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RESEARCH ARTICLE OPEN ACCESS

USE OF PHOTOVOLTAIC PANELS IN RESIDENCES AS A SOURCE OF PRIMARY ELECTRICITY GENERATION

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ABSTRACT

Population growth at a global level implies an increase in energy consumption by the population. This increase is expected in urban agglomerations composed of residences. The production of energy in the residential area has been discussed when talking about self-sufficiency and clean and sustainable energy. An aggravating factor in the context of forms of energy generation is the great impact of burning fossil fuels that release polluting gases when producing electricity. The present study sought to discuss, based on the literature, the use of photovoltaic panels in the generation of clean energy in homes as an alternative to conventional means. Therefore, the methodology used was based on the search for scientific studies in databases about the proposed theme. A bibliographic survey was carried out in order to obtain studies that would support the research. Studies in the databases Periódicos CAPES, Scholar Google and Scopus were found and selected based on certain criteria. Therefore, it was found that the use of photovoltaic panels in the generation of energy for homes is promising in reducing other energy sources. Several studies show the viability of this type of energy in homes in Brazil, which has a large availability of daily sunlight for its operation. However, the technology in question still has a high implementation cost, which may decrease with government incentives and a decrease in the values of its components. In addition, the use of solar energy compared to conventional means of energy generation has a compensatory value with its long-term use.

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I. INTRODUCTION

With population growth and the increase in the consumption power of emerging countries, the demand for energy is growing. The most recent increases have been mainly in low- and middle-income countries. This growth implies sharp rates of increase in energy consumption, being observed mainly in developing countries, such as in Latin America, where growth was greater than 100% in the last three decades [1].

The high growth rates of the global population living in urban areas intensify the use of energy sources that use the burning of fossil fuels that generate polluting gases such as carbon dioxide (CO^2), carbon monoxide (CO), particulate matter (PM) and other gases harmful to the environment and human health.

It is estimated that the contribution of greenhouse gases from electricity generation increases at an average rate of 2.1% per year along with the increase in energy consumption, which grows at a rate of 2.6% globally [2]. Studies prove the influence of pollutant emissions in the atmosphere from anthropogenic actions since the emergence of industry to the present day [3-5].

With the evolution of new technologies in the industrial age, new forms of energy generation were discovered, among them generation by burning fossil fuels, the main ones being: oil (10%), mineral coal (25.3%) and natural gas (20.7%). According to the International Energy Agency (IEA), it is estimated that by 2050 there will be an increase of almost 50% in world energy consumption [6].

Another worrying factor involves the issue of public health, the high concentration of particulate matter and polluting gases from human activities pose risks to human health and are associated with deaths from lung diseases annually [5], [7].

A study carried out with data collected by the World Health Organization (WHO) on particulate matter (PM) - mixture of solid and liquid particles suspended in the air - in 56 of the largest cities in the world showed that at least 96% of the population of the cities studied are exposed to fine particles exceeding the limits established by WHO [8]. Fine particles, especially those with a diameter smaller than 2.5 micrometers, are extremely harmful to health due to their ease of entering the respiratory tract and reaching the lungs.

Solar energy emerges as an extremely abundant source of alternative energy generation. The Brazilian territory has a high potential for capturing solar energy, especially the Northeast region due to its location closer to the Equator. According to the Brazilian Atlas of Solar Energy, the country receives a daily solar incidence of 4,500 to 6,300 Wh/m² throughout the year. Electricity consumption in the country in 2021 amounted to 500,209 GWh, corresponding to a 5% increase in energy consumption compared to the year 2020 (EPE, 2020) [9].

Electricity consumption has been increasing in Brazil. In homes, this increase occurs in two periods of the year: summer and winter. This is due to the use of air conditioning (summer) and electric showers (winter) by the population in these periods. The average consumption of electricity in Brazilian homes was 152.2 kWh/month [10], where the southern region has the highest consumption. However, this consumption may vary due to the greater occurrence of rainfall and milder temperatures, reducing the use of electricity. Linked to this, the use of renewable energy sources such as solar energy can further reduce energy consumption in homes.

In addition, the use of solar energy as a source of energy generation can help reduce the user's electricity bill. According to research carried out by Intelligence in Research and Consulting, about 46% of the population spends more than half of their income on electricity bills [11], placing Brazil in 10th in the ranking of countries that consume the most energy [12]. Therefore, the use of photovoltaic panels to generate energy in homes as a primary source, that is, homes powered by solar energy in its entirety, shows promise in both environmental and economic aspects.

Solar energy works by converting the energy received by the sun into electrical energy. The solar panel (photovoltaic plate) is composed of photovoltaic cells and works from the photovoltaic effect generating direct voltages and currents. This effect is due to the movement of electrons in the presence of light energy into the cell composed of silicon and absent of electrons, creating an electric current. Therefore, the solar panel can be understood as a source of current that depends on solar radiation [13].

Given the above, it is necessary to catalog the benefits of using solar energy as a way of generating energy in homes to assess the feasibility of using this type of energy in a primary way. The present study aims to analyze, from the literature, the use of photovoltaic panels in homes as an alternative energy source to conventional means of great economic and environmental impact. In addition, the cost benefit of using solar energy in the domestic context.

II. BIBLIOGRAPHIC REVIEW

Solar energy is an inexhaustible source of energy, as the timescale of life on Earth must be considered. The sun is an ordinary star that radiates energy due to the nuclear fusion reaction of hydrogen atoms forming helium, therefore, the sun is one of the most beneficial energy possibilities for humanity [14].

The sun is the largest celestial body in the solar system, with a mass of 1,989x1030 kg, representing 99.8% of the total mass of the solar system (composed of the sun and all the celestial bodies that orbit it. The radius of the sun is about 695 km, about 150 million kilometers away from the earth. In addition, it is mainly composed of hydrogen (91%) and helium (8.9%) The temperature of the sun's core is about 15,000,000°C, while on the surface it reaches 5,500°C [15].

The origin of most existing energy sources is from this star (the sun) to the earth, we can mention hydroelectricity, which occurs by evaporation and is responsible for the water cycle, thus damming the next generation. Wind energy, on the other hand, comes from the wind, through solar radiation that causes a large atmospheric circulation. Likewise, energy from biomass (firewood, charcoal, alcohol, etc.)

The sun radiates enough energy to Earth to meet 10,000 times the world's annual energy consumption and generate approximately 1,700 kilowatt hours of electricity per square meter per year. On the other hand, the availability of solar radiation depends on the latitude of the region, as the movement of the Earth around the Sun is described by an inclined plane at 23.5o from the equatorial plane [16].

There is radiation in all regions of the spectrum. However, the human eye is sensitive to less than an eighth of this radiation, which is around 400 to 750 THz (400 to 750 nanometers) – the visible region, which is narrow. However, the Sun holds 45% of all energy. The power density of solar radiation is called the solar constant and has a value of approximately 1360 Wm2. This density represents watts per square meter (energy flow) and varies according to the distance between the earth and the sun [17].

Taking this context into account, the definition of a photovoltaic energy system is made from the understanding that this system is composed of one or more photovoltaic modules, and a set of equipment, such as batteries, charge controllers, inverters and some protection equipment. These devices may vary by application. Photovoltaic systems contain solar cells that convert solar energy directly into electricity. Every solar cell has a layer of semiconductor material in its composition. When solar radiation falls on a solar cell, an electric potential (voltage) is developed between the layers of semiconductor material. This potential is responsible for the current flowing through the external circuit when the external circuit is closed [18].

Photovoltaic technology can be installed in almost all regions of the world. As they contain no moving parts, these systems operate silently. The lifetime of a photovoltaic system is typically 25 years [18].

Photovoltaic systems can be installed close to large energy consumer centers and connected or disconnected from the grid in a centralized or decentralized way. They can power small or large applications. In this context, the application of photovoltaic systems can be divided into: autonomous systems (OFF-GRID) and systems connected to the grid (ON-GRID) [18].

It is necessary to consider that systems not integrated to the grid have batteries that store the generated energy, this is not necessary in integrated systems, because in these cases the excess generated energy can be transmitted to the grid and located elsewhere [19].

In an OFF-GRID system, all the energy generated is stored in batteries, ensuring that the system meets demand even in periods of low sunlight, and it works as follows: the system captures sunlight from photovoltaic panels to generate electricity at from

direct current, which is passed by the charge controller responsible for protecting the battery from deep discharges and overloads, all this energy will be stored in a set of batteries, then it will convert it from DC to AC through an inverter of frequency, and only then will it be used for Consumption [20].

In this way, photovoltaic solar energy is a source of renewable energy into electricity, solar cells convert solar energy into solar energy, photovoltaic systems are connected to the grid and spread in the form of micro and small power plants that can increase the supply of electricity while helping to maintain our energy The renewable character of the matrix, in urban areas directly connected to the low voltage network, generates electricity and reduces the cost of generation, attracting the final consumer [21].

In addition to increasing the availability of electrical energy and environmental benefits, since the process of generating solar energy does not generate waste, the development of solar technology, in addition to boosting the national economy, has also generated many job opportunities and trained professionals well capable form of energy, because it does not release residual heat, does not alter the balance of the biosphere, does not involve burning fuel, does not produce any type of pollution, has a useful life of more than 20 years, requires little maintenance, is very simple and easy to install, and does not cause environmental impact, completely avoiding the greenhouse effect [21].

However, despite the many advantages of photovoltaic solar energy generation, the development of any energy source will bring changes. Thermoelectric power plants use toxic liquids, occupy a large area and alter the environment. Despite the negative effects, renewable energy is clean AND clean. Another disadvantage of being safe in relation to non-renewable energy sources is the high cost of investment in installing solar power plants [22].

III. MATERIALS AND METHODS

The present work has as a method the literature review that seeks to aggregate and synthesize the scientific knowledge already produced on the selected theme.

Explaining the method includes introducing the set of operations used, from the search for material, explaining the method, to the procedures used.

As for its nature, it is a theoretical work insofar as it is not a specific case study, but rather an analysis of a topic with the aim of enriching scientific knowledge on this topic.

A researcher's objective may be to develop new theories, create new theoretical models or establish new working hypotheses in various areas of human knowledge through deduction, induction or analogy.

The aim of this work is not to use the results in practice, but to enrich scientific knowledge and is therefore defined as theoretical research. It should be noted that the theoretical basis is the basis for the development of any type of research and the advancement of any scientific field.

As for the objectives, it was an exploratory study that, according to [23], "was designed to make the problem more familiar, with a view to making it more specific or building a hypothesis".

As for the methodology, qualitative research was used, characterized by the absence of quantitative data in the analysis.

In qualitative research, a deeper analysis of the phenomenon under study is carried out. Given the superficial nature of quantitative research, qualitative methods aim to highlight features not observed through quantitative research.

As for the form of the method, bibliographical research will also be used, that is, carried out from literature, contemporary or retrospective, considered of scientific validity.

With regard to technical procedures, the study used bibliographic data and literature analysis, as the work was carefully prepared from material already published, mainly books, opinions, articles, periodicals and materials available on the Internet.

Thus, this study was carried out using a bibliographic database such as information from articles obtained in the Google Scholar search engine (https://scholar.google.com/) with research related to the axes shown in Table 1. For the search engine, the words used in axis 1, 2, 3 and 4 were used together in the search for studies related to the research theme.

The search in the bibliographic database Periódicos CAPES was carried out for axis 5 and 6 for Scopus with axis 7. In the search engine and in the databases, there was no delimitation of publication dates, order by relevance, language definitions or filtering of results.

Table 1: Axes used for the research.

Scholar Google	Axle 1	Photovoltaic panels
	Axle 2	Residences
	Axle 3	Power generation
	Axle 4	Use of photovoltaic panels in homes
CAPES periodicals	Axle 5	Photovoltaic panels
	Axle 6	Residences
Scopus	Axle 7	Photovoltaic panels

Source: Authors, (2022).

The studies selected in the search were organized by relevance, where the results of the researched studies were checked for the choice of articles and works that were related to the theme of the present study. Among the selected results, scientific articles published in magazines or abstracts published in conference proceedings on solar energy, course conclusion works and master's dissertations were used.

The research aimed to deepen the scientific knowledge on the subject, characterizing itself as a basic research. It is of the descriptive type, based on theoretical subjects contained in books, articles and academic works for its literature base. This study is based on the type of bibliographical research which consists of collecting information from texts, books, articles and scientific materials. The collected material was used in the research in the form of quotations and references, serving as a theoretical basis for the development of the study. In addition, the generated study base served to compare information collected and finally produce conclusions on the chosen topic. The criteria for choosing articles and works to compose the bibliographic base of this study are arranged in the flowchart below. The process from defining the keywords to the articles selected for final discussion is shown.

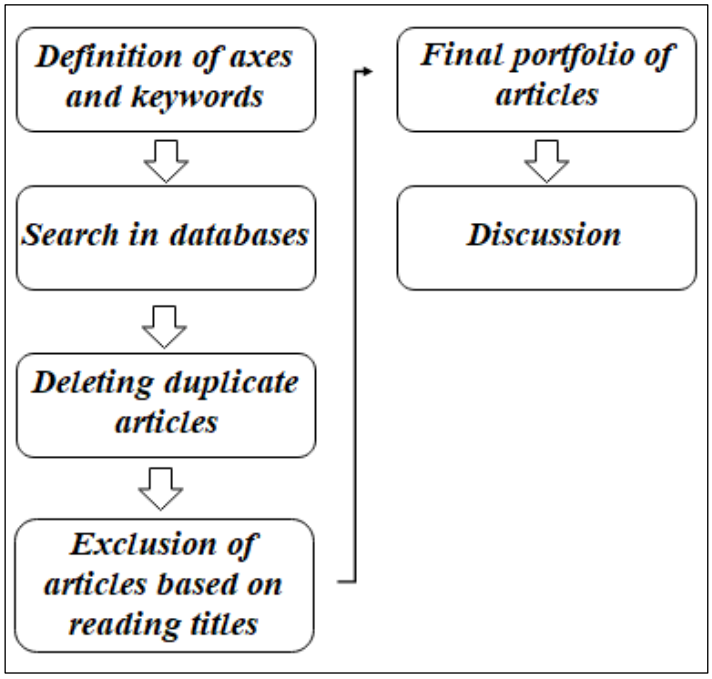

Figure 1: Flowchart used in the criteria for choosing the studies.
Source: Authors, (2022).

IV. RESULTS AND DISCUSSIONS

IV.1 PORTFOLIO SELECTION

Through the selection of studies to compose the research, it was possible to acquire articles from the electronic database divided between the bases shown in Table 1 and presented in the graph in Figure 2. The graph qualitatively shows the division of articles by database. It is noted that the Scholar Google and Periódicos CAPES databases presented a greater number of selected articles.

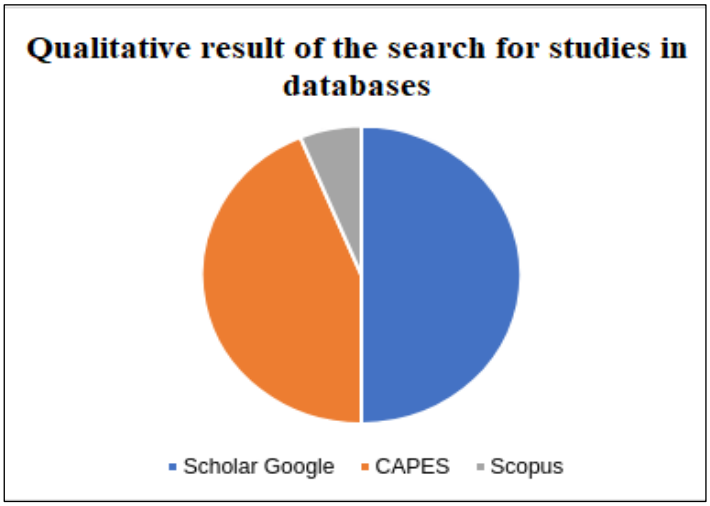

Figure 2: Graphical representation of the result of the search for studies in the databases.
Source: Authors, (2022).

Based on the criteria defined by Figure 2, a total of 15 articles were selected and saved in separate named folders with the corresponding database. Table 2 shows the number of articles obtained by database.

Table 2: Number of articles obtained from the research databases.

Data base	Total articles
Scholar Google	7
CAPES periodicals	7
Scopus	1

Source: Authors, (2022).

Table 3 summarizes the works selected in the databases that make up the study's portfolio. The abstracts show the main results obtained by the study, the year of publication, the method used and the objectives.

Table 3: Summary of selected studies in the databases by title/year, method used, objective and results achieved.

Title/Year	Method	objective	Results achieved
Cost comparison between photovoltaic solar energy and conventional sources (2006) [24]	Literary discussion on aspects of the cost of installing photovoltaic panels and conventional forms of power generation	Demonstrate comparisons between the cost of installing solar energy sources and other conventional sources for a national panorama	Use of energy powered by solar panels is efficient, however, the value to develop a solar system is much higher than the value for a hydroelectric plant
Photovoltaic solar energy as a complementary source of electricity for homes in the pursuit of sustainability (2008) [25]	Use of data from photovoltaic systems installed in Florianópolis - SC for the year 2007 and estimates for other Brazilian cities, in addition to using the demand curve.	Analysis of the energy generation potential from photovoltaic panels in Florianópolis – SC, Brasília – DF and Fortaleza from a 1 kWp power installation based on model scenarios from developed countries	The demand curve in Florianópolis and Brasília showed a similar behavior, while in Fortaleza the curve is more linear (greater use in the daytime period)
Integration of photovoltaic solar panels in residential buildings and their contribution in a mixed urban zone energy feeder (2009) [26]	Kits installed on roofs of residential buildings in a mixed-use neighborhood in Florianópolis - SC were used.	Evaluate how a photovoltaic system integrated in buildings can contribute to the energy available in an urban power grid	The kits contributed to the financial return with an average of 25 years along with the coverage areas of the city
Application of photovoltaic panels in homes: case study in Guaratinguetá and Seville (Spain) (2012) [27]	Installation of photovoltaic stations in residential for case study in both cities	Potential for installing a photovoltaic system in a house in order to reduce electrical consumption	For Seville, the value of installing the panels would be amortized in 8 years and for Guaratinguetá in less than 4 years
Application of photovoltaic solar panels as a complementary source of electricity in homes (2013). [28]	It used the calculation of the energy balance between generation and production for a real consumption curve and verified current tariffs and economic-financial viability.	Solve installations and network connections of a photovoltaic solar system, predicting costs based on available technologies.	Great potential for solar energy throughout the entire Brazilian territory and demonstrated the behavior of the system for residential consumption.

Title/Year	Method	objective	Results achieved
The use of photovoltaic energy in Brazilian homes: an implementation analysis (2013) [29]	Bibliographic survey and consultation in books and magazines in virtual and written collection	Present discussions regarding the implementation of renewable energy sources	The cost of implementing photovoltaic systems is still not viable for collective use
Technical and economic aspects of residential use of photovoltaic panels connected to the grid (2013) [30]	Installation of a PV system for a residence in the city of Curitiba: case study	Present the main technical and economic aspects regarding the use of photovoltaic panels in homes	Return on savings for a grid-connected system varies between 10 and 13 years and may decrease in the short term
Influence of urban configuration on photovoltaic generation with systems integrated into facades (2013) [31]	Exploratory study of different urban sites with potential for energy generation using parameters and urban scenarios with the Rhinoceros program	Evaluate the application of photovoltaic panels in different urban settings	The potential for installing PV panels is due to parameters such as: solar accessibility and height of buildings
Economic feasibility of installing photovoltaic panels in a residence in the city of Caratinga - MG (2016) [32]	Installation project of photovoltaic panels in medium-sized residence	To analyze the feasibility of installing photovoltaic panels in a medium-sized residence in the state of Minas Gerais	The project proved to be viable with cost-effectiveness accepted and considered by the owner of the residence.
Economic viability of using solar panels in the horizontal condominium Bela Vista: Case study (2016) [33]	Interviews were carried out in the condominium about the average monthly energy consumption and the use of equations for panel sizing	Show the economic viability for the implementation of an energy generating system using photovoltaic panels in a horizontal condominium	The use of solar energy is a viable system capable of meeting the energy demand of the residence.
Use of photovoltaic panels in homes (2019) [34]	Search on the Google Scholar platform for articles, books and scientific documents	Bring concepts of sustainability, world and national panorama of energy production	It showed the importance of using photovoltaic panels in global and local sustainability, however it presents difficulties in obtaining
Implementation of autonomous power generation systems for the semi-arid region of Paraíba (2019) [35]	Assembly of systems and equipment according to methodologies of other articles	Evidence of the operation of three autonomous energy generation systems in homes, including solar energy	Solar incidence helps not only the solar energy generation system but also the electrochemical reactor.
Economic impacts of expanding the use of residential solar energy in Minas Gerais (2019) [36]	Uses regional model built for Minas Gerais with structural equations and parameters detailed in other articles	Simulate the impacts of using photovoltaic energy in homes in Minas Gerais on the local economy	The adoption of photovoltaic panels impacts several sectors and would cause a relative increase in the consumption of financial services
The application of clean technologies for sustainable urban development through the deployment of photovoltaics (2021) [37]	Deductive method of bibliographic review on the subject in magazines, publications, dissertations and among others	To present how it is possible to apply clean technologies in sustainable urban development by applying solar energy	The deployment of PV panels show promise in the use of clean technologies, however government incentives are needed
Cost and benefit of photovoltaic panels in residences in Rio de Janeiro (2022) [38]	Case study that uses economic and financial indicators to analyze the cost-benefit of installing photovoltaic systems	Analyze the cost-benefit ratio for the implementation of a photovoltaic system	Costs with electricity are reduced even though the initial expense is high, containing a quick installation system, clean energy generation and without emitting pollutants into the environment

Source: Authors, (2022).

IV.2 PORTFOLIO DISCUSSION

Based on the 15 articles of the final portfolio, the works are discussed so that the feasibility of using photovoltaic panels in the generation of energy in homes can be explored from the perspective of economic, social and environmental factors.

IV.2.1 Operation of Photovoltaic Panels

Solar energy can be obtained through the photovoltaic effect, from semiconductor materials, that is, materials with a conductivity value that are between insulators and conductors. The conductivity of a material is a microscopic property that indicates a great ability to easily carry electrical charges. In addition, they have a valence band and conduction over an energy interval less than or equal to 3 eV [28].

The representation of semiconductors is given by silicon doping. By adding to the intrinsic crystal that has 4 electrons in its valence layer, the behavior of the material is modified and it becomes a conductor. Doping silicon with an element such as phosphorus results in a free electron in its conduction band. This process characterizes an N-type semiconductor material, also known as a negative electric charge carrier. By adding an element with 3 electrons in the valence layer, we have a carrier of positive charges characterizing a P-type semiconductor material. P-type and N-type semiconductor materials are electrically neutral. By joining both materials, you have a P-N type joint. For this junction, the free electrons from N move to P and with this movement the initially neutral semiconductors generate a negative electric potential in P and a positive one in N. This movement occurs in order to create an electric field and establish an equilibrium electric. Such value of electric field that needs to be generated in order to create an electric balance is what determines the gap value, that is, a value of energy at which an electron crosses the junction. All this movement to fill the gap and the conduction band is the process of generating electrical energy. When exposed to the incidence of photons of light, that is, sunlight with energy greater than the gap value, electrons are stimulated to jump to the conduction band, generating the energy that is collected by the conductors [26]. Figures 3a and 3b illustrates how photovoltaic cells work.

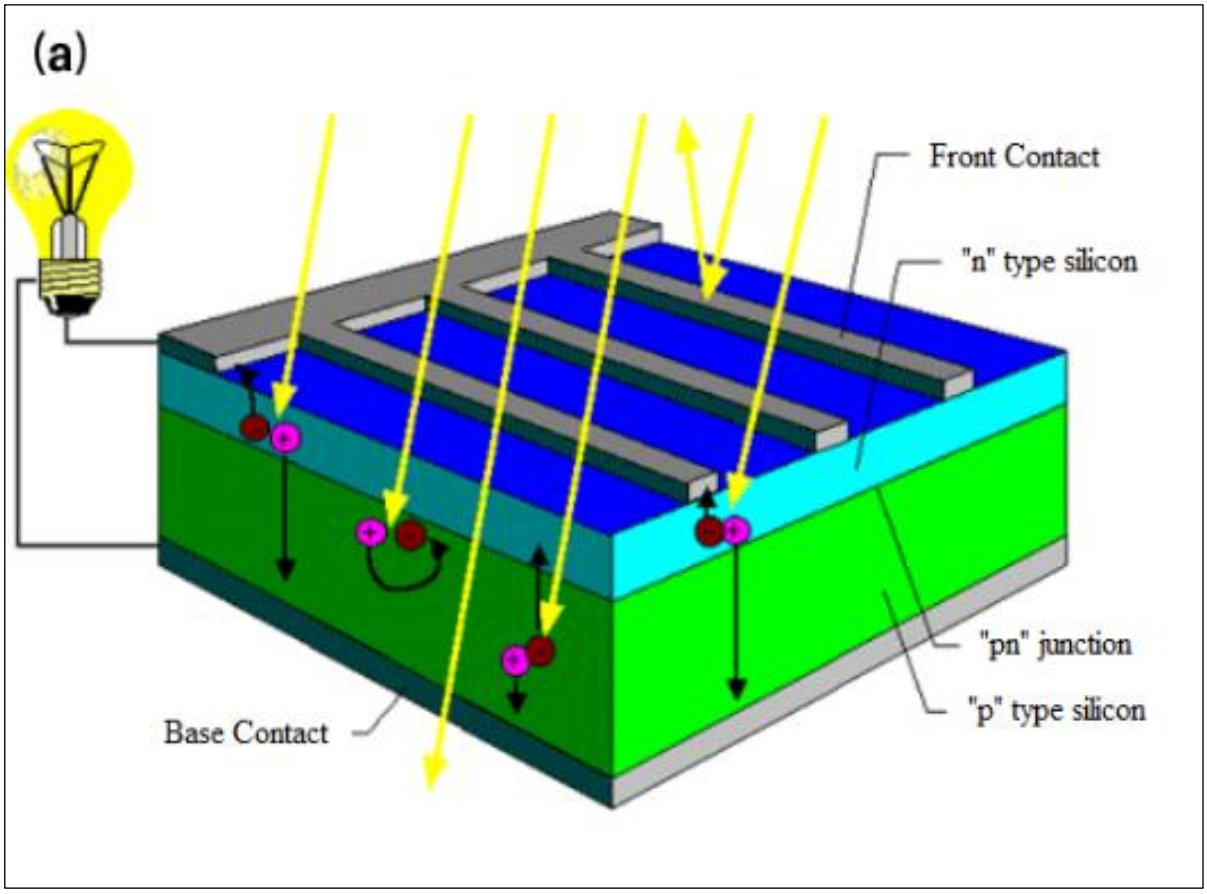

Figure 3a: Operation of a photovoltaic cell. Cross section of a photovoltaic cell.
Source: [22].

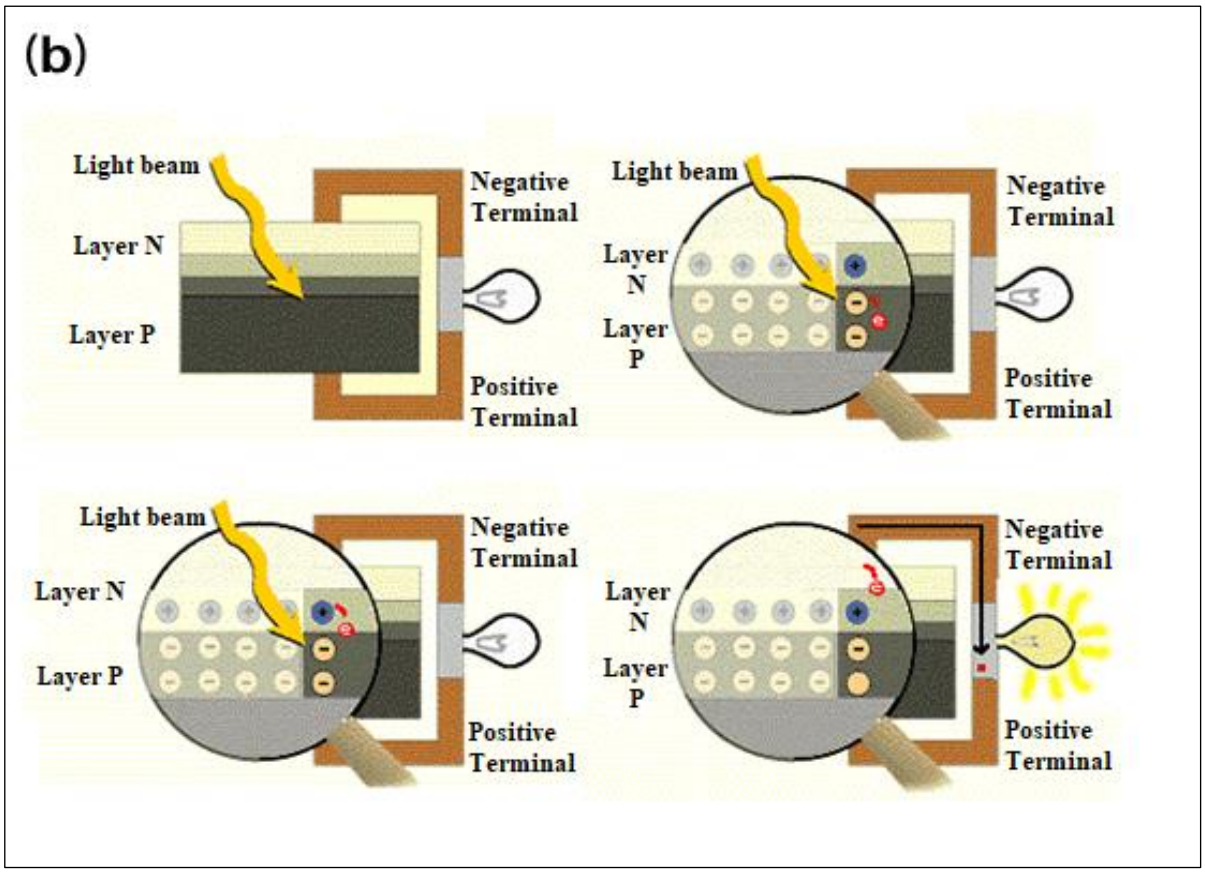

Figure 3b: Operation of a photovoltaic cell. Photovoltaic effect at the P-N junction.
Source: [22].

IV.2.2 Installation of a Photovoltaic System

A photovoltaic system consists of: (a) photovoltaic generation modules, (b) wiring, (c) solar panels, (d) converter system, (e) protections and (f) connections. You can install photovoltaic systems in two ways, which are isolated or connected to an electrical grid. Separately, they serve places such as homes that are far from the public power grid. The other way is the installation with the connection of the modules to the conventional electrical network, integrating the modules in buildings [26].

Figure 4: Composition of the photovoltaic solar system connected to the grid.
Source: CSR ENERGIA SOLAR, (2008) [39].

IV.2.3 Use of Photovoltaic Panels in Homes

The interest in implementing a photovoltaic system in homes lies in the ability to generate energy using a renewable and clean source as fuel, since commercial and residential buildings capture about 50% of the electricity consumed in Latin America. This would imply a decrease in the use of energy generation powered by burning fossil fuels that are harmful to the environment.

The [25] demonstrated through power generation data and the use of two photovoltaic systems for three locations the demand curve of residences. The results showed that these curves are variable and depend on factors such as consumption habits, occupancy rate and energy use at times with larger family residences.

Furthermore, due to the variability of solar incidence in Brazil, the operation of a photovoltaic system will be proportional to the availability of solar radiation, and there may be a need to use the local electrical grid.

With regard to solar availability, studies are carried out in the region of the Brazilian territory with the greatest potential for using solar energy. Thus, [35] used autonomous technologies for power generation, including the use of solar panels for the semi-arid region of Paraíba.

The system proved to be useful for use in condominiums that want to use clean energy in more general energy demands, in order to reduce costs such as electric fences, automatic gates, blackout prevention, among others.

The [33] showed the economic viability of implementing a system for power generation using solar panels in a horizontal condominium. By means of equations, the dimensioning of the system was done in addition to research to obtain the electrical demand of the residents. One of the objectives of the project was also to analyze the replacement of the energy matrix partially for periods where there is no use of solar energy, such as at night. The implementation of the system proved to be a viable alternative with a useful life of 25 years.

The use of energy generation by photovoltaic panels is also analyzed in buildings. [26] developed a study on the applicability of a system of photovoltaic panels connected to the electrical grid and integrated into buildings, analyzing the contribution of this type of energy generation in residential buildings in urban areas. The study used kits installed on the roofs of buildings in a mixed neighborhood in the city of Florianópolis - SC.

It was concluded that the roofs had a high potential for energy generation when installing the kits in the sunniest part of the roof. In addition, they showed the contribution of kits, since the peak of energy generation corroborates with the peak of consumption of buildings, whether for commercial, services and residential demand, since it is a mixed neighborhood.

The [40] showed, through a bibliographical survey, an overview of the implementation of photovoltaic energy in homes in the Brazilian territory. The authors showed that the use of energy sources becomes urgent in relation to the growing energy consumption in homes. In 2009, average consumption was around 150 kW/h per month and rose to 153 kW/h per month in the following year, representing an increase of 1.1% according to [16].

These values show the proportionality of energy consumption to the increase in population, that is, with the increase in population, the demand for energy must be proportional, and the contingent can increase by at least ten million.

The [32] analyzed the economic viability of deploying photovoltaic panels in homes by assembling a photovoltaic system in a home. The system was free of interferences such as buildings

that generated shadow and disabled the functionality. Power generation by this means proved to be feasible with an estimated time of 10 years for the user to enjoy the electricity generated by the system at no extra cost. The generation of energy by photovoltaic panels is directly linked to the concept of sustainability. The search for an energy source that can supply the energy demand while not harming the environment for the next centuries, as well as generations, is the objective of several nations.

The [34] sought to conceptualize sustainability inserted in energy production based on a survey of documents, articles and books. They showed that the word is related to energy production due to the possibility of obtaining energy from an independent, inexhaustible and non-polluting source. This source would bring benefits to the global energy matrix.

IV.2.4 Investment Cost

Another determining factor in the use of this type of power generation is its investment cost. Studies have tried to estimate the economic impacts of using renewable energy sources [41-43]. Costs are considered in three main items: photovoltaic panels, inverter and the system of equipment involving mechanical structures, electrical equipment, cables for connections in addition to the general implementation costs [40].

According to ANEEL, to meet the demand of a family, the system's generation power must be 29 kWh in 8 panels, resulting in the cost of R$ 19,900 to install these kits. This cost makes photovoltaic technology still not very viable and expensive for a low/medium income family, since the government does not provide assistance in obtaining this system. Furthermore, the incidence of a high tax burden makes installing the system even more expensive than in other countries.

According to [40], a family that consumes up to 528 kW/h would have to disburse almost R$ 50,000. This is possibly the biggest barrier to the extension of this technology.

The [40], quoted the investment required to obtain the components of the photovoltaic system without including the cost of installation.

Table 4: Cost of equipment without installation price.

Kits	KW/h power	Cost (BRL)
1	29.38 KW/h month	BRL 2,7560.00
8	235.04 KW/h month	BRL 19,932.00
18	528.84 KW/h month	BRL 46,608.00

Source: [44].

Table 5: Cost of equipment without installation price.

The amount	equipment and installation
14	Mitsubishi 255W Premium Solar Photovoltaic Panels
1	Out Black Charge Controller 80-48V – 3840W
1	Inverter Out Black – 3.6 W – GUF 3648
1	Flex Ware Surge Protector
1	Mate System Display and Controller LCD 4-in.
4	Moure Clean 220 AH Stationary Battery
Total	BRL 42,435.00

Source: [45].

Tables 3 and 4 show the quotation on the websites. For families that spend more than 500 KW/h per month, the total value is shown in table 4. It is observed that the value is still high and with the possibility of being an even higher value depending on the size of the residence and the demand of the family composition.

The [36] sought to analyze the impacts caused by the use of renewable energy for a set of families, showing the difference between different family groups in the state of Minas Gerais. The study performed economic and technical feasibility analysis for determining the energy conditions for the use of solar energy. They obtained that the use of solar energy is capable of causing impacts in different sectors depending on the family composition.

The [30] analyzed the technical and economic characteristics through a case study for the installation of photovoltaic panels in a residence located in the city of Curitiba. The payback time was around 10 years, with factors that may shorten this period, such as the implementation in Brazil of a sales system that allows the sale of the surplus generated. This system is also used in other countries, Germany for example.

However, comparing the cost between energy generation sources, it is observed that sustainable alternatives have a higher final price than alternatives more used as conventional sources [24].

The [38] carried out a case study on the installation of photovoltaic panels in a residence in Maricá in order to analyze the long-term cost-effectiveness of using this form of energy generation. They used economic and financial indicators for this analysis, such as: Net Present Value (NPV), Internal Rate of Return (IRR), Return on Investment (ROI) and Payback. These indicators infer the relationship between costs and benefits of installing photovoltaic panels. They used data provided by a company that provides photovoltaic panel installation services in Rio de Janeiro.

The study showed that the use of alternative energies was important in reducing expenses related to energy consumption. Table 5 shows the study budget. It is observed that the system requires a high initial cost, however, the amount spent is offset by the decrease in what is spent on electricity. According to the result obtained from the analyses, from the third year it is possible to obtain savings with the generation of energy used.

Table 6: Financial viability analysis.

Factor	Value
Investment value	BRL 26,968.00
Annual energy readjustment	7%
Service life of the photovoltaic system	25 years
Payback (payback time)	3 years
Return on Investment (ROI)	14 times
Internal Rate of Return (IRR)	41.52%
Discounted NPV (25 years and SELIC rate)	BRL 136,564.00
Total accumulated savings (25 years) = BRL 415,782.33	

Source: [38].

V. CONCLUSION

The present work sought to demonstrate, through bibliographical analysis, the use of photovoltaic panels in residences as a source of alternative energy generation to conventional means, widely disseminated nationally and worldwide. The use of solar energy in Brazil is still not widespread, even though it presents excellent conditions for this type of technology. The current energy matrix of the Brazilian territory is concentrated in the use of hydraulic energy, representing about 84% of the proportion of forms of energy generation. Worldwide, the large portion is concentrated on the use of energy generated by burning fossil fuels and only a small portion is represented by solar energy. Solar energy can have a great contribution in the generation of electrical energy for residential consumption and for other

purposes. The study showed the feasibility of using this form of energy generation as a potential replacement of the energy matrix in Brazilian homes. However, this form of energy generation still has a high initial investment cost, and the cost of implementing this system may be at least 5 times more than the expenditure on a conventional electrical network. In this way, it is necessary to encourage the government through public policies for sustainable development, focusing on the dissemination of the use of solar energy, in addition to reducing taxes for those who use this technology and the possibility of selling surplus energy.

In addition, with the reduction of the price of this technology as it evolves, they make possible the economic viability of this technology and boost its use in the residential area.

VI. AUTHOR'S CONTRIBUTION

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