariff parity to occur in all cities in Brazil and for solar photovoltaic energy to become more financially attractive, as solar photovoltaic energy has a trajectory of decreasing costs year after year and, at

> the same time, the electricity generated by conventional sources presents a trajectory of increasing costs.

With this in mind, it is important to highlight the need for incentives on the part of public policies to boost the sale of energy generated by renewable sources, aiming to favor the supply chain, generate jobs and contribute to economic and social growth, increasing competitiveness and development of this sector (STEFANELLO *et al.*, 2018).

2.2 Incentives for solar photovoltaic energy generation

For the country to be able to reach a level of sustainable development, it is necessary to have abundant sources of natural resources, participation in well-designed public policies and the involvement of the population through the creation of environmental awareness and changes focused on daily actions (FREITAS and DATHEIN, 2013).

Tax incentives are a way found by the government to reduce or waive the cost of taxes or charges on a certain activity or product, aiming to encourage the development of a certain sector (SACHSIDA and SIMAS, 2018). According França (2016), tax incentives allow the renewable energy sector to develop, expanding energy generation and marketing and favoring the sector's supply chain as a whole.

In order to make the production of photovoltaic energy in Brazil feasible, some fiscal and political incentives were created, in addition to REN 482/2012 (ANEEL, 2012), and have favored the expansion of this sector in the country. This work highlights those that have direct implication with the generation and expansion of the sector in question, among them: the ICMS Agreement (Tax on the Circulation of Goods and Services) of CONFAZ (National Council for Finance Policy), the REIDI (Special Regime of Incentive for Infrastructure Development), PADIS (Support Program for Technological Development of the Semiconductor and

Display Industry), and PROGD (Climate Fund Program and Distributed Generation Program).

CONFAZ entered into two agreements (101/97 and 16/2015, respectively CONFAZ, 1997; and CONFAZ, 2015), which guaranteed exemption from ICMS, a tax on the prices of domestic and imported products, interstate transport services and intercity and communication. The exemption applies to operations involving some equipment intended for the generation of electricity by photovoltaic cells, exempting states from charging ICMS on energy injected into the network.

REIDI is another project created by the government through Law No. 11.488 (BRASIL, 2007a), which suspends the payment of tax contributions: PIS (Social Integration Program), PASEP (Program for the Formation of Public Servant Heritage) and COFINS (Contribution to Social Security Financing), for cases of sale or import of new machinery, apparatus, instruments and equipment, and construction materials for use or incorporation in infrastructure works for fixed assets (BRASIL, 2007a).

This benefit extends to a legal entity governed by private law, which has an approved project for the implementation of infrastructure works in the transport, ports, energy, basic sanitation and irrigation sectors, which includes photovoltaic plants (BRASIL, 2007a).

Established by Law nº 11.484/07 (BRASIL, 2007b) and regulated by Decree nº 10,615 (BRASIL, 2021) and by the Normative Instruction of the Federal Revenue of Brazil nº 1,976 (BRASIL, 2020), PADIS is a set of incentives created with objective of attracting investments and leveraging the implementation of photovoltaic cells and modules/panels in the country, benefiting the production chain and commercialization of solar panels (BRASIL, 2021).

According to Articles 2 and 3 of Decree nº 10.615 (BRASIL, 2021), PADIS reduces to zero the rates of federal taxes and contributions, such as: IPI, PIS/PASEP - Import and COFINS - Import, levied on the import of machines, apparatus,

instruments, equipment, inputs and specific software, intended for fixed assets and production, in addition to the IPI, PIS/PASEP and COFINS rates on sales in the domestic market, of the IRPJ (Corporate Income Tax), and CIDE (Contribution for Intervention in the Economic Domain), provided that interested companies make investments in research and development activities related to the sector (BRASIL, 2021).

Within this context, the Climate Fund was created, established by Law nº 12.114/09 (BRASIL, 2009), and currently governed by Decree 10.143/19 (BRASIL, 2019), with the objective of minimizing the impacts of global warming, and reducing the emission of greenhouse gases. The program is linked to the MMA (Ministry of the Environment) and aims to guarantee resources to support projects or study and finance projects that help reduce the impacts caused to the climate and its effects, providing credit lines with the BNDES (National Bank of the Development), to support technological development and the production chain of the renewable energy sector.

Similar to the Climate Fund, the PROGD (Distributed Generation Program) is another incentive created by the MME (Ministry of Mines and Energy), which aims to expand actions to stimulate energy generation for own consumption, offering credit lines and ease of use. financing for the creation of projects to install solar panels in homes, industries, businesses, universities and hospitals, aiming to reduce the emission of CO_2 into the atmosphere and allow consumers to sell their excess energy to the local distributor, in exchange for credits that can be used within a period of five years, to reduce the electricity bill in other months (PORTARIA 538, 2015).

Another project that was recently approved by the Chamber of Deputies and awaits approval by the Federal Senate, is Bill PL 5829/19 (2021), which provides a series of benefits to encourage solar energy generation and support micro and mini energy generators. The proposal establishes a transition in the collection of

charges and tariffs for the use of distribution systems, maintaining the exemption from charges until 2045, for consumers who already have the structures and also for those who request access to the distributors' network, in the period of 12 months from the publication of the new legislation. For new consumers, there will be a gradual charging of charges, starting at 15% in 2023, until reaching 100% in 2029 (CAMARA DOS DEPUTADOS, 2021).

In this sense, we sought to analyze the benefits obtained with the installation of photovoltaic panels in the city hall, in order to identify mechanisms that help in the expansion of the use of photovoltaic solar systems in public or private places, ensuring improvement in energy efficiency, in addition to promote sustainability, protect and preserve the environment and the quality of urban life.

2.3 Curitiba Mais Energia program and the process of installation of photovoltaic panels at the Curitiba City Hall

The city of Curitiba is famous worldwide for its urban planning model, sustainability and concern for the preservation of green areas and the quality of life of the urban population (CMC, 2015).

According to the executive president of ABSOLAR, despite having a predominantly cloudy climate, the city of Curitiba has great potential for capturing solar rays and generating energy, with a high incidence of light rays, above, for example, Salvador, known for its sunny days throughout the year. According to the president, in solar energy generation, hot weather is a secondary factor, with the radiation index being the most relevant factor for the generation of photovoltaic solar energy (ABSOLAR, 2020).

With a focus on taking advantage of the existing solar potential, the capital created the Curitiba More Energy Program, developed with the objective of preserving the municipality's natural resources and encouraging the use of renewable energies. The project was selected by the C40 of the CFF (Cities Finance

Facility), a program financed by the German Ministry of Economic Development, which supports developing countries in implementing projects that help reduce GHG (greenhouse gas) emissions and global temperature. Curitiba competed with other 120 cities around the world and was one of the nine chosen to receive US$ 1 million, for structuring projects for the installation of photovoltaic panels in the city (PMC, 2018).

In order to make renewable energy generation projects feasible in municipal public goods, the mayor sanctioned on August 23, 2018, Law 15.277 (PMC, 2018), which includes the sources: hydraulic, kinetic (wind and ocean), solar, biomass, residual biomass, gravitational (tidal) and geothermal as possible generating sources.

According to the technical advisor of the SMMA (Municipal Environment Secretariat) of Curitiba, during a participation in the Connected Smart Cities and Mobility Forum, which dealt with environmental preservation projects in the municipality, the Curitiba Mais Energia Program began to become a reality with the project to install photovoltaic panels on the roof of the city hall. At a time when there is a lot of talk about global warming, pollution and the greenhouse effect, Curitiba is betting on a true “solar revolution”, with ecological solutions that mix urban aspects with nature, aiming to combat these problems (PMC, 2021).

On December 17, 2018, the Secretary of SMMA signed contract No. 23.293 with the company Quantum Engenharia Ltda., winner of the bidding process. On December 19 of the same year, the mayor signed the service order, authorizing the installation of 439 solar panels on the roof of the Curitiba City Hall building. The amount invested in the project was R$ 997,277.00, of which 86% was paid by Copel (State Electric Energy Company) and 14% was paid by the Municipality. Of this amount, BRL 552,374.11 refers to the amount defined in the contract for payment of the installation of photovoltaic panels to the company Quantum, the remainder

covers the modernization of 5.8 thousand lighting points with the exchange of conventional light bulbs for LED (PMC, 2018a).

The funds were obtained through a partnership between the city hall and Copel Energy Efficiency Program. This is a term of cooperation between the municipality and Copel, through which Copel transferred funds from the Public Call VPDE 003/2017 (PMC, 2018a), a project that was regulated by ANEEL, being one of the largest made possible by this program in the State of Parana.

According to Copel: by transforming a public building into a source of energy, the company and the municipality provide an example of how the use of financial and environmental resources can be reverted to the benefit of citizens. According to the president of Copel: "the company fulfills its role as a company committed to sustainability by encouraging, promoting and advising innovative projects that not only take advantage of natural resources but also generate savings for public coffers" (GOVERNO DO PARANÁ, 2019).

The photovoltaic system with a total capacity of 144 kWp, and capable of generating 212 MWh/year, went into operation on June 5, 2019, in celebration of World Environment Day, becoming the first public building powered by solar energy. According to the mayor, this is an energy efficiency milestone for the city of Curitiba (GOVERNO DO PARANÁ, 2019).

3 METHODOLOGY

The present study was developed with an exploratory character where, according to Andrade (2010), the purposes of an exploratory research are to provide more information on a given subject; to facilitate the delimitation of a theme; to define the objectives or formulate the hypotheses of a research, or to discover a new type of approach for the work in mind.

According to Marconi and Lakatos (2003), the exploratory study would be empirical research investigations whose objective is to formulate questions or a

problem, with a triple purpose: to develop hypotheses, increase the researcher's familiarity with an environment, fact or phenomenon, to conducting more accurate future research.

The data collection instrument adopted in the development of this work was the bibliographic research, according to Marconi and Lakatos (2003), it is a general overview of the main works already carried out, coated with importance, for being able to provide current data and relevant related to the topic.

For Köche (2011), the objective of bibliographical research, therefore, is to know and analyze the main existing theoretical contributions on a given topic or problem, making it an indispensable tool for any type of research.

This research was developed through bibliographic analysis obtained from secondary sources, such as: reading and recording of information extracted from articles, books, theses, dissertations, official and public archives related to the proposed theme. According to Marconi and Lakatos (2003), secondary sources cover all bibliography already made public in relation to the subject of study, from single publications, bulletins, newspapers, magazines, books, research, monographs, theses, cartographic material.

For Andrade (2010), secondary sources consist of literature about primary sources, that is, works that interpret and analyze primary sources. In this way, bibliographic research provides the development of a new approach to a given subject, providing innovative conclusions (MARCONI and LAKATOS, 2003).

After the data manipulation process, the interpretation and analysis of the data was performed, in an attempt to highlight the existing relationships between the phenomenon studied and other factors (MARCONI and LAKATOS, 2003). Therefore, according to Andrade (2010), the objective of the analysis is to organize and classify the data so that answers to the proposed problems can be extracted from them, while the interpretation seeks a broader sense in the answers. For the purpose of analyzing the benefits obtained after the installation of the photovoltaic system in Curitiba City Hall, a

survey was carried out on the municipality's transparency portal, in the sector of budget planning and execution expenses, where it was possible to access payments made to the company. Copel and obtain monthly electricity costs between January, 2017 and December, 2020 (PMC, 2021).

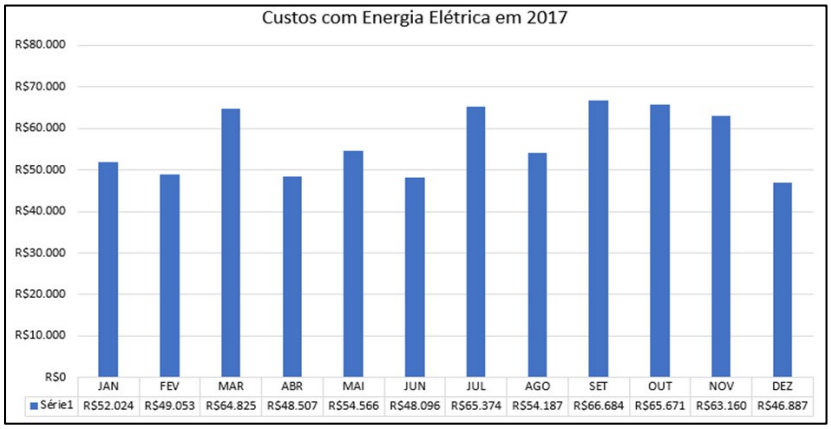
The period chosen was essential for the study, as it allowed for a comparison between the expenses incurred, two years before the inauguration of the project and a year and a half after the system was in operation.

4 ANALYSIS AND DISCUSSIONS

According to data obtained from the transparency portal, as of July 2017, the City Hall showed a considerable increase in electricity consumption, which represented a 36% growth in the value of invoices (Graph 1).

According to data obtained from the transparency portal, as of July 2017, the City Hall showed a considerable increase in electricity consumption, which represented a 36% growth in the value of invoices

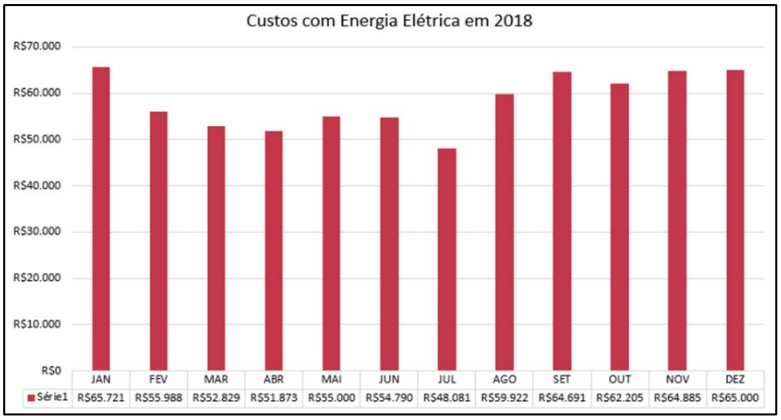
Graph 1 – Costs with electricity (BRL/month) at the headquarters of the City Hall of Curitiba in 2017



Source: Transparency Portal - City Hall (PMC, 2021)

In 2018, electricity consumption and expenses continued to increase every month (Graph 2), where only in July there was a reduction compared to the previous year.

Graph 2 – Costs with electricity (R$/month) in the City Hall in 2018



Source: Transparency Portal - City Hall (PMC, 2021)

Aiming to reduce energy costs, in 2018, the City Hall began the bidding process, with the intention of modernizing 5,800 lighting points, by replacing conventional light bulbs with LED, in addition to promoting the installation of photovoltaic panels at the headquarters, with the intention that the system, once installed, would supply a large part of the energy consumed monthly.

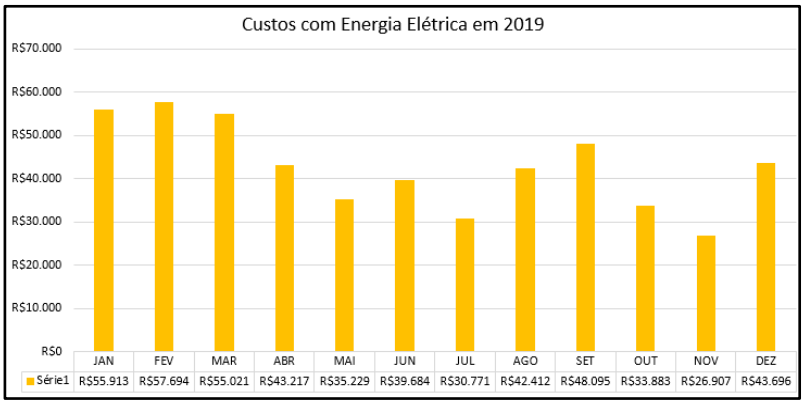
In early 2019, the company Quantum Engenharia began installing 439 solar panels on the roof of the City Hall. In total, 03 modules were installed, representing an area of 878m2, with a total capacity of 144 kWp and can generate 212 MWh/year (Figura 1)

Figure 1 – Photo of photovoltaic panels installed at the headquarters of the City Hall of Curitiba

Source: Prefeitura Municipal de Curitiba, 2019

On June 5, 2019, the photovoltaic system went into operation, starting to produce part of the energy consumed by the building, thus reducing the demand for energy supplied by Copel. It is possible to see a drop in the value of energy bills a few months after the start of operation of the solar panels (Graph 3).

Graph 3 – Costs with electricity (R$/month) at the headquarters of the City Hall of Curitiba in 2019



Source: Transparency Portal - City Hall (PMC, 2021)

According to SMMA, in one year of operation, the photovoltaic panels installed on the roof of the city hall were responsible for the generation of 205 MWh, it is clean energy that resulted in 28 tons less CO_2 released into the atmosphere, which can be compared to the “ecological work” of 200 trees.

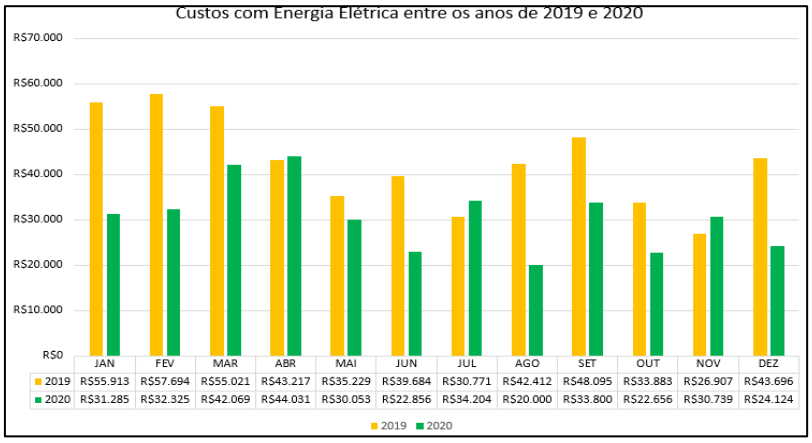
In addition to benefiting the environment, creating a renewable and sustainable energy source, the municipality also saved in one year of operation, the equivalent of R$ 106,000 in electricity costs, which represents savings equivalent to 38% in bills of light. It is noteworthy that part of this savings was due to the replacement of conventional light bulbs with LED and the awareness work carried out by the city with users and employees of the building.

It is important to point out that the time required to obtain the return on investment from solar panels is five years, considering that photovoltaic panels last at least 25 years, the other 20 years are of savings. In addition, the system requires

little maintenance, with only an annual inspection for cleaning and preventive evaluation being recommended.

In 2020, there was a reduction in average energy costs, demonstrating that the system becomes more efficient after a few months of operation (Graph 4).

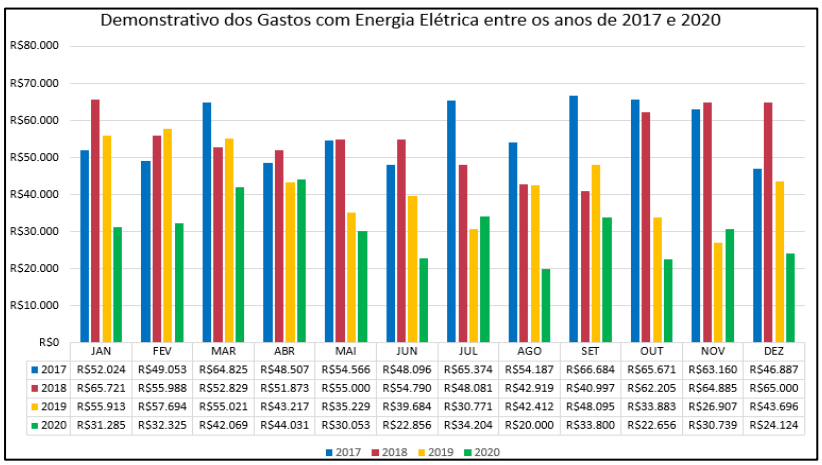
Graph 4 – Electricity costs (R$/month) in the City of Curitiba between 2019 and 2020



Source: Transparency Portal - City Hall (PMC, 2021)

In this context, Graph 5 provides a statement of average expenditures between the years 2017 and 2020, and it is possible to see that the invoices prior to the installation of the photovoltaic panels were close to R$ 60 K/month, this reality changes some months after the system starts operating, period in which it is possible to view average monthly invoices of R$ 20 K.

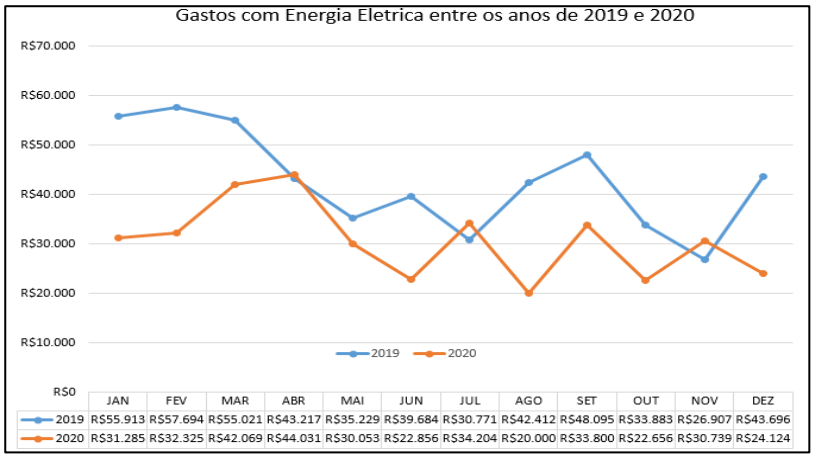
Graph 5 – Statement of electricity expenditures (R$/month) of the City Hall of Curitiba between 2017 and 2020



Source: Transparency Portal - City Hall (PMC, 2021)

The drop in energy consumption is even more evident when comparing the years 2019 and 2020 alone (Graph 6), in which it is possible to observe this reduction month by month.

Graph 6 – Comparison of electricity expenditure (R$/month) at the headquarters of the City Hall of Curitiba between 2019 and 2020



	JAN	FEV	MAR	ABR	MAI	JUN	JUL	AGO	SET	OUT	NOV	DEZ
2019	R$55.913	R$57.694	R$55.021	R$43.217	R$35.229	R$39.684	R$30.771	R$42.412	R$48.095	R$33.883	R$26.907	R$43.696
2020	R$31.285	R$32.325	R$42.069	R$44.031	R$30.053	R$22.856	R$34.204	R$20.000	R$33.800	R$22.656	R$30.739	R$24.124

Source: Transparency Portal - City Hall (PMC, 2021)

It is important to emphasize that the photovoltaic energy generated in the city hall is monitored through the Shine Monitor system, it is a device used to collect and send system information to an online platform, which checks the performance and progress of photovoltaic installations, facilitating access to data related to the quantity produced and also on the generated savings. In addition to identifying any system problems, allowing them to be corrected before jeopardizing the operation.

Thus, from an economic and environmental point of view, it is possible to affirm that the installation of photovoltaic panels at the administrative headquarters of the city hall achieved positive results, as it guaranteed a reduction in electricity costs, expanded the dissemination of sustainable projects, encouraged energy generation from the use of renewable sources, in addition to helping to diversify the municipality's energy matrix.

Some factors have contributed to the growth in the implementation of photovoltaic panels in homes, buildings and commercial establishments in the

region, such as: tax incentive programs, which promote the exemption of taxes and duties, helping to reduce costs for the acquisition of solar panels, and the availability of credit lines in financial institutions, which help to obtain resources and allow the best use of available solar radiation.

Within this context, the city hall expanded the projects for the installation of solar panels in the city, which include houses delivered by COHAB (Popular Housing Company, installation of solar energy on the Curitiba bus station, in the bus terminals in the Pinheirinho, Santa Cândida and Boqueirão neighborhoods, at the TECPAR Campus (Technology of Parana), among other universities, hospitals and schools.

In addition, the city is closer to enabling the implementation of the solar pyramid at the Caximba landfill, a photovoltaic and biomass generating unit with a total installed power of 5MW. It is estimated that the annual production of energy generated in Caximba is around 18,600 MWh, energy that will be used to offset approximately 43% of the consumption of municipal buildings in the city (PMC, 2020).

Another situation that has encouraged City Hall to invest in alternative energy sources is the serious water crisis that hit the region from the second half of 2020, the level of reservoirs is worrying, and it is necessary to carry out rotations between the city's neighborhoods so that there is no shortage of water for the population, this reality increases the cost of conventional electricity and reaffirms the justification for preparing this work, in addition to expanding the line of research to new others that aim to encourage the expansion of access to the source of photovoltaic solar energy in the municipality or other public bodies (PMC, 2021b).

5 FINAL CONSIDERATIONS

This study proves that the adoption of photovoltaic systems in public spaces helps to save electricity, combining environmental sustainability with great cost-

benefit, in addition to promoting economic development and helping to reduce environmental impacts in the region.

Between 2019 and 2020, the city of Curitiba recorded a 50% growth in installed photovoltaic power, from 6.6 to 9.9 MW, an important result for the municipality, which had accumulated investments in the sector, with the possibility of creating jobs and generating income for the population.

Given the above, it is believed that investment in photovoltaic energy generation systems should be encouraged by the public sector, so that they become more frequent, due to the possibility of energy savings and the rapid financial return of the system, of participation and encouragement of public policies, and awareness of the population in search of projects aimed at generating clean and sustainable energy.

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