

Economic Viability in Photovoltaic Panels: a Systematic Review in Capes Periodical Portal and Scopus Database

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Abstract — *To accomplish this work, it was necessary to perform a survey about studies on the economic viability of the use of photovoltaic panels. This investigation was carried out by a literature review, which is essential to provide theoretical support for future researches. This work aims at conducting an analysis on the subject in works that approach the economic viability and the use of solar panels, from a previous set of bibliographic references to assist the theory contribution of this work. The webibliomining was adopted to perform the mining of the bibliographic sources that compose this systematized review of literature based on search tools and access to bibliographic information on the Internet. Scopus Elsevier database was chosen, as it is the most comprehensive one concerning the other ones. The search terms applied were (“solar photovoltaic system board” OR “pv” AND “economic viability”) in the following fields: title, abstract, and keywords. This study also focuses on research relevance for companies interested in using the photovoltaic panels. Results points out that the United States is the country that publishes the most about the subject, as well as the area that publishes is Energy. It is also noticed that Brazil is among the countries of most interest in such issue. In this way, it is concluded that the analysis of the sample of articles found and analyzed here shows that solar energy has increased visibility and has been applied in domestic, rural, commercial, and industrial plants. Nonetheless, there is also a lack of incentives or tax credit to make this power source competitive and viable.*

Keywords— *Webibliomining; Economic viability; Photovoltaic solar system.*

I. INTRODUCTION

Environment preservation, sustainable development, energy grid change, increase in power demand and industrial development are some of the factors that stimulate the fossil fuel substitution by renewable and clean sources, such as the solar source (NASCIMENTO, 2017).

The photovoltaic solar energy is the power produced by the solar incidence that reaches the surface of the Earth in electromagnetic waves (photons), which can be diffused or directly converted into electricity (IMHOFF, 2007). Solar energy on Earth can be considered as the origin of the water cycle, of the wind, and of the photosynthesis of the plant and animal kingdoms, which also depends on the plant kingdom by means of the food chains.

In that way, this article addresses the webibliomining method proposed by Costa (2010), as it provides a selection of academic works to a researcher who has just entered an area of knowledge, and its methodology consists of six stages. This method has been applied to make it easy to find a theoretical reference about the economic viability and photovoltaic panels theme.

Jesus and Costa (2015) state that, generally speaking, direct mechanisms are used to perform this type of research. Then, the text is searched by keywords, author, or title, and there are no additional filtering on the records found.

During this work, some questions were raised, such as: Has this subject been the focus of study for a long time? What was the year of largest search? Has any author been stood out or been distinguished by the largest number of documents published about the topic? What is

the area that have most documents related to it? Which country publishes the most in the search for the keywords in this case? What has been said about this theme? Which universities have developed projects and studies?

Within this context, this paper aims at providing theoretical contribution to base and complement future works by means of a systematized review of literature, identifying works that address the economic viability of the use of photovoltaic panels, as well as presenting a view of scientific production using the Scopus Elsevier database from the Capes periodical portal.

These results highlight the graphs elaborated with the publication number on the subject, the authors who most relate the theme, besides the quantitative of works published per year, per country, and per area, so that they can help future works.

II. REVIEW OF LITERATURE

2.1 Solar power in the world

It is worth noting that, since ancient time, a need for the sun to feel its direct heat and light was already a necessity (CARVALHO; CALVETE, 2010). Da Cunha Kemerich et al. (2016) apud Hémerly et al. (1993) state that the “use of solar energy to provide light for lighting functions happened in the Paleolithic period”. Moreover, Da Cunha Kemerich et al. (2016) apud Farias & Selitto (2011) address that, since the beginning, there was already a concern about “obtaining a form of artificial light”. Then during the fire production period, by using a sticky plant, the man succeeded in managing his/her first step towards his/her purpose.

Furthermore, Carvalho and Calvete (2010) point out that there has been a “two thousand-year time gap”, which goes from the Greek-Roman architecture to the series production of current thin photovoltaic panels.

In Ancient times, Romans and Greeks efficiently managed to use the architecture in a passive solar design to take advantage of the capacity to warm and light interior architectural rooms, building the most important part of the house to the South. The need arises for human skill and, in this context, the Romans were more daring when they covered the open parts of the buildings with mica or glass to keep the heat of the winter sun.

Also Carvalho and Calvete (2010) cite that, in the nineteenth century, Auguste Mouchot, the “French inventor of the first active solar engine”, who was responsible for transforming solar energy into steam power, raised some questions, which were almost predictive about the thinking that the fossil fuels used at that time, especially coal, would be never exhausted:

“Possibly, the industry will stop finding resources in Europe to meet its prodigious necessities. Coal will be extinguished unquestionably. What will the

industry do at that moment?” However, his research abruptly ended. The cuts in English exports of coal to France caused the English monarch to renegotiate a more economic deal for the French for obtaining coal, making that first technological advance of solar energy succumb right after its beginning (somewhat premonitory and actual). The French monarch did not consider that alternative as a priority, with a consequent cut of funds to continue the improvement of technology. Since then, the time frame of the research in the solar energy area has been the same for its breakthroughs and setbacks, always from the same estimates, as well as its aim.

The most promising systems for the search for sustainable and renewable sources of clean power are photovoltaic cells, as they have capacity to convert directly solar light into electrical power.

Besides, the great photovoltaic market has had a significant increase, promoted by the policies started in countries such as Japan and Germany and which took place in this century. For instance, in the decade of 2000, Japan installed 25,000 solar panels in habitations. Such growth gave rise to a decrease in production costs, creating scale economies and establishing a 30 per cent increase of the photovoltaic sector annually worldwide, although with a continuing state support in many countries (CARVALHO; CALVETE, 2010).

According to the *Agencia Internacional de Energia-AIE* (International Energy Agency), by the year 2050, the solar generation of electrical power will be of 11% of the total amount, around 5000 TWh. To obtain that generation capacity, the solar installations occupied, in total, around eight thousand Km².

It makes it possible for the generation of solar energy to become the largest source of income in North Africa, exporting power to Europe, Russia, the Middle East, and other parts of Asia (MME, 2015).

Data from 2015 show that solar power installed until that year was of 234 GW, being 229 GW of photovoltaic generation (PG) and 5 GW of Concentrating Solar Power (CSP). With a mean capacity factor of 13.9%, the total generation was 253 TWh.

Observing data from the *Nucleo de Estudos Estrategicos de Energia* of the *Ministerio de Minas e Energia-MME* (Center of Strategic Power Studies of the Ministry of Mines and Power), Italy had the highest solar generation percentage regarding its total generation of 9.3%, followed by Greece (7.8%).

Spain has the highest capacity factor of 29.3% because of more than 40% of installed power of CSP, a large part with a heat storage between 7 and 8 hours to generate in periods with no sunlight.

The first five countries in installed power respond for 68% of the world total. In 2015, China (1st) and the United States (2nd) overtook Germany in solar generation.

In 2018, Brazil should be among the 20 largest solar power-generating countries in the world, considering the operation of 2.6 GW power already contracted. Geographically, the 234 GW of 2015 represent 1,635 km² of solar panels, or 40.4 km square of side, considering 143 W/m² (efficiency of 15% solar absorption) (ANEEL 2018).

2.2 Solar Energy and Brazil

For Nascimento (2017) apud MME (2017), Brazil had 81 MWp of photovoltaic solar power installed by the end of 2016, which represented 0.05% of total installed capacity in the country. Moreover, “from a total of 81 MWp in 2016, 24MWp corresponded to centralized generation and 57 MWp, to distributed generation (NASCIMENTO, 2017 apud MME, 2017).

In accordance with Nascimento (2017) apud Empresa de Pesquisa Energetica - EPE (2012), Brazil has “large reserves of quality quartz, because of its location and territorial extension, which can generate competitive advantages for silicon production with high purity grains, solar cells and modules, products of high aggregate value”.

The Agencia Nacional de Energia Eletrica - ANEEL (National Agency for Electric Power) asserts in its report on solar energy that its largest current applications are for water heating and photovoltaic generation of electrical power, the second most found in the North and Northeast Regions in communities that do not have access to the electrical power grid (ANEEL, 2018).

The solar source application to generate electrical power provides many benefits cited by the Associação Brasileira de Energia Solar Fotovoltaica-ABSOLAR (Brazilian Association of Photovoltaic Solar Power), both from the electrical, environmental, and socioeconomic perspective (ABSOLAR, 2017).

There is legal support for ANEEL Resolution 482, of April 7, 2012, which allows access to the micro-generation distributed to the national electric grid, ensuring a legal base for the response to the socioeconomic and environmental solutions of the generation and distribution of electrical power (MME, 2015).

With regard to the environmental aspect, Imhoff (2007) stresses solar energy is one of the least pollutant primary sources of power. It is silent, with a low maintenance level, less aggressive to the plant and animal kingdom than other power sources and, as it can be generated in its own consumer unit, it does not need

transmission lines, greatly minimizing its environmental impact.

After the introduction of the net measuring regulation in 2012, Holdermann et. al. (2014) examined the viability of small-scale, grid-connected development of the photovoltaic system as an alternative to environmental and socio-economic questions. Rocha et. al. (2017), complementing those studies, indicate that there is strong pressure for change in the means of power production and that the reading is an important mechanism in the dissemination of photovoltaic systems of small scale.

As a major solution to the socioeconomic power question, Vale et. al. (2017) addressed studies in the Programa Minha Casa Minha Vida (MCMV) (A program that provides support for the acquisition of a house or apartment for low-income families) to evaluate the reduction of costs and economic impacts of the installation of small-scale photovoltaic systems connected to the grid in the households of this Program.

In the view of Mitscher et. al. (2012), who performed a study on economic competitiveness of grid-connected micro-generation of electrical power, that system has already proved to be as commercially competitive, since there are tax exemptions.

Such study is based on the work of Byrne et al. (1998), who conducted a similar investigation in Mongolia, demonstrating its economic viability. Considering some technical differences, the socioeconomic scenarios are very similar, which is worthwhile to support the research carried out by Mitscher et al. (2012).

By its location and territorial extension, Brazil has the most renewable power grid in the industrialized world, with almost half of its production coming from water resources, biomass and ethanol, in addition to wind and solar energy. Figure 1 presents the power grid in Brazil.

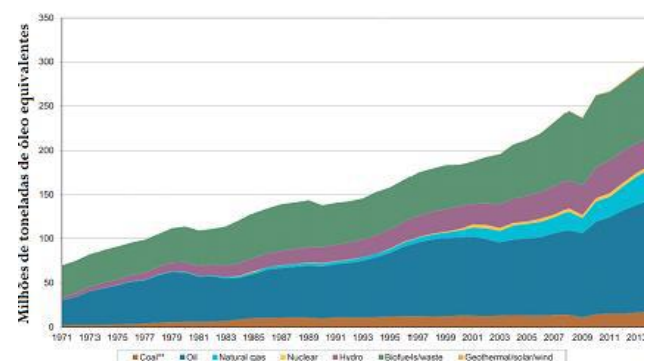


Fig.1: Total Primary Power Supply in Brazil (IEA, 2018)

Data from Figure 1 indicate the relation between million tons of oil equivalent in a period, in which it can be seen the Brazilian power grid. In green color, it is noticed that the biofuel production is increasing in the

country. In addition, Hydro, Nuclear, Geothermal, Natural Gas, and Oil sources had an increase throughout that period. Lastly, Coal was the one that kept greater linearity compared to the others.

As most of Brazilian territory lies between the Equator and the Tropic of Capricorn, there are no considerable variations in the sunlight duration. Nevertheless, to maximize the solar radiation use, it is essential to adjust the position of the collector or solar or photovoltaic panel at the local latitude and the year period when more power is required (ANEEL, 2018).

In Pereira and Oliveira (2011), photovoltaic panels are the main components of a power generating photovoltaic system, which are composed of a voltaic cell cluster that can be electrically associated in parallel and/or in series. Their goal is to detect solar irradiation and convert it into electric power. *ptar a irradiação solar e transformá-la em energia elétrica.*

2.3 Costs of Solar Power in Brazil

As stated by Nascimento (2017), the *MME* (2009) “highlights” two basic regulatory incentive mechanisms: the price system and the quota system”. The first is related to a value paid to the provider of the solar photovoltaic power generator in a determined period equal to or higher than twenty years. The second mechanism defines power and (or) energy goals from specific sources for concessionaires, distributors, large consumers, and other agents of the electric sector (NASCIMENTO, 2017).

Moreover, *Enel Soluções* (2018) literally describes solar power as being free of charge, as for the *Enel Soluções* (2018), “we pay for the system that converts solar energy into electrical power”, as shown below:

For example, a photovoltaic solar power system of 3.3 KWp worth R\$ 25 thousand, plus R\$ 6 thousand of maintenance in the 25-year period, is equal to a total investment of R\$ 31 thousand. In 25 years, the power generated will be of approximately 94 thousand KWh. If we divide the investment value by the power generated, we will reach the price of R\$ 0,31/kWh. A value 57.6% cheaper than the current electric power tariff in Rio de Janeiro State, which is R\$ 0,73.

The environmental costs of solar power generation, in terms of environmental impact, which were not specified herein, are lowest when compared to other energy sources, such as hydroelectric generation, where deviations in rivers and the construction of large reservoirs are necessary. In this case, there is a cost of vast areas, whether they are native forest or productive or inhabited land.

2.4 Types of Solar Power in Brazil

The most frequent type of solar energy conversion to electricity in Brazil is the Photovoltaic panels (Pp). According to Brasil (2015), in the 1950s, “solar panels converted only 4.5% of solar energy into electricity”, equal to 13Wp/m² at a cost of US\$ 1,785/Wp. In addition, he says the worldwide efficiency tripled to 15% (143Wp/m²), costing 1,370 times less, of US\$ 1.30/Wp.

Most of the photovoltaic panels (Pp) used nowadays, with a 95% market share, are manufactured in pure crystalline silicon (c – SI), and have power production between 13% and 17% (MME, 2015).

There is also a cheaper variant of Pp, with lower power efficiency, called thin layer cells, composed of thin layers of photovoltaic semiconductor materials (amorphous silicon – a-Si, cadmium telluride – CdTe, and copper-indium-gallium diselenide – CIGS) on a base made of glass, stainless steel or plastic.

Concerning the photovoltaic conversion into electrical power, its use attends to small systems and autonomous microsystems, in general Distributed Generation (DG) or in large plants, which use solar energy in a centralized way. On the other hand, the CSP process is suitable for large plants. Distributed Generation (DG) is the type of generation that is close to or in the consumer unit.

ANEEL approved in 2012 its Regulatory Resolutions 482 and 517, which regulate the microgeneration of electrical power, besides establishing the compensation system of electrical power (net metering), being currently used in many countries (ANEEL, 2018).

Therefore, in the DG system, the excess energy is distributed to the grid and, subsequently, balanced with consumption of that unit or another one, stating that it should have the same ownership. The power credits generated will be valid for 60 months. The process involves only the kWh exchange between consumer – generator and the power distributor.

The use of solar energy by concentration is also registered in Brazil, in a system called Concentrating Solar Power (CSP), to produce electrical power or heat. In the CSP process, the solar energy is concentrated in a receiver, which collects and transfers the energy to a heat transfer fluid that can provide heat for final applications, or activate thermal engines, or conventional steam turbines to generate electrical power (MME, 2015). There are heat stores in large CSP plants to supply heat and electricity at night or in cloudy sky conditions.

There are four types of CSP technologies: Parabolic Troughs (PT); Fresnel Reflector (FR); Solar Tower (ST); and Solar Disk (SD). In PC and FR, the solar energy is concentrated in a focal line, reaching operating temperatures between 300° C and 550° C. In ST and SD plants, the solar light is concentrated in just one spot,

which enables achieving operational temperatures higher than the PC and FR plants.

The reflecting mirror can be fixed or adjustable, together or not with the focal plan (MME, 2015).

The PT technology is currently the most developed and most employed in the market.

Synthetic oil or molten salt is applied in the heat transfer to a steam generator.

2.5 Brazilian Legislation on Solar Energy

For Portal Solar LTDA. – ME (2018), the Normative Resolution no. 482/2012 of ANEEL establishes “the general conditions for connection of the photovoltaic solar power systems in the electrical power grid”. The same way, the Portal Solar LTDA. - ME (2018) stresses that this is a “resolution that allows us to make the ‘exchange’ of energy with the electric grid”.

The Conselho Nacional da Política Fazendária - Ministério da Fazenda (CONFAZ, 2015), by means of the Ajuste SINIEF 2 (it provides for procedures relating to electric energy circulation operations, subjected to billing), repealed the agreement that "guided the taxation of the generated energy in the grid". The decision as to whether or not to tax the solar energy that is injected into the distributor's grid was made by each state.

Moreover, some states, such as Amazonas, Parana, and Santa Catarina, have still not exempted the solar energy production from the Imposto sobre Circulação de Mercadorias e Serviços - ICMS (tax on circulation of goods and services).

Lastly, the Federal Government, by the Law no. 13.169, exempted the PIS and COFINS to the solar energy injected into the grid (PORTAL SOLAR LTDA. - ME, 2018).

III. MATERIALS AND METHODS

In this step it is explained how the search was carried out, in a detailed way, in the Scopus Elsevier database, which was chosen because it is the most comprehensive in front of the other options

3.1 Regarding the purposes

Relating to the technical procedures, this is a theoretical-conceptual work of an exploratory nature and qualitative research approach, inspired by the webibliomining method introduced by Costa (2010), to perform the systematized review of literature.

3.2 Quanto aos meios

Inspired by the models of Freitas and Costa (2017), Jesus and Costa (2015), and Neves et al. (2015), the paper will cover six stages, as described in Chart 1.

Stages	
Stage 1	Definition of the research sample;
Stage 2	Research on the sample with keywords;
Stage 3	Identification of journals with the highest number of articles published on the theme;
Stage 4	Identification of authors with the highest number of publications;
Stage 5	Verification of Production chronology, identifying the highest production cycles;
Stage 6	Selection of the articles to compose the “starting point” for the bibliographic research.

Chart 1: Development model to carry out a bibliometry (Costa, 2010).

For the first stage, a literature review was made at Scopus Elsevier database, accessed in January 2018, by the Portal de Periodicos da Capes, once it includes, besides academic articles, other types of publications, like free- access publications, commercial publications, among others (ELSEVIER B.V., 2016). The exclusion filters were not used so that the range of documents in the found area would be larger.

The fields: title, keyword and summary were listed as a research field. This study embraced all areas of knowledge in the data bank. The operator "AND" guarantees that the publications found have all the words searched, while the use of the operator "OR" allows one or another term.

After the selection of the database, the search criteria were set. With the goal of making a broad coverage of the publications on the subject of economic viability of the use of photovoltaic panels, the area was researched as a whole, to compile all the possible studies developed.

For the second stage, the set of keywords ("solar photovoltaic system board" OR "pv" AND "economic viability") were defined in the search field in accordance with "title, keywords, abstract", reaching 187 results. These terms were chosen in a way that they could be located in the title of the article, in the abstract, or in the keywords of it.

There has been a limitation of research on the time period, including only the years covered by at least two publications, until January 2018, and on other topics, only the ten main topics returned by the database have been addressed. This methodology was used to make the data more meaningful and recent.

The third and fourth stages made it possible to identify the authors, journal largest number of publications. This study was conducted on the basis of the two main data delivered by the base, i.e., in each category, the first ten data supplied by the base were considered.

The fifth stage enabled the display of the productions and authors with more citations. Lastly, the sixth stage of the methodology suggested by Costa (2010) aims at a chronological survey of academic productions produced with the aim of presenting the scientific evolution on the subject.

IV. RESULTS AND DISCUSSIONS

At this stage, the 187 resulting articles were analyzed and, from this evaluation, a group of ten articles was composed, which approached more accurately with the subject of this study.

In this way, using this group, graphics containing these publications are shown here, which are associated with the amount of publications per year, which authors published on the subject, the origins of the articles, as well as their affiliations. The number of publications per country and per area is also shown, displaying those that are of interest.

4.1 Number of publications per Year

The data given in Figure 2 illustrate the number of publications in a temporal cut. They were considered only the years that presented no less than two publications on the subject.

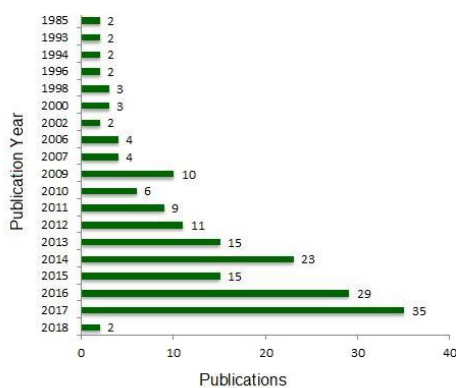


Fig.2: Graph of Frequency of publications per year from 1985 to 2018 (Scopus, 2018).

It can be seen that, from 2013 onwards, the published volume was higher. The year 2017 was the one that resulted in a larger number with 35 publications. This year of 2018 has already presented two publications.

4.1 Authors that published on the subject and number of citations

The data given in the Figure below show the graph of the authors who published the most about the subject and the number of citations.

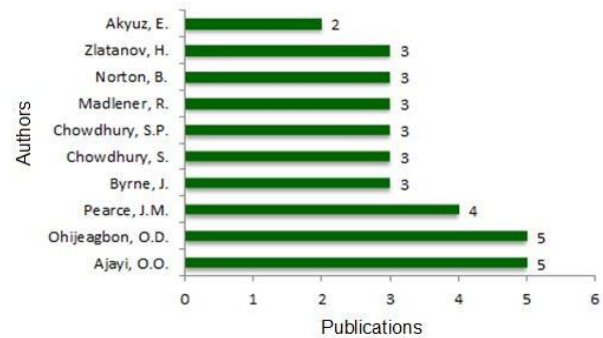


Fig.3: Graph of authors with higher Frequency of Publication (Scopus, 2018)

It can be noted that the authors Ohijeagbon, O.D. and Ajayi, O.O. were those who had the largest number of publications with respect to the theme studied in this work.

4.2 Source of publication

In Table 1, the source data of the publications are displayed, together with how many documents each one has. Furthermore, the impact factors of the Scientific Journal Rankings (SJR) and the impact of citations per documents are also shown.

Table.1: Number of published documents per publication source

Publication Source	Number of Documents	Impact Factor	
		SJR	Citation per doc.
Renewable and Sustainable Energy Reviews	14	3.0	8.78
Renewable Energy	12	1.7	4.8
Energy Policy	11	2.2	4.4
Conference Record of the IEE Photovoltaic	1	0.2	3
Applied Energy	8	3.0	7.58
Energy Procedia	6	0.4	7
Energy	5	2	4.95
Journal of Renewable and Sustainable Energy	5	0.4	2
International Journal of Hydrogen Energy	4	1.1	4
Energy Conversion and Management	3	2.2	9

Source: Scopus, 2018.

The data of the two main publication sources are listed in Table 1, along with how many documents each one

has. The Renewable and Sustainable Energy Review, with 14 publications in the area, followed by Renewable Energy, with 12, and Energy Policycom 11 were noteworthy.

In relation to the SJR, the source that is highlighted is Applied Energy, with 3.06, and Renewable and Sustainable Energy Reviews, with 3.05 value.

On the other hand, in the citations, it is noted that, in the first place, there is Renewable and Sustainable Energy Reviews, with a value of 8.78 per citation, followed by Applied Energy, with 7.58, and Energy Conversion and Management, with 6.06.

4.3 Affiliation

According to the information given in Figure 5, the two more relevant Universities or Organizations, also known as affiliations, are presented, as well as how many articles each one of them produces.

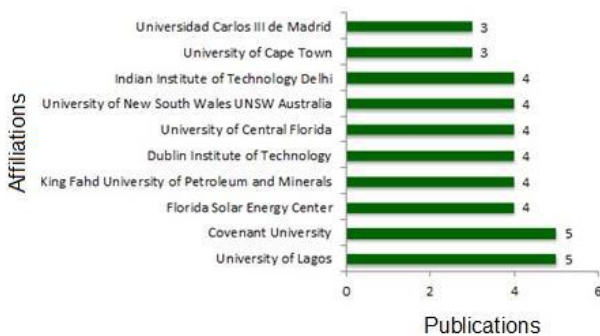


Fig.4: Graph of Affiliations with Higher Frequency of Publication. (Scopus, 2018).

It is worth noting, in Figure 4, Covenant University and the University of Lagos with five publications each.

4.4 Number of publications per country

The data in Figure 5 indicate the quantity of publications per country.

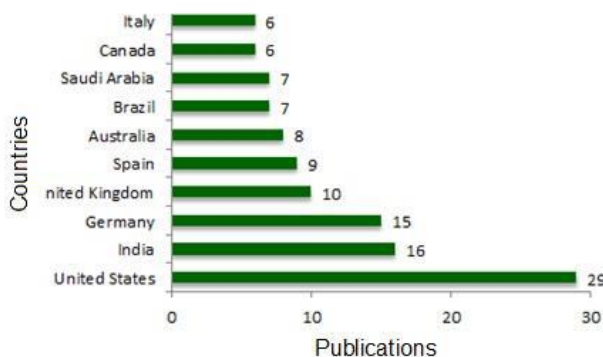


Fig.5: Graph of Countries with Higher Frequency of Publication (Scopus, 2018).

From data in Figure 5, the United States is the country that most research on the theme with 29 publications,

almost twice the following country. Then, India stands out with 16 publications and Germany, with 15. Brazil is among the ten most important countries, with seven publications, surpassing Italy and Canada.

4.5 Number of publications per area

The data contained in Figure 6 illustrate, in graph form, the knowledge areas with the highest frequency of publication.

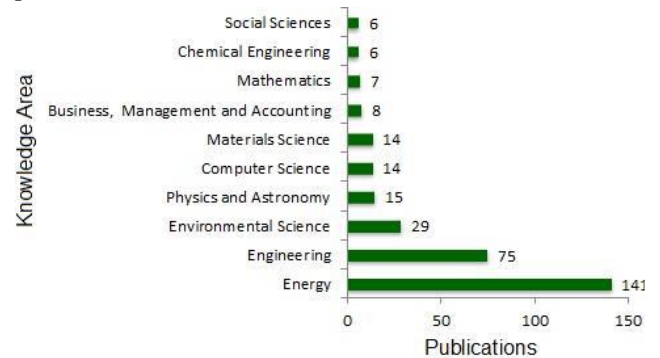


Fig.6: Graph of the knowledge areas with the highest frequency of publication (Scopus, 2018).

Among the various knowledge areas existing, the publications have been classified in ten areas: Energy; Engineering; Environmental Science; Physics and Astronomy; Computer Science; Materials Science; Business, Management, and Accounting; Mathematics; Chemical Engineering; and Social Sciences, as seen in Figure 7. The area of Energy is highlighted, with 141 publications, which is almost double of the second knowledge area, Engineering, with 75 publications.

4.6 Analysis of the article sample that forms the basis of the theme

In this phase, the 187 documents were examined and, according to the analysis of their scientific abstracts, ten articles were chosen from among the others. Available at Chart 2, they are those regarded by the author as the most relevant for the intended topic, as they will best correlate the economic viability and the photovoltaic solar system panels at a global level, in addition to focusing on the analysis of the articles produced in Brazil with the aim at identifying the results found with respect to the Brazilian authors.

Title	Author	Citations		Title	Author	Citations	
		Year	Count			Year	Count
THE ECONOMICS OF SUSTAINABLE ENERGY FOR RURAL DEVELOPMENT: A STUDY OF RENEWABLE ENERGY IN RURAL CHINA.	Byrne, J. , Shen, B. , Wallace, W.	1998	95	PRODUCTION IN BRAZIL: STOCHASTIC ECONOMIC VIABILITY ANALYSIS FOR SMALL SYSTEMS IN THE FACE OF NET METERING AND TAX INCENTIVES	Aquila, G. , Pamplona, E.D.O. , Chierigatti, B.G. , Lima, J.D.S.B.		
THE POTENTIAL AND ECONOMIC VIABILITY OF SOLAR PHOTOVOLTAIC POWER IN GHANA	Asumadu-Sarkodie, S. , Owusu, P.A.	2016	23	ANALYSIS OF THE ECONOMIC VIABILITY OF A PHOTOVOLTAIC GENERATION PROJECT APPLIED TO THE BRAZILIAN HOUSING PROGRAM “MINHA CASA MINHA VIDA”	Vale, A.M. , Felix, D.G. , Fortes, M.Z.Dias. , B.H. , Santelli, B.S.	2017	0
ECONOMIC VIABILITY OF SOLAR HOME SYSTEMS: CASE STUDY OF BANGLADESH	Asumadu-Sarkodie, S. , Owusu, P.A.	2010	43	IMPACT OF RURAL GRID-CONNECTED PHOTOVOLTAIC GENERATION SYSTEMS ON POWER QUALITY	Pinto, R. , Mariano, S. , Calado, M.D.R. , De Souza, J.F.	2016	7
DOMESTIC APPLICATION OF SOLAR PV SYSTEMS IN IRELAND: THE REALITY OF THEIR ECONOMIC VIABILITY	Li, Z. , Boyle, F. , Reynolds, A.	2011	37				
STUDY OF ECONOMIC VIABILITY OF PHOTOVOLTAIC ELECTRIC POWER FOR QUETTA – PAKISTAN	Khalid, A. , Junaidi, H.	2013	22				
DISTRIBUTED PHOTOVOLTAIC GENERATION IN BRAZIL: AN ECONOMIC VIABILITY ANALYSIS OF SMALL-SCALE PHOTOVOLTAIC SYSTEMS IN THE RESIDENTIAL AND COMMERCIAL SECTORS	Holdermann, C. , Kissel, J. , Beigel, J.	2014	15				
ECONOMIC PERFORMANCE AND POLICIES FOR GRID-CONNECTED RESIDENTIAL SOLAR PHOTOVOLTAIC SYSTEMS IN BRAZIL	Mitscher, M. , Rüther, R.	2012	33				
PHOTOVOLTAIC ELECTRICITY	Rocha, L.C.S.	2017	0				

Chart 2: Articles selected

Byrne et al. (1998) discussed the most recent case studies and modeling efforts that assessed the economic viability of photovoltaic and off-grid power technologies for rural applications in developing countries. They carried out case studies in 41 families of the Autonomous Region of Mongolia, located in the interior of China. It was seen in the analyses carried out that the leveled costs of the photovoltaic and off-grid systems on a domestic scale are competitive, in terms of costs, with conventional diesel sets, and the hybrid solar-wind systems seem to be an economic means of supplying electrical services throughout the year, in addition to meeting the energy demands of families that are most distant inland in Mongolia.

Asumadu-Sarkodie et al. (2016) assessed the potential and economic viability of photovoltaic solar power in Ghana, using the RETScreen software. A 5-megawatt solar power system is connected to the grid using a SunPower SPR-320E-WHT-D solar module, which can be used in the next localities: Navrongo, Bawku, Wa, Tema, Bolgatanga, Axim, Salaga, Kintampo, Kete Krachi, Tamale, Hohoe, Koforidua, Ejura, Takoradi, Bole, Sunyani, Bibiani, Cape coast, Prestea and Akuse. For this purpose, an investment of 17,752,179 dollars and 25,313 square meters of land were needed to install the system. As the potential of 5-megawatts is limited for

Accra, Kumasi, Wenchi and Tafo, there are photovoltaic solar energy potentials for low capacity photovoltaic modules, like these localities. To develop solar technology in a developing country, like Ghana, it is necessary to make government investments, like subsidies and the development of favorable economic environments for the investment in the private sector, which will promote the possibilities of investment in renewable energy in Ghana, in addition to reducing the power loss and leakage of energy, and increasing productivity and economic resilience.

Hossain Mondal (2010) argues that the city of Bangladesh is rich in solar incidence, thus, the photovoltaic solar system seems to be a good renewable energy investment. The most advantageous use for the domestic solar system (SHS) in Bangladesh is the generation of light. In rural areas, the most commonly used lamps are based on kerosene. The dry cell phone batteries have been utilized in radios and the car batteries have been slowly available in television sets where the battery charging systems are available. The cost of kerosene and battery charging is high and the solar system can compete with them. Six cases were examined with the aim of discovering the viability and economic sustainability of solar systems implemented in selected villages of the Gazipur district in Bangladesh, during the period from October 2004 to December 2004, and the data collection method used was based on questionnaires. Consequently, the solar system is financially attractive for small-scale rural businesses and for domestic lighting. Nevertheless, for domestic lighting needs the system is not financially and economically viable, without considering the social benefits.

Li et al. (2011) argue that, in years to come, renewable energy sources will be playing an important role in the production of electricity in Ireland. Electricity is mainly derived from imported gas and coal, given that Ireland has a lack of fossil fuels. As solar energy is widely available, freely accessible and environmentally friendly, it is becoming attractive to everyone, but has not been very widespread on both a large and domestic level in Ireland. The biggest challenge for the growth of this technology is the lack of clarity in the economy. Thus, the authors aimed at presenting a methodology to evaluate precisely the economic viability of a domestic solar system. To this end, they employed HOMER and Microsoft Excel software 2007 to perform energy and economic analyses. They carried out a realistic analysis of eight examples of domestic photovoltaic systems available in Ireland and concluded that these systems still do not seem promising even if they were given better financial support.

Khalid et al. (2013) intended to assess the viability of a photovoltaic power plant. For this purpose, they analyzed which would be the most adequate location by comparing the average monthly solar radiation data from eight Pakistani cities, and the city they selected for the 10-megawatt plant was Quetta. The software applied was the RETScreen, which proved that the plant could reach 23,206 GWh of energy per year. At a total cost of US\$ 50 million, a 50% debt rate, a 9% discount rate, the suggested photovoltaic plant generates electricity at a rate of US\$ 0.1557/kWh. In addition, the electricity produced is 30.8% more costly than the electricity delivered by the grid. The analysis of emissions revealed that the proposed photovoltaic power plant avoided the production of carbon dioxide in 17,938 tons / year. It was found that currently the suggested photovoltaic power plant is not viable if only economic factors are taken into account. If the total cost installed by the factory is approximately US\$ 35 million, the energy cost of the photovoltaic power plant will be equivalent to the electric power provided by the grid with no subsidy.

Holdermann et al. (2014) investigated the economic viability of the small-scale photovoltaic system and grid-connected in the Brazilian commercial and residential sectors after the introduction of the net metering regulation in April 2012. They applied the discounted cash flow method to calculate the necessary specific investment costs so that the photovoltaic systems are economically viable in each of the 63 distribution grids in Brazil. In its calculation, they included levies and taxes, taken from telephone interviews and published information. Another parameter was the application of the program PV*Sol to conduct local simulations of the head office of the distribution company. In the current situation scenario, photovoltaic power is not financially viable in any of the distribution grids in the commercial or residential sectors. As such, being the environment for grid-connected photovoltaic power, the commercial or residential sectors take on the lowest-cost photovoltaic system and a lower discount rate to establish the viability of the photovoltaic system.

Mitscher et al. (2012) assessed the economic competitiveness of photovoltaic solar generation connected to the grid and distributed by means of small-scale roof installations in five Brazilian cities. The locations represent a whole set of two essential parameters for the economic viability of photovoltaic solar irradiation and local electricity rates. The authors showed the leveled electricity costs for the photovoltaic production and the present net values for a specific photovoltaic system. The analysis includes three different scenarios of interest rates, which correspond to different conditions for the financing of the generators: subsidized

market, mature and adjusted by the country's specific risk. In analyzing net current values, the revenue flow is determined by the sale of photovoltaic electricity at current residential rates based on the net metering. By using subsidized interest rates, the analysis found that solar photovoltaic electricity is already competitive in Brazil, while in a country-specific risk-adjusted rate, the decreasing but still high capital costs of photovoltaics make its use economically unviable. In the tax rate of the mature market, the competitiveness of photovoltaics is largely dependent on the residential tariff. The economic competitiveness in this area is provided for places with high residential rates. The study showed the high generation potential distributed by photovoltaic installations in Brazil and proved that, in some conditions, the photovoltaic system connected to the grid can be economically competitive in a developing country.

Rocha et al. (2017) believe that there is growing pressure for a change in consumption and the production of energy standards in Brazil. Within this context, grid measurement is an important mechanism that stimulates the spread of small solar voltaic systems. As a complement to the net metering, a tax exemption is currently being offered in a number of Brazilian states. The purpose of the study was to evaluate the effect of the taxation exemption on the circulation of goods and services and the returns and risks of a photovoltaic micro-generation project in four cities in different regions of Brazil: Belem, Petrolina, Uberaba, and Uruguaiana. The simulation method employed was Monte Carlo (MCS), which takes into account uncertainties regarding financial and environmental variables. The results of the stochastic analysis of the economic viability allowed concluding that the taxation exemption on the circulation of goods and services (*ICMS*) is essential to make photovoltaic microgeneration viable in Brazil. In the cities analyzed, the photovoltaic microgeneration gave the investor economic unviability when the *ICMS* is charged. By considering the *ICMS* exemption policy, the cities of Petrolina and Belém had a high probability of viability. In relation to the risk analysis, the photovoltaic microgeneration achieved the best performance in Petrolina, both in terms of collection conditions and *ICMS* exemption. There is a high potential for solar use in the whole Brazilian territory, however, in the current state of evolution and because of the production chain of the Brazilian photovoltaic industry, high costs limit the growth of this technology. The study assists policy makers in evaluating incentive programs, highlighting that the tax exemption directly addresses one of the goals for which *ICMS* was developed, which is to stimulate the evolution of productive sectors, like the photovoltaic industry.

Vale et al. (2017) note that photovoltaic solar power grid-connected in Brazil is playing an increasingly significant role as a result of advances in photovoltaic technology, together with the reduction of capital and subsidy costs. In this way, the authors conducted an economic study of two projects in the government program "*Minha Casa Minha Vida*" (*MCMV*), in Sao Paulo State and elsewhere in Piaui State, by using the generation of distributed photovoltaic energy. The *MCMV* is the Brazilian Government's housing program that gives access to home ownership for low-income Brazilians in urban and rural areas. The analysis resulted from the evaluation of the present net value and the internal return rate, considering an attractive minimum return rate and varying the annual growth of the energy rates in 25 years of operation, which is the expected lifetime of the solar panels. These two cities were selected, since their federal states have different actions in relation to tax issues. The results demonstrated that, despite the fact that Piaui had a higher average solar incidence than Sao Paulo, the effect of the tax exemption on the circulation of goods and services is an advantage for investing in São Paulo.

Pinto et al. (2016) believe that photovoltaic (PV) generation systems have been applied more and more to produce electricity from renewable sources, taking a growing interest. The PV micro-generation installations connected in grids in private homes have increased because of government policies, and the greater attention on the part of the industry. As low voltage distribution systems (Low Voltage-LV) were built to provide the power flow in a single direction, the feed-in from the PV generation in rural low voltage grids can influence power quality (PQ-Photovoltaic Quality), and the operation and reliability of the installations. The authors intended to report the results of the PQ analysis of a real PV generation installation connected to a rural low voltage grid. Voltage fluctuations and harmonic voltage contents were noted. The statistical analysis showed a negative impact on the PQ produced by this photovoltaic installation and a small fraction of the energy in the sunny day is converted, resulting in revenue losses and forcing the converter to operate in an undesirable operating mode. The authors addressed the grid disturbances and their results with regard to the technical and economic viability of the photovoltaic system, and possible solutions. A strengthening of the low voltage grid was proposed and implemented. After this change, a new assessment of PQ resulted in a better impact on PQ, which made it economically viable.

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