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Implementation of photovoltaic energy, sustainability, economic and social development in a Higher Education Institution in Brazil

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ABSTRACT
Energy is a crucial element for human needs today. Traditional systems of energy generation have represented a problem in terms of their costs, their impact on the environment, and their impact on community life. Therefore, the search for clean and renewable energy sources that meet the needs of contemporary society becomes increasingly essential in the search for alternatives related to energy sources. The photovoltaic energy generation system explores the solar irradiation, making it possible to generate and store energy. This system finds good conditions for implementation in Brazil in terms of climatic characteristics, but investments and public policies that encourage and favor this process are still needed. This study aimed to identify how the deployment of photovoltaic mini-generation power plant in a federal university, the Federal University of Paraná (UFPR), can contribute to the university community in relation to cost reduction and environmental preservation. The methodology used was descriptive-exploratory, qualitative, through which an open questionnaire and a semi-structured interview were carried out, guided by the theme. After analyzing the data, the conclusion was that the system can bring benefits in the long term and that most of the interviewees consider Brazil's great potential in expanding the exploration of other sources of energy, besides hydroelectric, which, besides being costly, brings fewer advantages related to the environmental and social contexts.

Palavras-chave: solar energy; photovoltaic energy; sustainability.
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1 INTRODUCTION

With the globalized world growth, there is a tendency of populational increase in large metropolis, or even in rural areas. Its consequences are new housing, commercial and industrial constructions, lighting for homes and public roads to meet human needs. In turn, the demands for the construction of new plants that generate electricity increase. As a result, deforestation increases, bringing huge impacts to environmental resources, such as climate change, low quality, and quantity of water, silting up of reservoirs, riverbeds erosion, which triggers transformations in the entire ecosystem. This is the result of the conventional electric energy generation and production system, the use of hydroelectric plants.

Some alternatives, such as thermoelectric and nuclear plants, for instance, also directly impact the environment in which they are installed, leading governments to invest in safety systems to prevent environmental disasters. Before these negative impacts on conventional electricity generation,

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alternatives to meet the needs of electricity consumption that could be generated by renewable and non-polluting means were sought. One of the alternatives that present environmental and economic advantages is the generation of photovoltaic solar energy, through which, from the capture of solar energy, it is possible to generate and store electric energy for residential, commercial, industrial applications, among other social needs resulting from the human activity.

This article is part of a doctoral thesis that researches the development model of photovoltaic energy in Brazil as a favorable alternative to the environmental issue. The study aims to identify how the implementation of a photovoltaic mini generation plant in a federal university, the Federal University of Paraná (*UFPR – Universidade Federal do Paraná*), can contribute to the university community in relation to cost reduction and environmental preservation.

2 HISTORY OF HYDROELECTRIC POWER PLANT IN BRAZIL

The construction of the first hydroelectric plant in Brazil and South America took place in 1889, in the city of Juiz de Fora (MG), with 5 (five) turbines that generated 4.8MW. Due to the growth in demand, this plant stopped generating energy for the National Interconnected System (SIN) on April 2, 1980, through order number 928 published in the Federal Official Gazette and which today belongs to a company called Cemig (Energisa Group, 2022).

In 1905, a group formed by three entrepreneurs founded an electric power company in the state of Minas Gerais. Since its foundation, the electric energy company has progressed and provides such services as generation through hydroelectric plants, biomass, and wind energy systems to the community in several cities in this same state. The company is currently investing on clean renewable energy, such as the solar photovoltaic system (Energisa Group, 2022)

Since 1970, industries start investments and increase production in Brazil, since it is a developing country, consequently needing to meet the demands of electricity. In 1975, the construction of the *Itaipu* Binational hydroelectric power plant begins, through the Basic Plan for the Environment Conservation, which led to the formulation of projects aiming its animal and vegetation conservation. Thus, in 1979 and 1987, seminars on the Environment were held by *Itaipu* Binational (Mazzarollo, 2003).

3 CONSTRUCTION OF HYDROELECTRIC PLANTS IN THE INTERNATIONAL VIEW

The Plant construction had international repercussions due to environment damages, such as deforestation, flooding of fertile lands, in addition to causing the expropriation of residents in the regions along the rivers, in the name of economic development. In this context, the society started to analyze the idea of nature conservation proposed by Itaipu, inserted in a moment that is marked both

by the perception that development caused the devastation of the environment, and by the developmental idea in Brazil (Ziober; Zanirato, 2014).

It is understood that environmental problems do not affect only the places where disasters occur, but rather, they go beyond borders, reaching various places due to pollution caused by industries, emitting toxic gases in the atmospheres, rivers, and many other locations, leading, thus, to the emerge of the International Environmental Order to discuss environmental problems (Ribeiro, 2005).

As the environment disasters reached global scale, some international conferences started to arise, such as the one in Stockholm, Sweden, the United Nations Conference on Development and Human Environment. At that Conference, the issued addressed were atmospheric and water pollution, caused by industrialization and soil pollution, seeking strategies to reduce it, in addition to the demographic increase and its reflexes on Earth's resources. Another discussed topic were the so called “zero growth” (desiring to block the economic and industrial growth) and developmental growth (claiming growth coming from industry). This last developmental model would fit in Brazil (Ribeiro, 2005).

In this context, energy conservation appears as a new fact, a convergence of interest points in which companies and consumers start to seek, together, actions and postures that represent a good deal for both. Furthermore, energy conservation is among the initiatives that make up a commitment to the future, in which such fundamental aspects as environmental preservation, optimization of economic resources, among others, will determine the system effectiveness, a condition in which socio-economic benefits are important for sustainability.

The conservation of electric energy is also a practice used by people interested in reducing the environmental impacts of the main energy sources such as hydroelectric, nuclear, fossil fuels, among others. Also, conserving energy means to rationally use available electricity, thereby avoiding environmental damage. In Brazil, there were two energy systems that were renewable, hydroelectricity and biomass. Currently, there is also the photovoltaic system, which has the sun as a natural source. For the first system, there is high hydraulic potential; for the second, there are immense areas for agriculture; while the third, which is photovoltaic, it comes from the sun that generates clean energy.

4 ALTERNATIVE SOURCE

Solar radiation is the energy emitted by the Sun in the form of radiation, electromagnetic wave, so we understand that it is a source that can be used to generate electrical energy. But we cannot discard the two sources, sun and water, as great allies, as alternatives mentioned above. Thus, conserving energy is to obtain the best result with the lowest consumption, with no harm to industry, commerce, and service provision results, as well as home comfort. The most dynamic concept, which is associated

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with economic growth, productivity, environmental protection, and sustainable development, is defined as energy efficiency (Santos, 2022).

With conservation, there is an energy expense reduction, a better facility and equipment use, as well as an increased safety. Information on energy sources and their alternatives has increased, so that the consumer's first concern is the type of energy to be used, that is, photovoltaic, wind, biodigester, among others. Regarding the wind system, according to "Conectas Human Rights", wind parks in the northeastern hinterland have a direct impact on traditional communities, as observed by the Conectas team and the Internationale Accountability Project, located in *Chapada do Araripe*. The biodigesters that are used in rural fields take advantage of organic residues and sewage, collected in rural areas, are used on a smaller scale, because they depend on the waste resulting from each rural property. The sun, which exists in nature at no financial cost, provides energy by transforming its light into electricity through the photovoltaic effect. Thus, the electricity supply situation is not recent, as shown by the research carried out by the historian Verônica Pimenta Velloso in Brazil, a period in which the order of the day was the rationing of electricity due to the crisis in the sector. (Memory of Electricity, 2001).

In 1981, the federal government created the "Conserve" Program. It aimed to highlight Energy Conservation, an initiative that would have a commitment to the future, where fundamental aspects such as preservation of the environment, optimization of economic resources, among others, would determine the effectiveness of the system, generating maximum social and economic benefits. (Brazil, 2019).

In October 2001, Law No. 10,295 was enacted on the National Policy for the Conservation and Rational Energy Use, where the main topic was the maximum and minimum energy consumption of energy-efficient machines and appliances manufactured and sold in the country. In this program, minimum performance levels were inserted for three-phase induction electric motors, compact fluorescent lamps, and various household appliances. (Nogueira, 2007).

5 THE ENVIRONMENTAL DIMENSION

The environmental issue is undoubtedly quite complex, since it is integrated by several components of the physical environment (air, water, soil, subsoil), the biotic environment (fauna and flora) and the anthropic environment (social, economic, and cultural), which integrate among themselves, being able to be cause and effect simultaneously. It should not be forgotten that political, administrative, public, and private aspects also interfere in the environmental issue. (Oak, 2019)

The numbers indicate that population growth will be 0.74%, that is, Brazilian population would reach 213.3 million people in 2021 and the projection is that this number will increase until the year 2030. With this estimate of population growth, either an energy generation increase will be needed to

meet demand or an increase in generators production would be necessary to meet the predicted needs at peak hours. (IBGE, 2022).

With the emergence of technology of sunlight use, and because it is a system that does not generate pollution in the environment, the implementation of photovoltaic plants in several countries with sustainable energy matrix begins, strengthening itself in countries such as Germany, United States, China, and Japan. All these countries developed the National Innovation System and its public and economic policies together within each country reality. It is important to highlight that this process depends on public policies that enable and favor the implementation of renewable and clean energy generation systems, targeting investments to this project. Despite this, what is currently seen is still the privilege of investments directed to energy generated through hydroelectric plants, which are more expensive and less favorable to the environmental issue.

6 RULES AND RESOLUTION

In Brazil, with ANEEL Normative Resolution No. 482 OF 04/17/2012, an alternative that allowed the consumer to generate their own energy from a renewable source and that the surplus energy would return for distribution in their locality was presented. Normative Resolution No. 414/2010 aimed to reduce the costs and connection time of micro generation and mini generation to make the electricity compensation system compatible with the general supply conditions. Also with Normative Resolution No. 482/2012, revised by Normative No. 687/20156, there was an increase and improvement in the information on invoices to consumers. The Normative Resolutions were important for the growth in energy generation from renewable sources. The highlight of this movement took place in 2016, worldwide, mainly about photovoltaic solar energy, which came to benefit the Brazilian system in places such as: rural areas and urban centers, being favorable for Brazil due to the high radiation in territories, being able and favoring the installations of this system, whether private or public (Coelho et al., 2018).

Conserving energy is not just turning off energy, losing quality of life, failing to use the necessary energy, compromising productivity or production performance in industrial, commercial, agricultural, or public agencies and rationing applications. It is important to remember that conserving electrical energy is fundamental, in order to eliminate waste, use energy efficiently, spend only what is necessary, seek maximum performance with minimum consumption, have environmental education and make a commitment to the preservation of the planet environment.

For energy control, it is extremely important to monitor consumption and adopt measures to reduce it. For large consumers and institutions, the task of controlling consumption is complex and requires a lot of discipline and planning. With all this information, it represented a problem in the past,

with population growth and the consequent multiplication of industrial and economic activities, generating a gigantic energy consumption. To try to alleviate the situation, consumers, industries, businesses, and public intitutions started to use an immediate solution that was to replace incandescent and fluorescent lamps with more efficient equipment and more rational lighting, with greater use of sunlight, in addition to new more economical technologies obeying the Norms like *Inmetro* and the National Agency of Electric Energy - ANEEL. With all these measures and solutions found for the replacement of electrical equipment or materials, good results were not achieved. New studies were started on the choice of electric power generation system, but difficulties arose in seeking the financial resources for projects. As we mentioned earlier, this financing resource came after the creation of PROCEL, which brought benefits to concessionaires and consumers.

7 EVOLUTION OF THE PHOTOVOLTAIC SYSTEM

The Federal University of Ceará and the Federal Center for Technological Education of Ceará, in 2003, had the first experiment with a reverse osmosis installation activated to measure and collect data through solar energy by the photovoltaic system. This process of experiments was financed by resources from *Banco Nordeste* and from the National Council for Scientific and Technology Development (CNPq).

According to Bezerra (2021), the total photovoltaic power generation is installed, according to statistics on 12/31/2019 with distributed generation of 1,999.3 MW in Brazil, being: Southeast, with 729.6MW, South, with 587.4MW and North, with 60.3 MW. The total centralized power of 2,473.5 MW, of which 916.5MW in the Southeast, and 8.1 MW in the South and 14.0 MW in the North, totaling 4,472 MW, of which 1,616.1 MW in the Southeast, 595.5 MW in the South and North with 74.3MW. Only locations where there are photovoltaic solar source installations were mentioned.

Brazil is a country that has solar potential for generating electricity, unlike other countries where the sun throughout the day is not enough to generate electricity. But the incentives for acquiring the photovoltaic system are evolving for residential consumers. For industries and government agencies, there is an energy efficiency program system – PEE and a research and development program – R&D, together with the electric energy concessionaires. (Rosa; Gasparin, 2016).

In any location, being enhanced, the exploitation can enter a project for the energy supply to be hybrid, with mini-plants interconnected with the grid or not in the National Electric Energy Conservation Program - PROCEL of the Ministry of Mines and Energy - MME.

Research on renewable or alternative sources that aim to meet the needs of human beings, whether in industries, commerce, or homes, in addition to preserving the environment and conserving a source of electrical energy, began in past centuries.

With the evolution of scientific and technological knowledge, the renewable source that develops mostly worldwide and in Brazil is the photovoltaic source. Not only in increasing demands for electricity use, but tariffs and weather conditions also contributed to the evolution of photovoltaic module installations in all developed countries.

According to a study carried out by Silva et al. (2017) in relation to large cities note that, in the first place, it should satisfy the human and social needs of communities. So, the researchers' goals are to offer an energetically sustainable solution, which is photovoltaic solar energy, a promising alternative for the environment.

Investigations carried out by Vieira et al. (2018) indicate that with the growth of electricity demand, advantages of photovoltaic solar generation facilities were found due to the ease of installation and maintenance. However, with all the advantages that the photovoltaic system provides, the researchers evaluate the impacts on distributed generation in the transmission and distribution system, especially in photovoltaic solar generation, which presents variations in generated power throughout the day.

Silva et al. (2018) presented a study on the power factor correction of a photovoltaic system connected to the grid. Quality, problems and security in energy supply and power quality were analyzed in relation to the variation of reactive and active power. The results presented by the ANAREDE software to analyze the demand, the voltage variations and the power factor showed that there was a significant change. These values of power factor changes cause negative impacts on the financial sector, due to excess of system reactions.

Currently, alternatives are being sought by studying and researching new sources of electricity generation that cause less destruction of the environment and that economically do not affect production in industries, commerce, and residences. However, for research and projects and implementation of alternative sources, financial resources are needed that impact with high costs. For project evolution and implementation, many seek national funding from federal or international governments.

8 CONSTRUCTION OF HYDROELECTRIC PLANT

In Brazil, we can mention that, in general, the generation of electric energy comes from hydroelectricity, this sustains the instability due to climate dependence, depending on the rains and accumulation of water in the reservoirs, because for the generation of electric energy, the turbines depend on the water level reaching the technical conditions. Thus, the lack of sufficient amount of electricity to supply consumers indicates the need for an alternative such as thermoelectric or other sources, such as wind energy and photovoltaic energy.

Brazil is a country that has solar potential for generating electricity from other countries, where the sun, throughout the day, is not enough to capture radiation for the accumulation of electricity. However, in Brazil, the incentives for the acquisition of the photovoltaic system are still evolving in residential consumers, but industries and government agencies have an energy efficiency program system - PEE and a development research program - R&D, together with energy concessionaires. electricity. In Brazil, there are program incentives for the development of renewable sources of photovoltaic solar energy (Rosa; Gasparin, 2016).

Over the years, growth in Brazil and in the world is evolving technologically and economically. This causes an increase in the demand for electricity as the population rate increases. To meet the demand, it is necessary to increase hydroelectric plants, causing deforestation and depletion of natural resources. Thus, activating thermoelectric energy to meet the electrical demand, in turn, we will have greenhouse gas pollution (Knirsch, 2012).

9 INCENTIVES FOR INSTALLING SOLAR ENERGY

According to Silva (2015), the incentive programs for solar energy in Brazil that can be highlighted are:

- Direct sales to Consumers.
- Compensation system for Mini and Micro generation.
- Discount on the rate for the use of Distribution Systems (TUSD) and on the rate for the use of Transmission Systems (TUST);
- Light for All Program.
- Incentive Debentures.
- Agreement Number 101, of 1997 of the National Council for Finance Policy (CONFAZ).
- Special Incentive Scheme for Infrastructure Development (REIDI).
- Computer Law.
- Support Program for the Technological Development of the Semiconductor Industry (PADIS).
- Support to Energy Efficiency Projects (PROESCO).
- Differentiated Financing Conditions (BNDES).
- Innova Energy.
- Research and Development (R&D).

After these incentives mentioned above, there was a growth in solar energy in 2014, with the first Reserve Energy Auction _ LER 2014, having 400 registered photovoltaic generation projects, reaching a power of 10,790MWp with an investment of R$4.1 billion (EPE, 2014).

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With growth and interest in the diversification of the electricity matrix, the Ministry of Mines and Energy, in August 2015, held the first LER 2015, from photovoltaic projects, with the registration of 382 projects registered with a power of 12,528 MWp. Of these, 30 projects were contracted with a power of 1,043.7MWp, with an estimated investment of R$4.3 billion (EPE, 2015).

We can highlight that, in 2013, the State of Pernambuco held a specific auction for solar sources, with 6 projects contracted with a power of 122MW, at an average price of R$ 228.63/MWh (Silva, 2015).

10 EVOLUTION AND USE OF THE SOLAR SYSTEM

Effectively, in Brazil, there was potential and use of the solar system from 2012, with ANEEL resolution 482 and with auctions of Reserve Energy from photovoltaic solar source. With the resolution, there was development and interest on the part of consumers in relation to the installation of the photovoltaic system as an energy matrix, nationally.

In addition to this incentive, distributed generation and tax exemptions also represented important factors, such as the proposal that the ICMS, by the Government of each State, through the Secretary of Finance, would be levied only on the net portion of electric energy, after the compensation of energy electricity injected into the public network and not on the total gross consumption of the distributor (Rosa; Gasparin, 2016).

The evolution and growth of the exploitation of energy generated by hydroelectric plants in Brazil has advanced, according to research carried out by ANEEL of the geographic information system map of the Brazilian electricity sector, dated June 29, 2022, in which we have the following situations:

Simbology.
O - CGH – Hydroelectric generator center.
O - CGU – Undi- electrical generator center.
O - EOL - Wind
O - PCH – Small hydroelectric center.

O – UFV – Photovoltaic generator centers.
O – UHE – Hydroelectric plant.
O – UTE –Thermoelectric UAIN
– UTN – Thermonuclear plant.

According to the map above, there are 3232 Thermoelectric Power Plants (UTE) with a power of 54,302,276.81kW (in red), 223 Hydroelectric Power Plants (UHE) with a power of 103,454,926.00kW (in green) and Photovoltaic Plant (UFV)) 12,642 kW with a power of 61,931,418.88kW (in yellow). Adding the Thermoelectric (UTE) and Photovoltaic (UFV), list of hydroelectric plants, with two plants equated the power of the hydroelectric plant. In other words, the Thermoelectric Plant (UTE) can cause damage to the environment due to gas pollution whereas the Photovoltaic Plant (UFV), being clean energy, can contribute a lot to the environment and a sustainability system. Federal, state, and municipal governments must contribute and encourage investments and inspection in all spheres. Besides, the subject of clean energy system should be part of every technical school and Universities syllabus, due to its complexity. In the same way, technical training should be required for the installation procedure since the lack of proper knowledge could cause damage to consumers. Service providers must also have in-depth knowledge of all electrical material systems. Knowing the inclination of the modules (angles to the solar incidence ratio), understand about the rising of the sun, the times when the sunlight hits the modules for a longer time, and the quality of the inverters from direct current to alternating current are some of the fundamental skills and knowledge one should have to avoid energy leakage in voltages and electrical currents.

11 MATRIX BY FUEL ORIGIN

According to the ANEEL Fuel Origin Matrix statistic, dated on June 30, 2022, there are 2245 places where diesel oil has fossil origin. 59.02% of the electricity supply comes from the hydroelectric plant (UHE), and 2.87% from the photovoltaic system. Brazil is a country that has the best conditions for the implementation and use of the solar system. In order to grow, it depends on government incentives, on the dissemination of technical information that provides the population with greater understanding and acceptance of other forms of energy generation and on companies being technically prepared for this.

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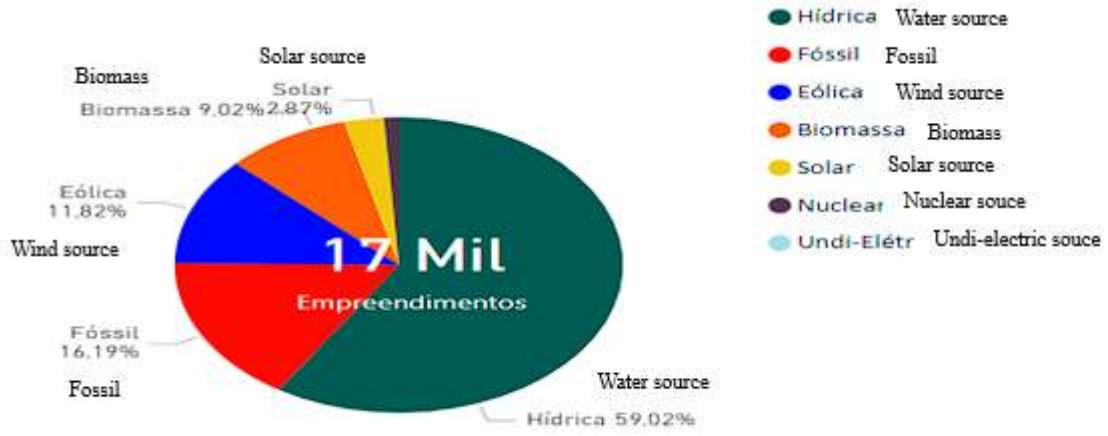
Graph 2: Energy sources in projects



It can be seen in the graph above that the Photovoltaic Plant (UFV - Solar) has a very low percentage of use. Thermoelectric power plants (UTE) may be replaced by clean energy systems, contributing to the environment and sustainability.

In the state of Paraná there are 17 hydroelectric plants (UHE) with a power of 15,065,636.00kW, 106 thermoelectric plants (UTE) with a power of 1,919,806.35kW and 20 photovoltaic plants (UFV) with a power of 4,513 .71 kW. Potential for growth at UFV.

12 RENEWABLE MATRICES

Statistics of the Superintendence of Concession and Authorization of Generation dated on June 30, 2022, from ANEEL informs:

Table 2: Power ratio in kW according to type

Quantity	Power	Model	Type
610	16.186.379.45kW	Biomas	Sugar cane
11.000	5.097.769.98Kw	Solar	Sun
824	21.886.178.86	Wind	Wind
1.377	109.454.145.59	Plant	Hydro

According to the table above, the solar system is evolving, despite the fact that the installed quantity is higher than the other plants, but in installed potential it is still lower than all the plants.

13 MATRIX BY CONSTRUCTION PHASE

Project under construction according to ANEEL dated on June 30, 2022.

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Figure 1 - Projects under construction and energy sources

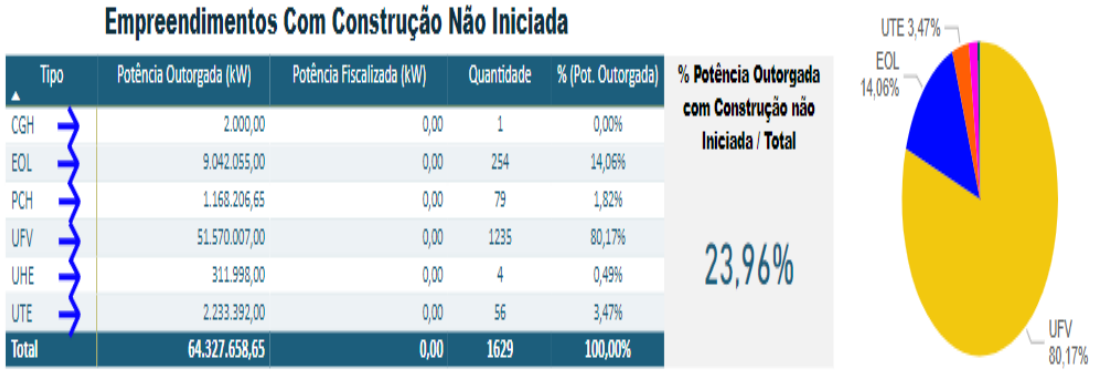
Empreendimentos Em Construção

Tipo	Potência Outorgada (kW)	Potência Fiscalizada (kW)	Quantidade	% (Pot. Outorgada)
CGH	7.700,00	0,00	4	0,04%
EOL	6.326.705,00	0,00	169	34,01%
PCH	440.503,10	0,00	33	2,37%
UFV	5.038.135,60	0,00	126	27,08%
UHE	141.900,00	0,00	1	0,76%
UTE	5.296.621,50	0,00	55	28,47%
UTN	1.350.000,00	0,00	1	7,26%
Total	18.601.565,20	0,00	389	100,00%

% Potência Outorgada em Construção / Total

6,93%

Figure 2: Uninitiated construction projects and energy sources



Empreendimentos Com Construção Não Iniciada

Tipo	Potência Outorgada (kW)	Potência Fiscalizada (kW)	Quantidade	% (Pot. Outorgada)
CGH	2.000,00	0,00	1	0,00%
EOL	9.042.055,00	0,00	254	14,06%
PCH	1.168.206,65	0,00	79	1,82%
UFV	51.570.007,00	0,00	1235	80,17%
UHE	311.998,00	0,00	4	0,49%
UTE	2.233.392,00	0,00	56	3,47%
Total	64.327.658,65	0,00	1629	100,00%

% Potência Outorgada com Construção não Iniciada / Total

23,96%

The data shown indicate that among the projects with construction not started, the Photovoltaic Plant (UFV) model is on the rise, due to the incentives that the government is providing to consumers.

14 ADVANTAGES OF PHOTOVOLTAIC POWER GENERATION

The advantages of generating electrical energy through the product of natural material that the sun and in turn transforms into electrical energy without the use of fossil fuel, we have a photovoltaic system we have some advantages (Hubner, 2016).

- No need for fossil fuels;
- Its useful life is about 25 years;
- This is an easy-to-modulate system (ABB, 2010).
- It has high reliability and has no moving parts (Assunção, 2010).
- The module is easy to transport and adaptable, allowing simple, adaptable components to meet varying power needs.

• The system size can be adjusted to several milliwatts or kilowatts of applications because the installed power can be changed by adding additional modules.

• Reduces operating costs, almost no maintenance;

• Quiet, without disturbing the environment;

• The module can withstand extreme weather conditions such as hail, wind, temperature, and humidity.

Disadvantages:

• The cost of the initial investment is high, as the manufacture of photovoltaic modules requires a very complex technology.

• Due to changes in energy (the sun), power generation is erratic. The amount of energy generated depends on the incidence of solar radiation at the installation site, the inclination and direction of the panel, the presence or absence of shadows and its components.

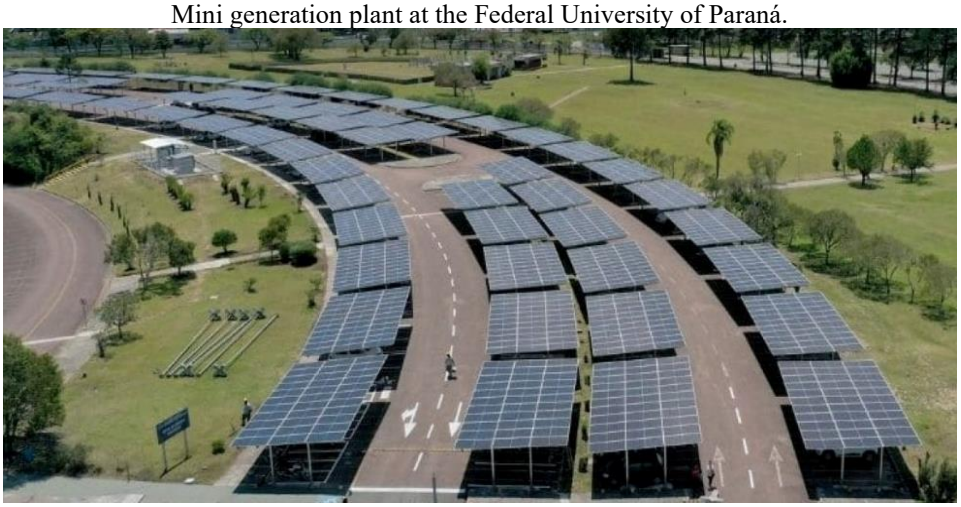
• Compared to the investment cost, the module's actual conversion rate is reduced.

• When the system is isolated, a row of batteries is needed to store energy, which further increases the cost of the photovoltaic system.

Installations of photovoltaic systems.

Photovoltaic.

Mini generation plant at the Federal University of Paraná.



The project for the implementation and execution of the photovoltaic system at the Federal University of Paraná stopped emitting 96 tons of carbon gas per year, which is equivalent to the preservation of 4,372 trees. The objective of the project, together with the UNIVERSIDADE, FUNPAR, COPEL AND ANEEL, with the ENERGI-UFPR campaign and the Internal Energy Conservation Commission (CICE-UFPR) was to make clean energy available, installing photovoltaic panel modules and generating resource savings in the reduction of electrical energy for the University.

The Copel and Aneel offered around BRL18 million to invest in research and development projects in energy efficiency at UFPR starting in 2016. The expectation was to obtain savings of BRL 1.5 million per year in energy electricity (UFPR,2020).

15 METHODOLOGY

The methodology used was descriptive-exploratory, qualitative, through which an open questionnaire was carried out. Each participant was interviewed individually, in a written questionnaire and recorded interview. In this study, specifically, the results referring to the questionnaire will be presented and, later, a broader study will include the data from the interviews. Teachers from the UFPR in Engineering or areas related to the subject and professional engineers with knowledge of photovoltaic energy were interviewed regarding the reflexes of the implementation of a photovoltaic mini generation system on the university campus and regarding this system generation and its prospects in Brazil.

Each participant was invited to answer an open questionnaire on the investigated topic. For data analysis, the content is systematized by what was expressed by a certain group of people in a discursive way, extracting the central ideas from each of the statements. The sequence of the interviews follows according to the professional types: professor and Vice-Director of the Biology Sector (interviewee A), Tax Engineer at UFPR (interviewee B), Professor at Electrical Engineering at UFPR and engineer (interviewee C), Engineer and Director of engineering company of the photovoltaic system installations (interviewee D); Civil Engineer and construction inspector at UFPR (Interviewee D), Maintenance Engineer of a company in the electrical and fiber optic cable factory (Interviewee F).

16 RESULTS

The questionnaire brings questions about the results of the implementation of an energy efficiency project and mini generation of photovoltaic energy in a public institution of higher education.

Regarding the question about the reduction in electricity consumption due to the increase in energy efficiency in the lighting system, most participants answered agreed that there was a reduction

in electricity consumption. One participant, though, believes that the system did not reach its full objective yet, due to the period of intermittent operation of the plant, as it can be identified in the speech: “I believe that it has not been possible to achieve this objective, yet, due to the long period of inactivity of the plant, as well as its intermittence of operation.” (Interviewee A).

The second question wondered if there was a reduction in the maintenance costs of lighting systems, and most of the interviewers agreed that there was a reduction. This agreement can be represented by interviewee B: “Yes, up to 40% reduction in lighting consumption.” One of the participants reported not having enough data to answer this question.

When asked if they considered that there was a reduction in electricity costs, most of the interviewers agreed, indicating a reduction of up to 50% in energy costs, even considering the effects of the pandemic and the increase in consumption in general at the university, according to the answer of the interviewee C: “Yes, there was a reduction. See, this reduction is not visible, as the university has been increasing consumption and we also had the effect of the pandemic, but basically there was a 50% reduction in lighting.”

In relation to energy efficiency practices through training actions, the participants were asked if there was training aimed at these practices. Half of the participants indicated that no type of training had taken place in their sector; the other half stated that training took place, although it was directed only to managers, as interviewee B says: “There was training only for managers.”

Regarding the first part of the questionnaire, which had as main objective to detect the perception of the participants in relation to the operation and the observable results resulting from the installation of the solar capture system and photovoltaic electricity generation, it was found that most of the responses pointed to a positive result for the university and the community involved in the process of consuming this energy.

Considering the process of improvement in the generation of renewable energies between the higher education institution and the energy company partner in the project, participants were asked if they believe that the quantity and quality of conventional plants remain the same, if they need to be increased or if there is a trend in the increase of systems that take advantage of sunlight through the photovoltaic system. Half of the participants believe that there is a trend towards increasing investments in alternative energy sources, as can be highlighted in: “I understand that the photovoltaic system will advance further, especially with the arrival of batteries, because it is possible to store electrical energy in the battery, because the values of the batteries will be cheaper, then it starts to publicize this system. Because the photovoltaic system, energy is stored during the day, and you can use it at night. This could be for any general system. Let it be industries, residential.” (Interviewee D). A quarter of the participants stated that it is important that both sources be expanded, because despite

the advantages, the energy generated by photovoltaic generation would have less impact on energy demand, due to its low magnitude of power achieved. The last quarter indicated that there was no university guideline regarding the energy source used, only regarding the reduction in energy consumption, according to interviewee C: “There is no university guideline regarding the type of generation source to be used”. be used. There is only the guideline to reduce energy consumption and energy bills.”

Participants were asked how much the project to reduce energy consumption through the photovoltaic generation plant can interfere in the change of culture in the perspective of organizational sustainability. Most participants believe that the effect of awareness occurs, because the community perceives the importance of reducing energy consumption, reaching those who are inserted where the installation of the process takes place, in addition to the financial issue related to cost savings, as if you can check: “There is an awareness effect, the community notices that it is important to reduce energy consumption.” (Interviewee C). One participant reported that the reach has been limited, due to the inconsistency of the plant's operation, as stated by interviewee A: “So far, the reach has been limited, in my sector, due to the inconsistency of its operation.”

Regarding the question about the possibility of the emergence of new electric generation systems after the 21st century, all participants answered affirmatively, demonstrating a great tendency to expand possibilities in the energy generation sector. It is possible to perceive this thinking through some answers: “Yes, the expectation is for new sources of generation and also for technological replacement, for example using the heating system by exchanging heat with the ground.” (Interviewee C); “Yes, there are already promising experiments in the generation of electrical energy through nuclear fusion, which will soon be a reality. Not to mention that this type of energy generation does not generate waste.” (Interviewee E); “There are several research that aim to find other energy generation alternatives.” (Interviewee F).

17 CONCLUSION

The generation, conservation, and distribution of energy in Brazil, considering environmental, social and economic issues, is undergoing transformations that occur gradually, with actions and strategies that are beginning to be outlined in the national scenario, following international trends. In this context, in the exploration of clean, renewable energy sources that do not generate waste, the photovoltaic energy generation system stands out, which has great exploration potential in our territory, depending on public policies that encourage the implementation and expansion of this type of power generation system. Analyzing the results, it was possible to conclude that the system can bring benefits in the long term, since in the short term some participants have already identified these advantages,

while others stated that their benefits have not yet been identified. In addition, it was found that most of the interviewees consider Brazil's great potential in expanding the exploitation of other energy sources, in addition to hydroelectricity, which, in addition to being expensive, brings fewer advantages related to the environmental and social contexts. In addition, they understand that there is a need for government investments and incentives to the private sector so that clean energy generation is privileged, especially about the photovoltaic energy generation system.

The evolution of materials technology and use of the photovoltaic system are expanding due to its facilities and maintenance facilities. Care must be taken in the elaboration of the projects, observing the entire solar energy system and the location of the module installations, so that the incidence of the sun occurs according to the mathematical calculations of the solar angles, with the objective that the energy generated in the modules has better use in the period of solar incidence.

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