EUROPEAN ACADEMIC RESEARCH
Vol. IX, Issue 10/ January 2022

Impact Factor: 3.4546 (UIF)
DRJI Value: 5.9 (B+)

ISSN 2286-4822
www.euacademic.org

Photovoltaic Solar Energy: Relevant Aspects for Sustainable Solutions

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Abstract

This article shows a conception about the new paths of energy generation, society has evolved and since the burning of fossil fuels, to the scarcity of oil reserves in the world. The Industrial Revolution in the 18th century gave the kick-off for the insertion of technologies and Electric Energy became more abundantly required and the energy matrix was developed to keep up with advances. This study aims to make a bibliographical approach on the relevance of the sustainability of the use of Photovoltaic Solar Energy (ESF), a proposal for an innovative and sustainable energy matrix. The method adopted for the research was the deductive one. The characteristic of the research encompasses three aspects of relevance: it is exploratory research,

with a qualitative approach and technical procedures of bibliographic character. At the end of the research, it was observed that technological advances brought with their environmental problems. Environmental policies must be of fundamental importance in developed and developing countries that seek new forms of energy consumption, promoting investments for renewable energy generation, solar energy is a promising source.

Keywords: Photovoltaic, Renewable Energies, Electricity, Energy Matrix.

INTRODUCTION

An inexhaustible source of light, the Sun is considered the "star king", that is, it is the source of energy responsible for the origin of many other sources considered renewable. Taking as an example the hydroelectric plants, which are based on the use of water as a source of energy, which indirectly also need the sun, in the phenomenon of flooding or ebb rivers. Many energy sources are considered clean, have a direct or indirect relationship with the sun, source of light, and promoter of life.

The energy in the universe is constant and its transformations are ways of association that give meaning to systems. The use of photovoltaic solar energy (ESF) can be considered inexhaustible, if taken into account its time scale, as the sun was responsible for many phenomena for the construction of continental and oceanic relief, that is, since its formation of planet Earth. Given this scenario, this study asks the following question: What is the relevance of using the ESF. The answer to such question comes from the study of its potentialities, as a premise a bibliographical survey on the use of Photovoltaic Solar Energy as an energy matrix should be carried out. The basis for this study is the potential of the sun. Silva (2018) cites that energy from the sun totals 137 MW and tends to grow until the year 2050, with 37 GW of distributed generation.

This scenario arises from man's need to generate energy from the beginning. Martins (2018) emphasizes that the Industrial Revolution (18th century) in England, where the production of energy through the burning of fossil fuels (Coal Mineral) began, was a milestone in this regard, as the mechanization of production with the help of energy from burning coal, brought countless benefits to society.

The energy matrix has been developing exponentially, the emergence of new technologies brings advantages and problems, aimed at the Environment, which has been aggravated as the evolution of society persists. The focus of this study is to analyze the relevance of photovoltaic solar energy when transformed into Electric Energy.

Elétrica (2018) indicates that solar energy is considered a renewable and inexhaustible source of energy. Unlike fossil fuels, the process of generating electricity from energy sources is powered by polluting material. Energy is the main input in a lot of social discussions and dictates rules in the economy, health, education, in short, energy is relevant in social life.The use of ESF, in theory, can be a long-term solution to problems related to electricity, taking into account all the advantages and disadvantages of its use. This is because, to make the use of the ESF advantageous and competitive, there is still a need for a lot of investment in this area, since only a small portion of the use of the ESF is harnessed and transformed into Electric Energy, due to the yield of solar panels and a whole technology that advances by leaps and bounds.

This study addresses a bibliographical context, exploring factors that support innovation by valuing generation sources capable of regeneration, with the aim of highlighting the relevance of using solar energy against the changes in the energy supply system in Brazil that it makes the services more expensive.As an answer, new configurations and more mature perceptions are expected about the value of changes and the ability to consciously take advantage of the natural resources available and aimed at social and environmental balance.

1. MATERIAL AND METHODS

The topic of photovoltaic solar energy is a concern for society, as its use generates opportunities, but also promotes uncertainty. To choose the theme, the need for a contextualization of the relevance of the use of solar energy, and its surrounding assumptions, was observed, where Portela (2020) points out:

> data and its relevance as an energy matrix for decentralized use; the third part shows the data researched on websites about the use of decentralized solar energy in the Tapajós river basin in the practical and environmental education dimensions and which organizations carry out these works; the last part is the final considerations of the study. (PORTELA, 2020. p. 02).

In this work, the deductive method was used, which aims to formulate hypotheses and confirm them, where Pina (2019) defines that:

> […] method is the set of systematic and rational activities that, with the greatest security and economy, allows reaching the objective – valid and true knowledge – outlining the path to be followed, detecting errors, and assisting the scientist's decisions,A method is not rigorous because it is qualitative or quantitative, both options can be adopted very little or very rigorously. In fact, Mitchell (2018, p. 15) argued, in a recent analysis of the domain of organizational behavior, that the increases in sophistication in theory and methods have been "dramatic". This evolution embraces, as it seems

> legitimate to defend, MQ and quantitative methods. If authors are armed with appropriate conceptual tools, collect data without interfering with participants' responses, and are transparent in the way they present the evidence collected, rigor can be achieved by the study. Symmetrically, a quantitative study full of sophisticated and correctly applied statistical paraphernalia can be too lax if, for example, (PINA, 2019.p.193).

To confirm the hypothesis presented on the subject, previous academic studies relevant to the literature review were used, where Soares (2018) clarifies that:

> "Bibliographic research is the systematic study developed based on material published in books, magazines, newspapers, electronic networks, that is, material accessible to the general public. It provides analytical tools for any other type of research, but it can also be exhausted in itself. The published material can be a primary or secondary source. The bibliographic research and the review article share the characteristic of searching a bibliographic reference in several sources. However, it was evidenced that the authors share the idea that the review article needs a systematized data collection procedure, while the bibliographic research is open. The authors' reflection that the review article needs to have a well-defined research question was also evident, that you need to present an answer at the end of your report, while bibliographic research can be used as a means to explore knowledge about a certain topic, without, however, presenting a conclusion." (SOARES, 2018. p. 334).

The research subject was investigated through books and scientific articles published in the last seven years (2014-2021). The reading selection was analyzed in a selective way, identifying the main points of the studied subject for better development of the work. The subject was organized in a logical way, through documents, articles, notes, among others.

For this study, the use of graphs and tables served to illustrate in a didactic way the advantages and disadvantages of transforming the ESF into Electric Energy. Since "photovoltaic solar energy" can be used in numerous different ways, also varying according to the location of the Earth's surface in question. Thus, according to a study published in 2007 by the World Energy Council, in 2100, 70% of the energy consumed will be of solar origin (PINTO et al., 2015, p. 09).

This propensity for diversified uses of photovoltaic solar energy is what formalizes the on-grid and off-grid systems and such information is not yet popular, which restricts the possibility of citizens choosing ways to use new energy sources, to justify the investments it is necessary to know the fundamentals and relevance.

2. THEORETICAL FOUNDATION

Photovoltaic solar energy is an option for sustainability in today's society, with the option of diversifying the use and valuing of available natural resources. The growth in the production of solar energy is a reflection of a global scenario-driven towards the diversification of energy sources according to Nitsenko (2018); Hauser (2018); Rodríguez (2018).

According to Maji (2019) with the search for alternative and clean means of production, aiming at meeting the growing demand, without compromising the future of the environment. Freitas (2018) the advancement of technology in the construction of photovoltaic panels, the decrease in prices and the possibility of better integration with various types of urban spaces, are some of the main reasons that turned solar energy into a popular clean energy option, especially for urban consumers.

According to Cunha (2019), electricity consumption in Brazil has been growing over the years. According to 2017 data, consumption reached a result of 467TWh, values that place the country among the ten largest consumers in the world.The participation of the Southeast region in this consumption corresponds to about 50%, something that demonstrates the importance of this area for the analysis of the energy scenario in Brazil according to EPE (2018).

Irena (2018) & Inter Solar (2016) highlight that according to the report,

> there was a drop of 69% in these costs, with an expectation of a drop of more than 50%, compared to 2016 values, for the year 2020, with Brazil being one of the countries with a great contribution to this change, with an emphasis on a decrease in installation costs of residential photovoltaic systems by about 30%. In order to portray the growth of solar energy in this new energy scenario, we highlight the growth in installed capacity worldwide of more than 450%, reaching around 230 GW installed in the most diverse countries. When sending the analysis to Brazil, the highlight is the projection of values, which show the country entering the top 10 with the highest production of photovoltaic solar energy through a 150% increase in capacity in the period between 2016 and 2020, which evidences this decrease in costs linked to photovoltaic solar energy (IRENA, 2018.p 10 and INTER SOLAR, 2016. p. 5).

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The perceptions of solar energy on the global and national scenario emphasize that there has been an increase in the use of energy as a way of mitigating the impact, although initially, the investments are high, the use of solar energy brings benefits to the consumer and to the environment.

3. RESULTS AND DISCUSSION

For a better understanding of the relevance of transforming the ESF into electrical energy, this study listed some specific objectives, as outlined: a) describe which energy sources are available for use by society; b) punctuate the process of transforming the ESF into electrical energy, and c) contextualize the types of ESF production.In Pinto's (2015) studies, the authors point out that renewable energies are unlimited energy sources, that is, they are constantly being renewed. In this way, they can be used to produce electricity sustainably and not pollute our planet.

Until the end of the 20th century, the way most used by man to produce electricity was through the burning of fossil fuels, such as oil, coal, and natural gas, and nuclear energy. These two ways of obtaining electricity are considered non-renewable energies, as they are limited and polluting resources, despite having a very high yield.

The second even releases radioactive waste, which is highly dangerous for our well-being and for life in general. Thus, the energies that human beings consider renewable are energies that come from the Sun (solar energy), water (water energy and waves and tides), wind (wind energy), the center of the Earth (geothermal energy) and biomass, among others.

Gélio (2021) shows that almost all energy sources – hydraulic, biomass, wind, fossil fuels and ocean energy – are indirect forms of solar energy. In addition, solar radiation can be used directly as a source of thermal energy, for heating fluids and environments, and for generating mechanical or electrical power.

It can also be converted directly into electrical energy, through effects on certain materials, among which thermoelectric and photovoltaic standout. For a better understanding of the above-mentioned comment, this research provides an explanation (Table 1) of some renewable energies.

From an environmental perspective, the importance of solar energy is that it is generated without emitting gases responsible for the greenhouse effect, being an alternative, clean and renewable energy. It is essential that the population encourages the use of this technology in order to improve their relationship with nature, favoring populations not supplied by conventional electricity. Furthermore, it is possible to reduce electricity consumption and protect future generations.

Table 1. Renewable Energy Sources.
Source: Pinto (2015)

Hydro energy	Hydroelectric production takes place in hydroelectric plants. Hydroelectric plants are the most efficient way to generate electricity1 and contribute to the stability of the electricity system.
The energy of thewavesand tides	The energy available at sea, waves, and tides are very abundant. Equipment for converting this renewable energy into electricity is still under development, seeking to improve performance and resistance to the hostile maritime environment.
wind energy	Currently, the wind is one of the most attractive ways to produce electricity. In areas where the speed of the wind is considered necessary; it is possible to install a wind farm.
Geothermal energy	Geothermic is the energy of the Earth's interior heat and is a resource available in places with volcanic activity, where there is water or rocks at high temperature, and in areas where it is possible to reach magmatic strata. The use of this energy to generate electricity is done through a turbine whose blades are moved by the Earth's heat. In addition to being used for electricity production, this renewable energy source can be used as a heat source for greenhouses or pumps.for heating or cooling buildings.
biomass	Biomass is organic matter, of plant or animal origin, that can be used as a source of energy. This category includes the use of algae cultivated or harvested on the coast, waste resulting from human activity, such as by-products from the forest, agriculture, livestock or from the exploitation of the wood industry, and even the biodegradable part of solid urban waste, which are raw materials for the production of electricity, heat and transport fuels. The use of these residues for electricity production plays an important role in minimizing the risk of fire if forest clearing is combined with land use planning.
Solar energy	The production of electricity through solar energy is possible through photovoltaic cells or by heating a fluid. In the first case, the cells are made up of silica, phosphorus and boron which, upon receiving the sun's rays, originate the production of electricity, which can be stored in a battery or injected directly into the electricity grid through an inverter. In the second case, mirrors are used that concentrate sunlight to heat a fluid, generating steam that turns the blades of a steam turbine, producing electricity. The sun can also be used to heat water or to heat buildings. This type of use can replace traditional means of heating, avoiding the use of electricity or gas. The solar potential is lower in winter than in summer; in the case of hydro or wind,

The different forms of sustainable energy generation have their degree of exploration still in the process of expansion, as studies advance, new possibilities are adjusted and the one who gains from this is society, which now has the option of choices, changes in uses, or even their conciliation.

This last topic finally illustrates the ESF, the central theme of our study, for this reason, it will be more discussed during the research. Nascimento (2017) comments in his research that ES capture methods can be divided into direct and indirect and active and passive, as described below:

Table 2. Types of Solar Energy Production.
Source: Pinto (2015).

direct	means that there is only one possible transformation to make the energysolar is a type of energy usable by man.
indirect	means that it takes more than one transformation forusable energy to emerge.
Passive Systems	are generally direct, although they (sometimes) involve convective fluxes, which is technically a conversion of heat to energy. mechanics.
Active Systems	are generally indirect and are considered systems that appeal to the aid of electrical, mechanical, or chemical devices to increase energy production capacity.

What can be observed during this study is that many authors comment that electricity from the ESF is practically in almost all human activities. Right after the first Industrial Revolution, the need for electricity was created in all everyday activities.

Following this line of reasoning Pinto (2015) comments that after a major evolution in the way in which solar energy was transformed into Electric Energy, as initially the energy from the sun was not used to produce electricity, which sometimes polluted the environment, finally emerged the two most comforting ways for our environment of how to produce electricity, which emerged from the use of renewable energy: thermal and photovoltaic (Figure 1).Nascimento (2017) mentions that energy is conducted respecting the precepts of physics:

> "The first is characterized by the appearance of a potential difference, caused by the junction of two metals when such junction is at a higher temperature than the other ends of the wires. Although widely used in the construction of temperature meters, its commercial use for electricity generation has been made impossible by the low yields obtained and the high costs of materials" (NASCIMENTO, 2017. p. 03).

The energy generated follows patterns that create a circuit and lead to potential modification and application. Society begins to discover ways to value the different forms of energy present in nature and the discovery of material properties, favors the production of clean and sustainable energy.Regarding the photovoltaic FISCH (2018) highlights as being:

> "Resulting from the excitation of electrons from some materials in the presence of sunlight (or other appropriate forms of energy). Among the most suitable materials for converting solar radiation into electrical energy, which is usually called solar or photovoltaic cells, silicon stands out. The conversion efficiency of solar cells is measured by the proportion of solar radiation incident on the cell surface that is converted into electrical energy" (FISCH, 2018.p.10).

As the energy is placed in the circuit due to the photovoltaic effect through the conduction band, it lacks the characteristics of capturing and transmitting

this energy. The photovoltaic solar system is an alternative that does not emit noise, does not cause a strong environmental and visual impact and investments have a guaranteed return.

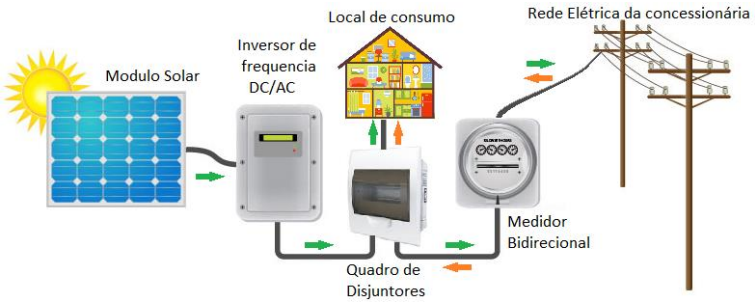

Figure 1. Illustration of a photovoltaic electricity generation system.
Source: http://www.senergam.com.br/pagina/8-solar

According to Matavelli (2013) ES can basically provide three types of processes: thermal, electrical and chemical. The first process has processed at different temperatures. Some examples are space and water heating (using flat collectors), evaporation, distillation, solar ovens, and parabolic solar ovens. The second consists of processes that are directly transformed into Electric Energy, as is the case with photovoltaic processes and thermoelectric generators. Finally, chemical processes consist of using solar energy to carry out chemical processes. Examples of this type are photolysis (breakdown by the action of sunlight) and photosynthesis.

The same author also comments that electrical energy is based on the production of electrical potential differences between two points. As a result, electrons move between these points creating an electrical current. It can be used in various equipment for domestic and industrial use. Electricity is generated through water, sun, and wind and is considered a form of clean energy, as it has low levels of pollutant production. The electrical energy generation process consists of converting another form of energy into electrical energy, mainly from kinetic energy. The distribution, from the plants, takes place through the electrons found in the conductors of the transmission lines. In Brazil, Electric Energy is mainly generated by hydroelectric plants. In table 2,

Table 3. Installed capacity, by generation source.
Source: ANENERGIA ELÉTRICAL (2013).

Enterprises in Operation				
Type	**The amount**	**Power (kW)**	**Supervised Power (kW)**	**%**
Hydroelectric Power Plant (CGH)	426	260,579	261,785	0.21
Wind Power Plant (EOL)	103	2,136,168	2,137,372	1.7
Small Hydroelectric Power Plant (PCH)	462	4,634,488	4,595,348	3.66
Central generator Solar Photovoltaic (UFV)	35	6785	2,785	0
Hydroelectric Power Plant (HPP)	194	86,713,255	80,797,124	64.3
Thermoelectric Power Plant (UTE)	1765	37,746,583	35,894,903	28.6
Thermonuclear Plant (UTN)	two	1,990,000	1,990,000	1.58
Total	**2990**	**133,487,858**	**125,679,317**	**100**

The working principle of photovoltaic cells is simple and is based on the properties of semiconductor materials. At the top, there is a metallic structure and just below there are two layers. The top layer is called “n” type silicon and the bottom layer is called “p” type silicon. The joining of these two layers is called a “pn” join.

The most used semiconductor is silicon because its atoms are characterized by having four electrons that bind to neighboring atoms, forming a crystalline network. When adding atoms with five bonding electrons, like phosphorus, for example, there will be an excess electron that cannot be paired and that will be loosely bonded to its parent atom. This causes, with little thermal energy, this electron to free itself, going to the conduction band. Phosphorus is an electron donor and is called dopant n. On the other hand, atoms with only three bonding electrons are introduced, as is the case with boron. These atoms have a deficiency of one electron to satisfy the bonds with the silicon atoms in the lattice. This lack of electrons is called a hole or gap, and with little thermal energy, an electron from a neighboring site can pass into these holes. Boron is therefore said to be a p dopant.

If starting from pure silicon, boron atoms are introduced in one half and phosphorus in the other, the pn junction will be formed. What happens at this junction is that free electrons from the n side pass to the p side where they meet the holes that trap them. This causes an accumulation of electrons on the p side, making it negatively charged, and a reduction of electrons on the n side, which makes it electrically positive. These trapped charges give rise to a permanent electric field that makes it difficult for more electrons to pass from the n-side to the p-side. This process reaches an equilibrium when the electric field forms a barrier capable of barring the remaining free electrons on the n-side.

4. CONCLUSION

The insertion of energy from renewable energy sources in the global energy matrix has been increasingly necessary due to the increase in electricity consumption and environmental problems caused mainly by the burning of fossil fuels.The conversion of solar energy into electrical energy using photovoltaic cells has become a very viable alternative, as it uses an inexhaustible source of energy if we consider the terrestrial time scale. In addition to using only sunlight to generate electricity, photovoltaic modules do not need to be located in specific areas, do not generate noise during the conversion process, and can be coupled to buildings.

Although several leading countries in electricity generation from sunlight, such as Germany, Italy, Japan, and the USA, invest for greater efficiency and use of sunlight, the average prices are relatively high due to the conversion rate of approximately 18%. However, in a few years, with more advanced technologies, the efficiency of photovoltaic cells will be much higher than those found today, due to studies and possible elements that can be added to the photovoltaic cell. This increase in efficiency and improvement of technology can be observed in several other technologies and thus will lead to a greater use of photovoltaic cells to generate electricity.

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