sustainability

Review

Identification and Analysis of Impact Factors on the Economic Feasibility of Photovoltaic Energy Investments

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Abstract: The introduction of environmental impact targets around the world has highlighted the need to adopt alternative sources of energy, which can supply the demand and mitigate the damage caused to the environment. Solar energy is one of the main sources of alternative energy, and is considered an abundant source of clean energy. However, to facilitate and encourage investors interested in the installation of photovoltaic energy systems for electricity production, it is essential to evaluate the factors that impact the economic viability of the projects. Therefore, the objective of this research is to present a systematic analytical framework, in order to identify and analyze the main factors that impact the financial feasibility of projects for the installation of photovoltaic energy plants. For this purpose, a systematic literature review was carried out, analyzing the main studies related to the topic and identifying the main factors that may financially affect investments in photovoltaic energy systems. From this review, 29 influencing factors were identified and separated into five categories, namely, location, economic, political, climatic and environmental, and technical factors. The main factors highlighted are the investment cost, power generation, operation and maintenance costs, solar radiation, lifetime, energy tariff, efficiency, electricity consumption, and interest and taxes. The results may assist policy makers, investors, researchers, and other stakeholders to identify the key factors that are being examined in the literature, and to evaluate which ones should be considered in their study to ensure the sustainable development of power generation through the solar source.

Keywords: solar energy; photovoltaic; economic viability; economic feasibility; risk factors

1. Introduction

The generation of electrical energy is essential for the quality of life and human development. However, the way in which this energy is generated can cause damage to the environment and harm human life. Non-renewable energy sources are used on a large scale in the world, and this causes various concerns. According to the International Energy Agency (IEA) [1], electricity in 2016 was still dominated by fossil fuel sources. Moreover, the world's total primary energy supply (TPES) increased almost 2.5 times between 1971 and 2016, oil being the dominant fuel source (although it reduced from 44% to 32% of TPES). The IEA [1] also highlights the reduction in the use of fossil fuels and the trend of growing participation of renewable energy sources (RESs), reaching about 11% in the world energy matrix in 2016.

Energy resources considered renewable include solar, geothermal, wind, biomass, oceanic, and various types of hydroelectric energy [2]. RESs are viable alternatives to fulfill energy demand, reduce energy costs, and mitigate environmental impacts. Within these sources, photovoltaic (PV) energy stands out, converting sunlight into electrical energy. The sun is the main source of energy on our planet, but today a minor portion of that energy is harnessed, and the potential for further developments is huge.

Several factors can influence the economic feasibility of PV systems in the world. According to Karimi et al. [3], the implementation of PV systems on the roof, for example, can be economically viable, but these systems could not offer great economic benefits. As such, an incentive policy is recommended, in which the owners can sell the electricity generated by the PV systems and obtain benefits. Viana et al. [4] state that the investment cost in PV generation systems is high and this makes access in the short term difficult; thus, improved policies are needed to encourage this generation of energy. However, as indicated in Spertino et al. [5], the target for PV systems is to reach the grid parity, namely, the condition in which the generation cost using PV equals the price of the electricity taken from the grid.

Specific technical aspects relevant to the investments refer to the PV plant structure. Fixed PV plants are generally cheaper than the corresponding PV plants that could be installed in the same site with sun-tracking configurations [6]; the latter would also need higher maintenance due to the mechanical stress of the moving parts. Furthermore, to avoid the shading effect, which decreases the performance efficiency of the PV arrays, the distance between the PV modules has to be sufficiently high [7], limiting the area available for PV array installation. Moreover, the cost of the PV plant is also affected by the presence of different types of PV system cooling technologies [8,9].

According to Tervo et al. [10], the addition of battery energy storage is a factor that optimizes the PV energy system and, for the locations studied, could represent a substantial gain in the electricity use of the system. For Cucchiella et al. [11], the profitability of PV plants highly depends on the self-consumption portion of energy. When the PV plant is installed on land with high levels of sunlight, with longer battery life and adequate capacity, the net present value (NPV) is increased, making the investment more economically viable.

A broader view of the economic feasibility of PV energy investments needs to identify the risk factors that can make investments in PV energy financially unviable. Several factors have been pointed out around the world and vary among different studies.

Thus, the aim of this paper is to investigate which are the main impact factors on the economic feasibility of PV energy investments. These impact factors are identified, discussing how they are treated in economic feasibility analyses, and finally are organized into five categories. For this purpose, a systematic literature review (SLR) was carried out, to group and examine the main publications related to the topic and indicate the parameters that affect financially and are evaluated in economic feasibility analysis studies. Such information is relevant, as the interest of the stakeholders has grown substantially, and much of the previous research in related fields lacks integrity and universality. In addition, no reviews were found that present an insightful discussion of such factors. Thus, the extensive systematic literature review about PV investment analysis aims at providing a summary and guidelines, for both researchers and investors, on the main variables that directly impact on the return on investments.

2. Materials and Method

In this research, the SLR was used for searching and grouping articles and research reviews that deal with the economic viability of PV systems in the world. According to Webster and Watson [12], a relevant literature review is an essential feature of any academic project. For Okoli and Schabram [13] and Rowley and Slack [14], one of the purposes of literature reviews is to provide a theoretical basis for further research and to learn the breadth of research on a topic of interest. Thus, this research presents an SLR, aimed at gathering a sample of publications on the economic feasibility of PV energy investments, to understand and investigate the economic parameters more analyzed in the literature.

Levy and Ellis [15] classify the literature review as a systematic process basically divided into three stages: input, processing, and output. Adapting the model they developed, for the SLR presented in this paper, the process is divided into three phases: (i) the input phase, where the research problem, objectives, search terms, criteria for inclusion or exclusion of manuscripts, methods, and tools to be used are defined; (ii) the processing phase, in which the search for publications in the defined databases are carried out, with an analysis of the search results and the application of desired filters to refine the search and the documentation of the results; and, finally, (iii) the output phase, in which an analysis of the articles resulting from the search is carried out and a final sample table is built with the synthesis of the research. Figure 1 shows the adapted model of conducting the SLR in the three phases.

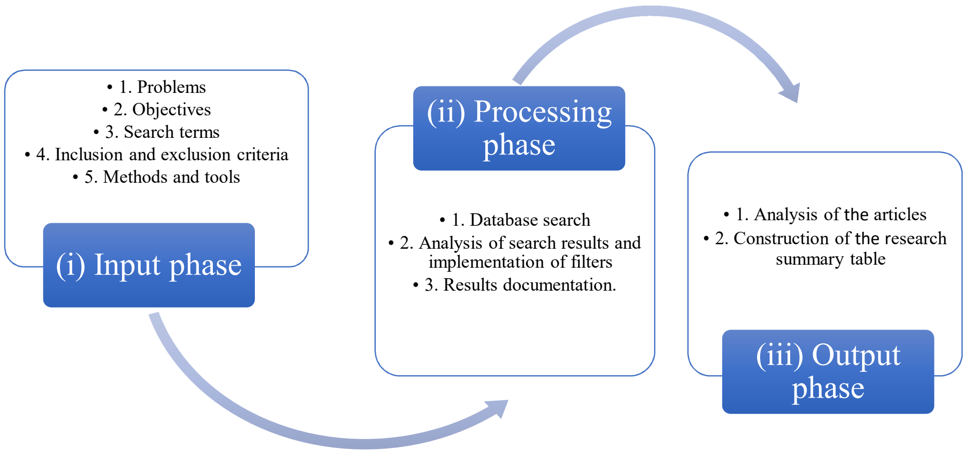

Figure 1. Conducting model of systematic literature review (SLR) in three stages. Source: adapted from Levy and Ellis [15].

2.1. Input Phase

This first stage is the planning phase of the SLR. The first step was to define the research problem: "What factors can influence the economic feasibility of PV energy projects?"

Along with the definition of the problem, the research objectives were aligned, to identify studies that address the relevant topic and, in these studies, verify the factors that have a financial impact, according to their authors.

In this research, the only database selected was the Web of Science (WoS), as it is seen as a reliable database with relevant and high-quality works published in journals with considerable impact in the literature. WoS includes more than 10,000 magazines and comprises seven different citation databases, including different information collected from journals, conferences, reports, books, and book series. Finally, as WOS is the oldest citation database, it has strong coverage with citations and bibliographic data [16].

Table 1 shows the search terms defined and used in the database. The last search performed on the database was made on 18 January 2020, considering all publications until 31 December 2019.

Table 1. SLR search terms.

Search	Search Terms	Location in Structure
Search 1	("economic feasibility" or "economic assessment" or "economic viability") AND ("solar energy" or "solar power" or "photovoltaic")	Title AND Topic
Search 2		Topic AND Title

After completing the search in the database and collecting the publications from the initial sample, inclusion and/or exclusion criteria were applied to refine and improve the sample, focusing on the objective of this research. The main defined criteria for inclusion of works in the sample were:

(a) Research applied to the world context.
(b) Research in the form of articles and reviews, for providing greater accessibility and dissemination of the contents to the academic and professional community.
(c) Availability of access to the complete content.
(d) Literature focused on the economic evaluation of PV energy.
(e) Papers available in the English language.
(f) Works that were not found in the search, but are considered important for the research.

Concerning the defined criteria for exclusion of works in the sample, the main criteria used were:

(a) Lack of access to the complete content.
(b) Duplication of works.
(c) Works available only in languages other than English.
(d) Research with issues that are outside the scope of this research.

The bibliometric software VOSviewer was used for data network analysis, and Microsoft Excel was the tool used to prepare the synthesis of the results.

2.2. Processing Phase

This is a phase where the search in the database is effectively carried out, using the search terms defined in the previous phase and applying filters that could improve this search, according to the scope of this research. The only filter used in the search for the papers found refers to the format of these manuscripts, to select only those available in article or review formats, as they are the most appropriate and relevant formats for this research. In the search result, after applying the filters, the number of the initial sample was 485 works.

Applying the exclusion criteria previously defined, from the initial sample of 485, 471 works remained. The sample articles were then read, in order to further refine the search by studying the manuscripts. Figure 2 presents a summary of the steps for reading the articles in this review, showing the number of articles remaining after each step.

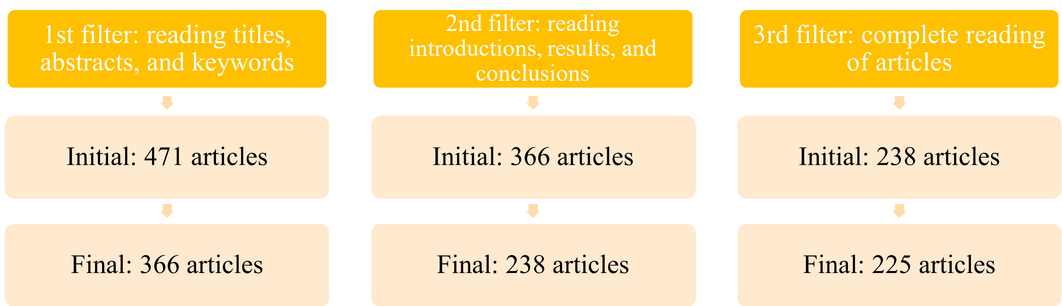

Figure 2. Summary of the stages of reading the articles.

In Figure 2, it can be seen that, at first, there were 471 articles in the search. After reading titles, abstracts, and keywords, this number was reduced to 366 papers, as some of the subjects discussed in the manuscripts were beyond the scope of this research.

Following the reading of the articles, in the second stage, the results and conclusions were read for summarizing and presenting the main contents of the manuscripts. In this stage, it could be verified whether the manuscripts in fact dealt with the economic feasibility of solar energy and analyzed the impact factors as expected. At the end of this stage, the sample decreased from 366 to 238 works.

In the last reading stage, the remaining works in the sample were read completely. The final sample was then defined, with a number of 225 manuscripts.

2.3. Output Phase

Table 2 shows the synthesis of the research results. The analysis and discussion of the impact factors on the viability of PV energy projects are presented in Section 3.

Table 2. Synthesis of the final sample of articles.

	Authors	Locations	Journals
[3]	Karimi et al. (2019)	Iran	*Environmental Progress & Sustainable Energy*
[4]	Viana et al. (2019)	Brazil	*Engenharia Agricola*
[7]	Awan (2019)	Saudi Arabia	*Journal of Renewable and Sustainable Energy*
[10]	Tervo et al. (2018)	United States	*Renewable & Sustainable Energy Reviews*
[11]	Cucchiella et al. (2018)	Italy	*Sustainability*
[17]	Bimenyimana et al. (2019)	Rwanda	*International Journal of Photoenergy*
[18]	Lee (2019)	South Korea	*Renewable Energy*
[19]	Babatunde et al. (2019)	Nigeria	*African Journal of Science Technology Innovation & Development*
[20]	Yendaluru et al. (2019)	India	*Environmental Progress & Sustainable Energy*
[21]	Ellabban and Alassi (2019)	Australia	*Energy Reports*
[22]	Mehrpooya et al. (2019)	Iran	*Energy Reports*
[23]	Goswami et al. (2019)	India	*Environmental Progress & Sustainable Energy*
[24]	Lopes et al. (2019)	Brazil	*Journal of Material Cycles and Waste Management*
[25]	Kang et al. (2019)	South Korea	*Energy & Environment*
[26]	Ilse et al. (2019)	Germany	*Joule*
[27]	Ramanan et al. (2019)	India	*Building Services Engineering Research & Technology*
[28]	Ouedraogo and Yamegueu (2019)	Burkina Faso	*Energy Science & Engineering*
[29]	Adesanya and Pearce (2019)	Nigeria	*Renewable & Sustainable Energy Reviews*
[30]	Silveira et al. (2019)	Brazil	*Navus-Revista de Gestao e Tecnologia*
[31]	Alhaj and Al-Ghamdi (2019)	Qatar	*Solar Energy*
[32]	Barone et al. (2019)	Greece	*Energy Conversion and Management*
[33]	Garcia-Saez et al. (2019)	Spain	*Renewable Energy*
[34]	Jo and Jang (2019)	South Korea	*Sustainability*
[35]	Eshraghi et al. (2019)	Iran	*Sustainable Energy Technologies and Assessments*
[36]	Li (2019)	China	*Energy Sources Part A-Recovery Utilization and Environmental Effects*
[37]	Kumar et al. (2019)	India	*Energy*
[38]	Liu et al. (2019)	Australia	*International Journal of Electrical Power & Energy Systems*
[39]	Buonomano et al. (2019)	Italy	*Renewable Energy*
[40]	Farias-Rocha et al. (2019)	Philippines	*Journal of Cleaner Production*
[41]	Chiacchio et al. (2019)	Italy	*Energies*
[42]	Jamali et al. (2019)	Iran	*Solar Energy*
[43]	Espinoza et al. (2019)	Peru	*Renewable Energy*
[44]	Wang et al. (2019)	Turkey	*Journal of Cleaner Production*
[45]	Milousi et al. (2019)	Greece	*Sustainability*
[46]	Xu et al. (2019)	Pakistan	*Processes*
[47]	Lammoglia and Brandalise (2019)	Brazil	*Independent Journal of Management & Production*
[48]	Leite et al. (2019)	Brazil	*Energy Conversion and Management*
[49]	Asif et al. (2019)	Saudi Arabia	*Smart and Sustainable Built Environment*
[50]	Talavera et al. (2019)	Spain	*Renewable Energy*
[51]	Gurturk (2019)	Turkey	*Energy*
[52]	Mostafaeipour et al. (2019)	Iran	*Desalination*
[53]	Talavera et al. (2019)	Spain	*Energies*
[54]	Brunini et al. (2019)	Brazil	*Revista Brasileira De Ciencias Agrarias-Agraria*
[55]	De Lara et al. (2019)	Brazil	*Brazilian Archives of Biology and Technology*
[56]	Mohammad and Ismael (2019)	Iraq	*Aims Energy*
[57]	Kharseh and Wallbaum (2019)	Sweden	*Energies*
[58]	You et al. (2018)	China	*Energy*
[59]	Lee et al. (2018)	South Korea	*Applied Energy*
[60]	Al-Saqlawi et al. (2018)	Oman	*Energy Conversion and Management*
[61]	McTigue et al. (2018)	United States	*Applied Energy*
[62]	Kassem et al. (2018)	Cyprus	*Global Journal of Environmental Science and Management-Gjesm*
[63]	Poonia et al. (2018)	India	*Cogent Engineering*
[64]	San Miguel and Corona (2018)	Spain	*Renewable & Sustainable Energy Reviews*
[65]	Mohammadi et al. (2018)	Iran	*Energy*

Table 2. *Cont.*

	Authors	Locations	Journals
[66]	Schopfer et al. (2018)	Switzerland	*Applied Energy*
[67]	Lorenzo et al. (2018)	Ecowas Region	*Energy*
[68]	Buonomano et al. (2018)	Italy	*Energy*
[69]	MacDougall et al. (2018)	Canada	*Renewable Energy*
[70]	Aderemi et al. (2018)	South Africa	*Energies*
[71]	Lourenço et al. (2018)	Brazil	*Energies*
[72]	Ayadi et al. (2018)	Jordan	*Sustainable Cities and Society*
[73]	Islam (2018)	France	*Sustainable Cities and Society*
[74]	Noro and Lazzarin (2018)	Italy	*International Journal of Low-Carbon Technologies*
[75]	Carrico et al. (2018)	Angola	*Journal of Sustainable Development of Energy Water and Environment Systems-Jsdewes*
[76]	Zhang et al. (2018)	United States	*Applied Energy*
[77]	Yu (2018)	France	*Energy Policy*
[78]	Okoye and Oranekwu-Okoye (2018)	Nigeria	*Renewable & Sustainable Energy Reviews*
[79]	Vides-Prado et al. (2018)	Colombia	*Renewable & Sustainable Energy Reviews*
[80]	Fereidooni et al. (2018)	Iran	*Renewable & Sustainable Energy Reviews*
[81]	Liu et al. (2018)	China	*Energy Conversion and Management*
[82]	Garcia et al. (2018)	Brazil	*Brazilian Archives of Biology and Technology*
[83]	Silveira et al. (2018)	Brazil	*Brazilian Archives of Biology and Technology*
[84]	Yu (2018)	China	*Energy Sources Part A-Recovery Utilization and Environmental Effects*
[85]	Choi et al. (2018)	United States	*International Journal of Sustainable Energy*
[86]	Lee et al. (2018)	United States	*Technological and Economic Development of Economy*
[87]	Rocha et al. (2017)	Brazil	*Journal of Cleaner Production*
[88]	Hammad et al. (2017)	Jordan	*Renewable & Sustainable Energy Reviews*
[89]	Bahrami et al. (2017)	Nigeria	*Renewable Energy*
[90]	Patil et al. (2017)	India	*Renewable Energy*
[91]	Adefarati and Bansal (2017)	South Africa	*Applied Energy*
[92]	Ramli et al. (2017)	Saudi Arabia	*Journal of Renewable and Sustainable Energy*
[93]	Lari and Sahin (2017)	Saudi Arabia	*Energy Conversion and Management*
[94]	Asaee et al. (2017)	Canada	*Energy and Buildings*
[95]	Qolipour et al. (2017)	Iran	*Renewable & Sustainable Energy Reviews*
[96]	Prehoda et al. (2017)	United States	*Renewable & Sustainable Energy Reviews*
[97]	Ramirez-Sagner et al. (2017)	Chile	*Renewable Energy*
[98]	Bianchini et al. (2017)	Italy	*Renewable Energy*
[99]	Oh et al. (2017)	South Korea	*Applied Energy*
[100]	Khaenson et al. (2017)	Thailand	*International Energy Journal*
[101]	Cucchiella et al. (2017)	Italy	*Energies*
[102]	Kazem et al. (2017)	Oman	*Case Studies In Thermal Engineering*
[103]	Vale et al. (2017)	Brazil	*Energy Policy*
[104]	Das et al. (2017)	Malaysia	*Renewable & Sustainable Energy Reviews*
[105]	Anagnostopoulos et al. (2017)	Greece	*Energies*
[106]	Peters and Madlener (2017)	Germany	*Applied Energy*
[107]	Nyholm et al. (2017)	Sweden	*Renewable Energy*
[108]	Niajalili et al. (2017)	Iran	*Solar Energy*
[109]	Sampaio and Gonzalez (2017)	Brazil	*Renewable & Sustainable Energy Reviews*
[110]	Camillo et al. (2017)	Portugal	*Solar Energy*
[111]	Tomosk et al. (2017)	United States	*Renewable Energy*
[112]	Ozcan and Akyavuz (2017)	Turkey	*Applied Thermal Engineering*
[113]	Hairat and Ghosh (2017)	India	*Renewable & Sustainable Energy Reviews*
[114]	Silva and Hendrick (2017)	Belgium	*Applied Energy*
[115]	Haegermark et al. (2017)	Sweden	*Energy*
[116]	Xue (2017)	China	*Journal of Renewable and Sustainable Energy*
[117]	Okoye and Solyali (2017)	Nigeria	*Energy*
[118]	Dowling et al. (2017)	United States	*Renewable & Sustainable Energy Reviews*
[119]	Alsharif (2017)	South Korea	*Energies*
[120]	Sabo et al. (2017)	Malaysia	*Applied Energy*
[121]	Asaee et al. (2017)	Canada	*Applied Energy*
[122]	Ramirez et al. (2017)	Spain	*Energy Policy*
[123]	Kang et al. (2017)	United States	*Journal of Renewable and Sustainable Energy*
[124]	Emmanuel et al. (2017)	New Zealand	*Energy*
[125]	Talavera et al. (2017)	Spain	*Energy*
[126]	Modi et al. (2017)	Denmark	*Renewable & Sustainable Energy Reviews*
[127]	Stevovic (2017)	Serbia	*Archives for Technical Sciences*
[128]	Girma (2017)	Ethiopia	*International Journal of Sustainable Energy*
[129]	Shaahid (2017)	Saudi Arabia	*Thermal Science*
[130]	Bhakta and Mukherjee (2017)	India	*Journal of Renewable and Sustainable Energy*
[131]	Ajayi and Ohijeagbon (2017)	Nigeria	*International Journal of Ambient Energy*
[132]	Mokheimer et al. (2017)	Saudi Arabia	*Applied Energy*
[133]	Linssen et al. (2017)	Germany	*Applied Energy*
[134]	Brusco et al. (2016)	Italy	*Applied Energy*
[135]	Choi and Song (2016)	South Korea	*Sustainability*

Table 2. *Cont.*

	Authors	Locations	Journals
[136]	Quansah and Adaramola (2016)	Ghana	*Sustainable Energy Technologies and Assessments*
[137]	Lee et al. (2016)	United States	*Renewable Energy*
[138]	Baneshi and Hadianfard (2016)	Iran	*Energy Conversion and Management*
[139]	Edalati et al. (2016)	Iran	*Energy*
[140]	Halder (2016)	Bangladesh	*Renewable & Sustainable Energy Reviews*
[141]	Isa et al. (2016)	Malaysia	*Energy*
[142]	Hussain et al. (2016)	South Korea	*Solar Energy*
[143]	Corona et al. (2016)	Spain	*Solar Energy*
[144]	Zhang et al. (2016)	China	*Applied Thermal Engineering*
[145]	Sarasa-Maestro et al. (2016)	Spain	*Energies*
[146]	Arsalis et al. (2016)	Cyprus	*Energies*
[147]	Schinko and Komendantova (2016)	Algeria	*Renewable Energy*
[148]	Li and Yu (2016)	China	*Journal of Cleaner Production*
[149]	Jones et al. (2016)	Jordan	*Desalination*
[150]	Rodrigues et al. (2016)	Portugal	*Solar Energy*
[151]	Napoli and Rioux (2016)	Saudi Arabia	*International Journal of Water Resources Development*
[152]	Munoz-Cruzado-Alba et al. (2016)	Spain	*Energies*
[153]	Lee et al. (2016)	United States	*Renewable & Sustainable Energy Reviews*
[154]	Bendato et al. (2016)	Italy	*Energy*
[155]	Arabkoohsar et al. (2016)	Brazil	*Energy*
[156]	Ranjan and Kaushik (2016)	India	*International Journal of Low-Carbon Technologies*
[157]	Akikur et al. (2016)	Malaysia	*Clean Technologies and Environmental Policy*
[158]	De Boeck et al. (2016)	Belgium	*Renewable Energy*
[159]	Solano et al. (2016)	Ecuador	*IEEE Latin America Transactions*
[160]	Song and Choi (2016)	South Korea	*Energies*
[161]	Haysom et al. (2016)	United States	*Progress In Photovoltaics*
[162]	Falter et al. (2016)	Germany	*Environmental Science & Technology*
[163]	Mehang et al. (2016)	Indonesia	*International Journal of Renewable Energy Research*
[164]	Finenko and Soundararajan (2016)	Singapore	*International Journal of Global Energy Issues*
[165]	Rahman et al. (2016)	Bangladesh	*International Journal of Renewable Energy Research*
[166]	Blanco-Silva et al. (2016)	Spain	*Journal of Environmental Protection and Ecology*
[167]	Asumadu-Sarkodie and Owusu (2016)	Ghana	*Energy Sources Part A-Recovery Utilization and Environmental Effects*
[168]	Bianchini et al. (2016)	Italy	*Renewable Energy*
[169]	Bianchini et al. (2015)	Italy	*Solar Energy*
[170]	Cucchiella et al. (2015)	Italy	*Energies*
[171]	Xavier et al. (2015)	Brazil	*Energies*
[172]	Hirvonen et al. (2015)	Finland	*Energy Policy*
[173]	Poghosyan and Hassan (2015)	United Arab Emirates	*Renewable Energy*
[174]	Ghosh et al. (2015)	India	*Renewable & Sustainable Energy Reviews*
[175]	Salehin et al. (2015)	Bangladesh	*International Journal of Renewable Energy Research*
[176]	Hirth (2015)	Germany	*IET Renewable Power Generation*
[177]	Ataei et al. (2015)	Iran	*Advances In Energy Research*
[178]	Kumar et al. (2014)	India	*Energy For Sustainable Development*
[179]	Chiaroni et al. (2014)	Italy	*Energy Conversion and Management*
[180]	Hoppmann et al. (2014)	Germany	*Renewable & Sustainable Energy Reviews*
[181]	Bakos and Petroglou (2014)	Greece	*Renewable Energy*
[182]	Li et al. (2014)	China	*Renewable Energy*
[183]	Tijani et al. (2014)	Nigeria	*Journal of Renewable and Sustainable Energy*
[184]	Fortunato et al. (2014)	Italy	*Energy Conversion and Management*
[185]	Holdermann et al. (2014)	Brazil	*Energy Policy*
[186]	Akikur et al. (2014)	Malaysia	*Energy Conversion and Management*
[187]	Liu (2014)	China	*International Journal of Electrical Power & Energy Systems*
[188]	Dagtekin et al. (2014)	Turkey	*Energy Exploration & Exploitation*
[189]	Mir-Artigues (2013)	Spain	*Energy Policy*
[190]	Choi et al. (2013)	South Korea	*International Journal of Precision Engineering and Manufacturing*
[191]	Orioli and Di Gangi (2013)	Italy	*Renewable & Sustainable Energy Reviews*
[192]	Paudel and Sarper (2013)	United States	*Energy*
[193]	Schallenberg-Rodriguez (2013)	Spain	*Renewable & Sustainable Energy Reviews*
[194]	Khalid and Junaidi (2013)	Pakistan	*Renewable Energy*
[195]	Telsnig et al. (2013)	South Africa	*Journal of Energy In Southern Africa*
[196]	Yaqub et al. (2012)	United States	*Engineering Management Journal*
[197]	Mitscher and Ruther (2012)	Brazil	*Energy Policy*
[198]	Tan et al. (2012)	China	*Journal of Energy Engineering-Asce*
[199]	Cellura et al. (2012)	Italy	*Renewable & Sustainable Energy Reviews*
[200]	Askari and Ameri (2012)	Iran	*Energy Sources Part B-Economics Planning and Policy*

Table 2. *Cont.*

	Authors	Locations	Journals
[201]	Branker et al. (2011)	Canada	*Renewable & Sustainable Energy Reviews*
[202]	Li et al. (2011)	Ireland	*Energy*
[203]	Peters et al. (2011)	Switzerland	*Energy Policy*
[204]	Kaabeche et al. (2011)	Algeria	*Solar Energy*
[205]	Azzopardi et al. (2011)	United Kingdom	*Energy & Environmental Science*
[206]	Moser et al. (2011)	Morocco	*Journal of Solar Energy Engineering-Transactions of The Asme*
[207]	Bilton et al. (2011)	United States	*Desalination and Water Treatment*
[208]	Ramadhan and Naseeb (2011)	Kuwait	*Renewable Energy*
[209]	Mokhtar et al. (2010)	United Arab Emirates	*Applied Energy*
[210]	Mondal (2010)	Bangladesh	*Renewable Energy*
[211]	Bode and Sheer (2010)	South Africa	*Journal of Energy in Southern Africa*
[212]	Zaki et al. (2010)	Malaysia	*Energy Conversion and Management*
[213]	Qoaider and Steinbrecht (2010)	Egypt	*Applied Energy*
[214]	Kornelakis and Koutroulis (2009)	Greece	*IET Renewable Power Generation*
[215]	Focacci (2009)	Italy	*Renewable & Sustainable Energy Reviews*
[216]	Moral et al. (2009)	Spain	*Spanish Journal of Agricultural Research*
[217]	Wu et al. (2009)	Taiwan	*Renewable Energy*
[218]	Shaahid and El-Amin (2009)	Saudi Arabia	*Renewable & Sustainable Energy Reviews*
[219]	Al-Soud and Hrayshat (2009)	Jordan	*Journal of Cleaner Production*
[220]	Olivier et al. (2008)	South Africa	*Renewable Energy*
[221]	Shaahid and Elhadidy (2008)	Saudi Arabia	*Renewable & Sustainable Energy Reviews*
[222]	Shaahid and Elhadidy (2007)	Saudi Arabia	*Renewable & Sustainable Energy Reviews*
[223]	Bojic and Blagojevic (2006)	Serbia	*Energy Policy*
[224]	Celik (2006)	Turkey	*Renewable & Sustainable Energy Reviews*
[225]	Ghoneim (2006)	Kuwait	*Energy Conversion and Management*
[226]	Odeh et al. (2006)	Ireland	*Solar Energy*
[227]	Schmid and Hoffmann (2004)	Brazil	*Energy Policy*
[228]	Varela et al. (2004)	Spain	*International Journal of Energy Research*
[229]	Tsoutsos et al. (2003)	Greece	*Applied Thermal Engineering*
[230]	Bakos and Soursos (2002)	Greece	*Energy and Buildings*
[231]	Kolhe et al. (2002)	India	*Energy Economics*
[232]	El-Nashar (2001)	United Arab Emirates	*Desalination*
[233]	Khouzam (1999)	Australia	*IEEE Transactions On Energy Conversion*
[234]	Hovsepian and Kaiser (1997)	Armenia	*Energy Sources*
[235]	Karim and Rahman (1993)	Bangladesh	*Solar Energy Materials and Solar Cells*
[236]	Sharan et al. (1985)	India	*Solar Cells*

3. Results and Discussions

In this section, the main results of the search analysis are presented. First, we discuss the main information about the sample characteristics. In addition, the keywords used in the search are shown and analyzed. Finally, as the principal objective of this article, the main impact factors identified in the final sample are discussed.

3.1. Characterization of the Final Sample

The characterization has been carried out by using the criteria indicated below.

Year of publication: The oldest article in our sample was published in 1985, followed by a publication in 1993. From the 2000s onwards, a greater number of publications in the area have been identified, reaching its peak in 2017 with 47 published works. Figure 3 illustrates the evolution in the number of publications per year of the studies found in the sample. These results confirm that the interest in the research on the economic feasibility of solar/photovoltaic energy in the world has grown especially in the last 10 years.

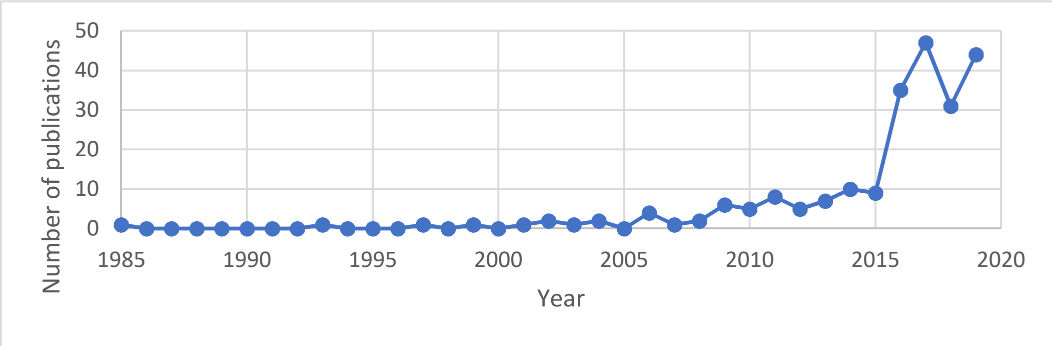

Figure 3. Evolution of the number of publications per year in the final sample.

Place of publication: It is easy to see how much the place of study influences the analysis of economic feasibility of this type of project. In fact, when analyzing these studies, it is possible to identify similarities of the analysis between manuscripts from the same region and differences when the manuscript comes from a different region. Figure 4 shows a map of publications, where we can observe a greater interest in parts of Europe, North and South America, and some countries in Africa, Asia, and Oceania. Observing the number of countries found in the sample of studies, it is clear that the interest in the study on the feasibility of solar energy projects is a trend in many regions of the world, totaling a number of 55 countries found in the search.

Brazil and Italy are the countries that most appeared in the sample, with 18 and 17 publications, respectively. In addition to Brazil and Italy, countries like Spain, the United States, Iran, and India, for example, appear in the sample with a high number of publications, with at least 13 papers each. Other countries appear with fewer publications, but not less relevant, as shown in Figure 5.

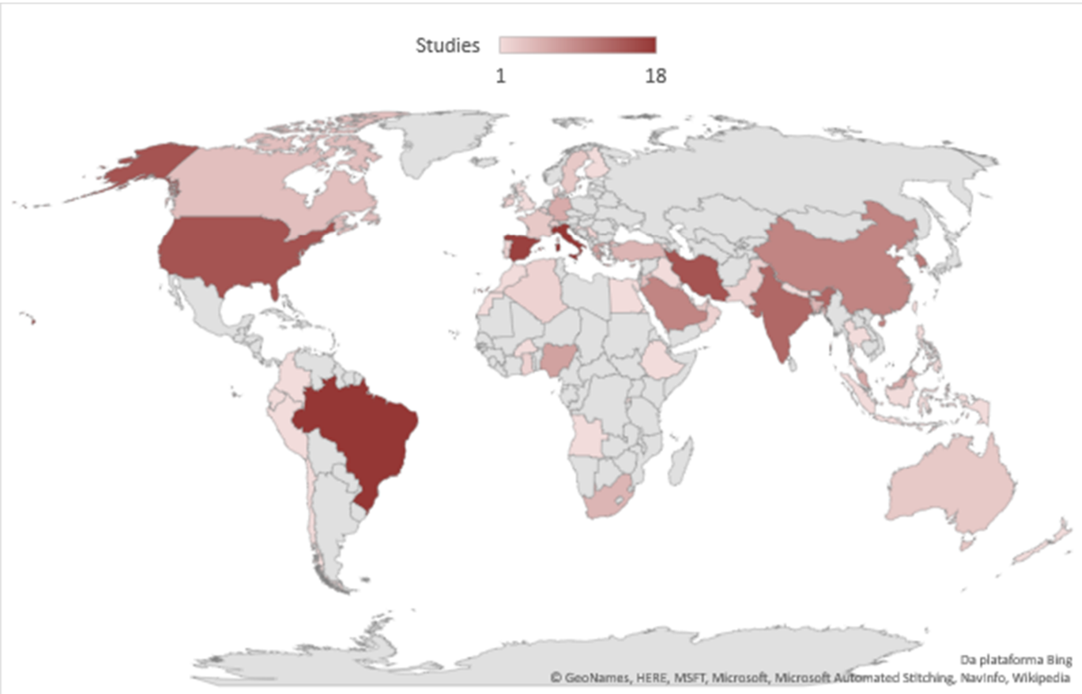

Figure 4. Map of sample publications.

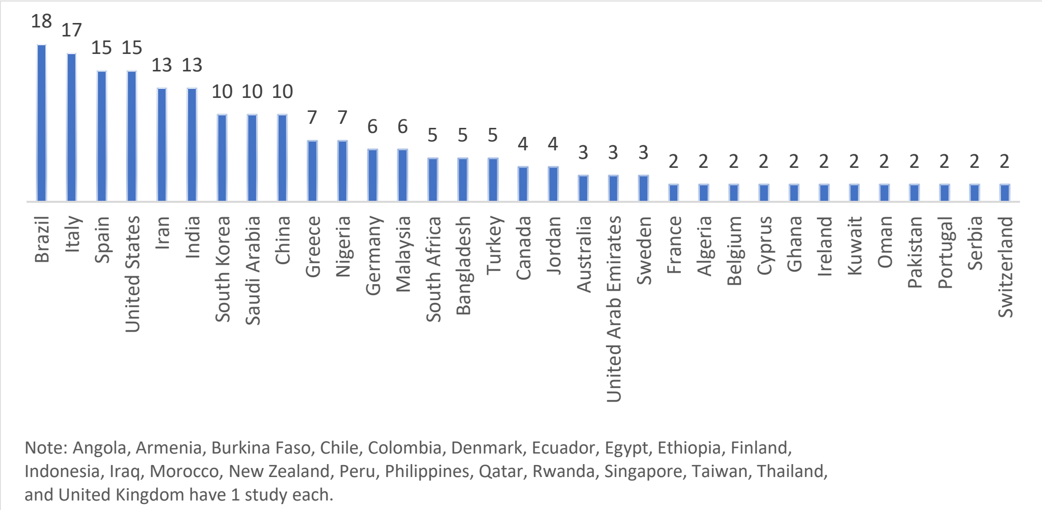

Figure 5. Number of publications by country.

Number of citations: The number of citations usually shows the effectiveness, novelty, and quality of the article. Figure 6 shows the articles most cited in the sample. In particular, the average number of citations per year shows what is being cited over time, and provides useful information for recently published articles.

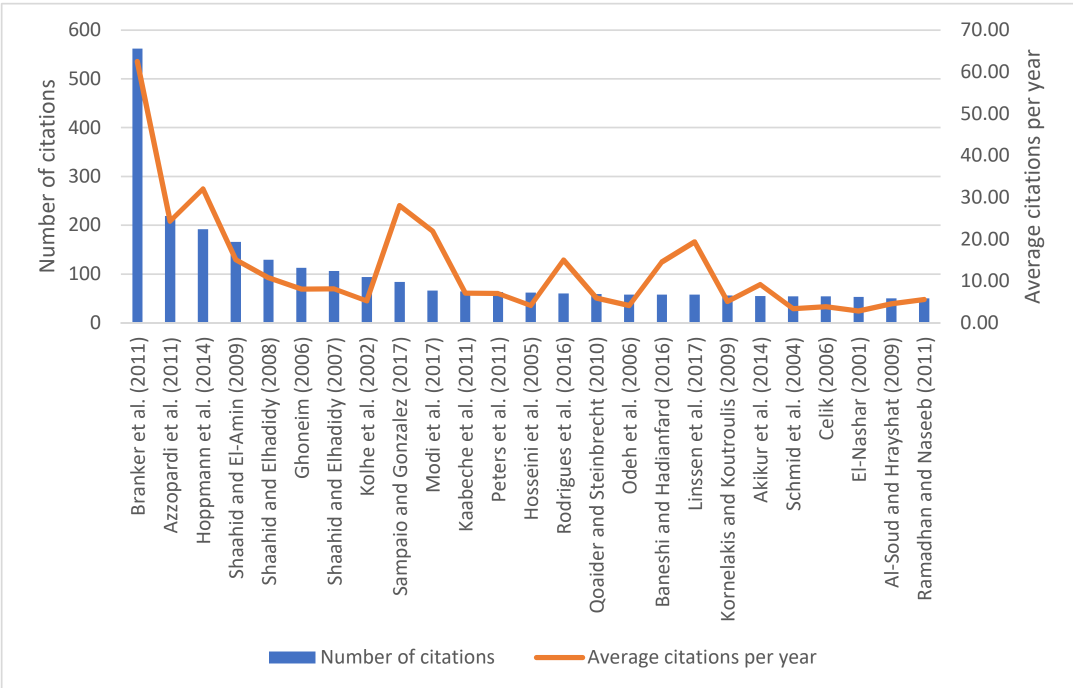

Figure 6. Number and average of citations of the most cited articles in the sample.

Considering the overall number of citations (562) and the average number of citations per year (62.4), Branker et al. [201] is the study with the greatest impact in our sample. Other references of great impact of the sample, with more than 100 total citations, are Azzopardi et al. [205], Hoppmann et al. [180], Shaahid and El-Amin [218], Shaahid and Elhadidy [221], Ghoneim [225], and Shaahid and Elhadidy [222].

3.2. Data Network Analysis

Using the VOSviewer software as a tool, a network analysis of the sample data was performed to observe the use of the main keywords in the final sample of research papers. In this way, it is possible to assess which are the main terms used, and the links among them. In this analysis, a map was created based on the bibliographic data, selecting the data from the final sample of 225 studies. The type of analysis selected was "co-occurrence", the method was "full counting", and the unit of analysis was "author keywords". For better visualization of the data network, we opted for a minimum occurrence of five times, where a map was generated with all the keywords that appear at least five times in the sample works. Of a total of 725 words identified, 28 were shown on the data network. The visualization "overlay mode" was selected to observe, in addition to the words themselves, the evolution with which these terms have been used over the years in the sample studies, as shown in Figure 7.

Figure 7 shows that the word "photovoltaic" is the most used by the authors, which appeared in 31 sample publications. The term "solar energy", which is often used in conjunction with the term "photovoltaic", is also widely used by researchers, with a number of 30 appearances in the sample. The terms "renewable energy" and "economic analysis" appear next, mentioned in 21 publications each. It is also possible to notice, thanks to the overlay visualization mode, that terms such as "net metering", "techno-economic analysis", and "homer", for example, are being discontinued in these works. Conversely, new words are emerging and being used as keywords in the search for articles and reviews, such as "economic assessment", "levelized cost of energy (LCOE)" and "self-consumption", for example.

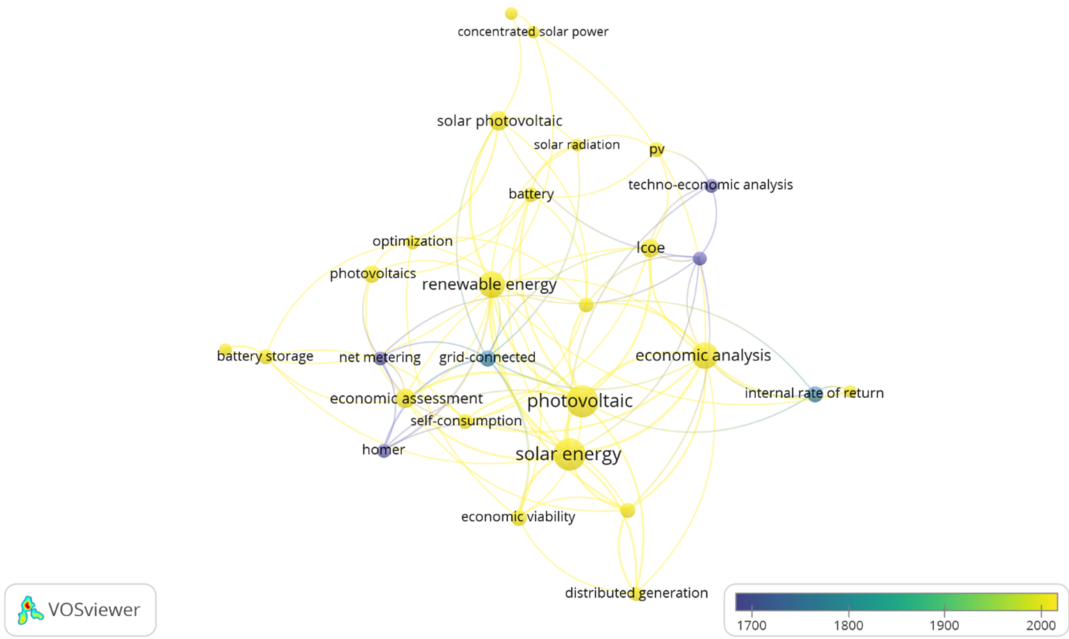

Figure 7. Map of bibliographic data of the main keywords of the sample, in overlay mode.

3.3. Impact Factors Identified

According to the SLR carried out in this research, a total of 29 parameters were identified as impact factors on the economic viability of the solar/photovoltaic energy projects.

Among all the factors or variables found, the investment cost was identified as the most prominent, present in 219 of the 225 works in the final sample. The following most recurrent factors in the studies analyzed are power generation, operation and maintenance cost, solar radiation, and useful lifetime. In addition to the most recurring factors, there are factors found less frequently but relevant to economic feasibility studies on solar energy, such as the effects of shading and dirt. These factors, according to the authors, directly affect the efficiency of energy generation, and may even cause financial costs beyond those expected during the system's useful life. Figure 8 presents all the impact parameters identified in the sample, in the descending order of occurrence.

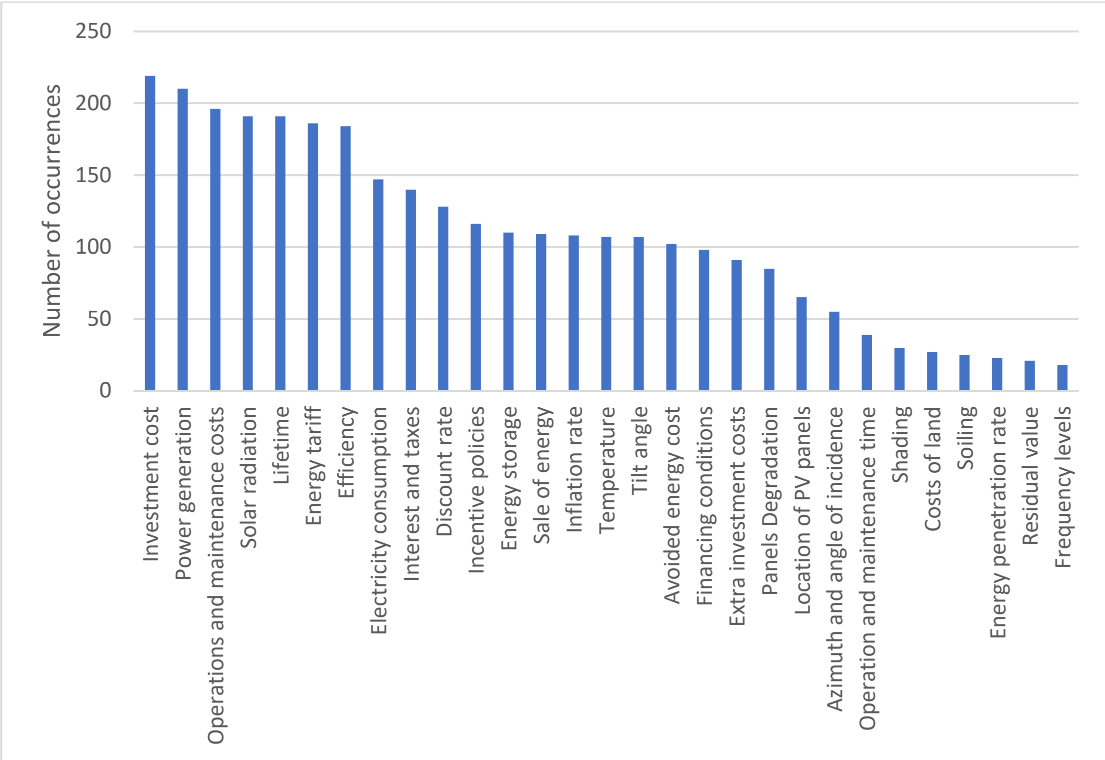

Figure 8. Parameters of impact on photovoltaic (PV) energy investment.

In their study, Rediske et al. [237] separated factors of decision making in the installation of renewable energy projects into categories. Observing the reference classifications, and adapting it for this research, according to the factors identified here, the parameters of this work were classified into five categories, based on the point of view in which they fit:

(i) location factors;
(ii) economic factors;
(iii) political factors;
(iv) climatic and environmental factors; and
(v) technical factors.

Table 3 shows a summary of the impact factors identified, the classification in which they were included, the references, and the total number of times they were found in the articles.

Table 3. Summary of identified impact factors.

Classification	Factors	References	Total
Location	Azimuth and incidence angle	[7,17,20,24,27,32,36,40,41,43,46,49,51,57,59–62,69,75,76,78,80,83,85, 86,88,89,92,93,95,97,98,108,111,115,117,121,124,130,137,148,150,153, 155,161,167,184,186,193,200,204,207,209,225]	55
	Location of PV panels	[7,19–21,26,27,29,41,43,46,48,50,52,62,65,67,69,72,74,75,77–79,83–87, 89,92,97,99,102,103,109,111,113,118,119,122,125,129–131,136,147, 149,150,154,158,161,167,170,179,182,187,194,195,197,206,207,221, 222,224,234]	65
	Shading	[7,20,21,23,24,26,59,67,75,80,87,97,123,135,137,151,160,178,184,188, 190,191,193,196,199–202,214,216]	30

Table 3. *Cont.*

Classification	Factors	References	Total
Economic	Electricity consumption	[3,4,7,17,19,21,22,27,29,30,33,35–41,43–52,54–59,64,66,67,70,72–77,79–83,88,91–94,96–101,104,105,107,108,110,113–115,117,119–122,124,127,129–134,137,138,140–142,144–146,148–151,155–159,161,163,165,166,170–175,177,179,180,183,185,186,188–193,195,196,198–200,202,204,206,207,209,211–213,215,217–222,224,226,227,229–231,233–235]	147
	Investment cost	[3,4,7,10,11,17–25,28–31,33–61,63–70,72–160,162–236]	219
	Operations and maintenance costs	[3,4,7,10,11,17–25,28,29,31,33–37,39,40,43–53,56–61,63–70,72–74,76–79,81–83,85–93,95,97–102,104–111,115–139,141–147,149–160,162–171,173–175,177–206,208–220,222,224–226,228–236]	196
	Extra investment costs	[3,10,17,19,21–26,28–32,36–40,42–44,51,58–61,63–66,70,72–74,76–78,81,83,85,86,88,92,93,98–102,104,106,107,111,115,116,119,120,122,128,130,131,136,138,141,143,147,149,158,164,165,167,168,175,177,178,183,187,191,196–200,204,205,210,211,224,231]	91
	Residual value	[17,23,43,51,63,73,81,85,110,115,119,124,130,131,139,145,184,192,212,224,226]	21
	Avoided energy cost	[4,7,11,19,22,30,33,39–45,47,48,53,54,59,60,65–68,71,73,74,76–78,82,83,85,88,91,93,94,99,101,103,107,110,115,118–122,124,125,127–129,135–140,142,143,150,153,159,161,163–165,167,169–172,174,176,179,188–191,199,208,210–212,215,217–223,225,229,232,233,235]	102
	Costs of land	[22,23,28,31,60,73,100,113,116,117,120,143,147,151,154,156,163,165,168,174,178,181,182,203,209,214,219]	27
Political	Energy tariff	[3,4,10,11,17,21–24,26–33,35,37,39–41,43–55,57–63,65–70,72–75,77–84,86–89,92–97,99,101–108,110,111,113–116,118,120–134,136–151,153,154,157–159,161,164–181,183–187,189–199,201–203,205,206,208,211–215,217,218,220–230,232–235]	186
	Financing conditions	[10,11,19,21,23,28–32,34,38,40,41,43,44,47,50,51,53,55,59,64,65,67–69,76–78,82,85–90,94,96,98,100,101,103–105,113,115,116,121–123,125–127,133,134,136–141,143,145–147,154,162,164,166,167,170,173,174,178–181,185,189,192,194,196–198,201–203,206,209–211,213,215,219,226,228,233]	98
	Discount rate	[4,10,19,21–23,25,26,28–30,33–35,37,38,40,41,43,46–51,53,57,59,60,63–70,73,76–78,80,83,85–90,93,97–99,103,105–108,110,111,114–120,124,125,128,131,135–137,139–141,143,147,148,150,151,153,154,157–160,164,167–169,172–174,178,180,182–185,188,190–194,196–198,201–205,208,210,214,215,223–226,228,229,231,233,235]	128
	Sale of energy	[3,10,11,20,23–25,27,32–35,39–43,47,51,53,57–61,64–66,68,71,73,76–79,86–88,92,94,95,97,99,101,104–107,110,114–116,118,122,124,125,127,130,131,134–136,138,139,141,143,147,151,153–156,158,160–162,166,169–172,174,176,178–181,184,187–192,196–199,201,202,206,210,213,214,219,223,228,233,234]	109
	Incentive policies	[4,11,17,18,21,23–25,28–31,34,40,41,46,47,49,58,59,64,65,68,69,71,74,76–78,84–88,90,94,96,97,99,101,103–105,107,109,110,113–116,118,122,125–127,133–141,143,145,147,150,151,153,157,158,161,164,166,169,170,172,174,176,178–180,182,184,185,187,189–192,194–199,201–203,206–208,210,211,213–215,219,223,224,227–230,233,234]	116
	Interest and taxes	[4,7,10,11,21,23–25,29–31,40,41,43,47,50,53,56–59,61,63,64,67,72–74,76–81,83–88,91,92,94,97,101,103,105,107,111,114,115,119,121–126,130–134,136–143,145–150,152–154,156–158,162,164–180,183,185,186,189–192,194,196–208,211,213–216,220,223,224,226–230,232–234]	140
	Inflation rate	[4,10,11,21,23,28–30,40,41,43,48,50,53,56,57,59,61,65,66,73,76,78,83,85–88,90–93,98,99,101,103–105,108,111,113,115,120–126,128,136,137,139,141–143,145,148,150,153,158,159,163,165–174,179–185,189–192,194,196–199,201–206,212,214,215,220,223–226,228,229,231–233,235]	108

Table 3. *Cont.*

Classification	Factors	References	Total
Climatic and environmental	Solar radiation	[3,4,7,10,11,17–23,25,27,28,30,32,33,35–37,39–43,45–49,51–53,55,57–76,78–89,91–95,97,98,100–104,106–109,111–115,117–132,134,135,137–150,152,154–165,167–175,177–190,192–195,197–209,211,213,214,216,218–232,236]	191
	Temperature	[7,10,17,18,21,24,26,32,33,36,39,41–43,46,49,60–63,66,68–70,73–75,78–81,85,87–95,98,102,104,106,108,109,111,112,117,118,120,121,123,124,126,130–132,134–139,142,146,149,152,154,155,157,159,160,167–169,173,177,178,181,183,184,186,188,192–194,199,200,202–204,206,207,209,213,214,216,217,219,220,223,224,228–230,232]	107
	Energy penetration rate	[17,34,51,52,58,73,77,81,93,120,121,129,130,147,156,163,175,176,197,200,218,221,222]	23
	Soiling	[20,21,23,26,43,87,97,98,109,115,116,123,124,135,137,139,150,168,178,188,190,193,194,200,202,205]	25
Technical	Frequency levels	[17,34,65,67,80,91,92,100,113,136,149,152,165,177,178,188,224,233]	18
	Energy storage	[4,10,11,17,29,33–39,41,46,52,54,57,60,61,63,64,66,68,70,73,75–79,81,90–96,98,101,102,104,107,108,110,112,117–119,121,126,129–131,133,134,138,141–145,147,148,151,152,155,157,158,162,163,165,171–177,179,180,182,183,186,187,189–191,193,195,198,200,203,204,206,209–211,213,218,219,221,222,224,225,227,231–233]	110
	Efficiency	[4,7,10,11,17–20,22–28,32–34,36–52,55–61,63–66,68–71,73–78,80,82,83,85,87–95,97–104,107–115,117–124,126–139,141,142,144,146,148–152,154–157,159,161,162,164,165,167–175,177–180,182,184–190,192–194,196–209,211,212,214–217,219–222,224–227,229,232,234,236]	184
	Power generation	[3,4,7,10,11,17–19,21–30,32–62,64–83,85–108,110–148,150–203,205,208,209,211–216,218–228,230,233–236]	210
	Operation and maintenance time	[17,19,37,44,51,52,56,64,69,70,76,77,90,98,104,106,116,118,127,130,131,136,145,148,154,165,166,173,175,186,193,195,196,213,218,221,222,230,231]	39
	Lifetime	[3,4,10,11,17–19,21–24,28–31,33–38,40,41,43–51,53,54,57,59–61,63–70,72,73,76–83,85–94,97–111,113–131,133,135–148,150–154,156–160,162–167,170,171,173–175,177–180,182–205,207–218,220–229,231–235]	191
	Panels degradation	[7,10,20,21,23,24,26,30,36–38,40–43,47,48,50,53,58–61,64,66,67,69,76,78,81,85–89,92,93,97,98,101,103,104,109–111,115,119,120,122,124,125,133,136–139,143,144,146,147,150,153,154,158,162,164,166,168,169,172,174,178,180,182,184,188,191,196,198,200,201,203,205,211,219]	85
	Tilt angle	[7,10,11,20,21,23,26,27,32,36,40,43,46,48,49,51,54,55,57,59,60,62,66,69,72,75,76,78–80,83,85,86,88,89,93,95,97–99,101–103,107,108,111,114–117,119–121,123,124,126–128,130,131,135–137,139,145,149,150,152,153,155,156,158–161,164,165,167,168,170,172,175,177–180,184,188,191–194,199,200,202–204,207,209,213,214,220,222,224,225,228,230]	107

3.3.1. Location Factors

Azimuth and Incidence Angle

Azimuth and angle of incidence are the angles formed between the projection of the sun's rays and the earth's surface, and vary according to the movement of the sun. These angles should serve as a reference in the assembly and installation of the PV panels, to maximize the capture of solar energy during the day. For Bhakta and Mukherjee [130], the orientation of the PV matrix can be described with two angles: the slope and the azimuth.

According to Awan [7], the performance of the PV system can be improved by continuously adjusting the position and inclination angles of the modules in relation to the azimuth position, using sun-tracking systems. This helps maintain the position of the PV panels in the sun, and maximizes their efficiency. According to Farias-Rocha et al. [40], studying the average solar radiation, the best position and inclination of the panels in relation to the azimuth angle is defined, in order to increase the annual solar radiation in the panels.

For Bimenyimana et al. [17], the angle of incidence and solar azimuth vary throughout the year, and, thus, the production of solar energy varies. From their research results, the solar production varied from 0.7 to 6.4 kW during the year, the incidence angle varied from 0° to 92° and the solar azimuth varied between −162.5° and 171°. According to Yendaluru et al. [20], the incidence angle value can be used to determine completely shadow-free regions in the location, and the concept of shadow formation is influenced by this value.

Location of the PV Panels

The location where the panels will be placed will directly influence the generation of solar energy. In addition to the geographic conditions, the energy policies in each region may vary, affecting differently the feasibility of the project. Because of that, many researchers are concerned with studying and comparing sites before the installation of the PV system. It is worth mentioning that the location where the PV panels are installed is a controllable variable, since the investor can choose the better location for installing the PV plant or farm.

Chiacchio et al. [41] analyze a domestic PV plant connected to the grid, evaluated in different geographical locations. In their study, they assess how different environmental conditions can affect not only the energy production and self-consumption regimes, but also the aging of the system components, especially in the storage system. Awan [7], before evaluating the performance of a rooftop PV system in Saudi Arabia, stated that 44 sites were analyzed in the country and based on the result, the best region for implementing the PV project in Saudi Arabia was defined. According to Bhakta and Mukherjee [111], the economic viability depends more on electricity tariffs than on irradiance levels. Therefore, the authors argue about the importance of comparing locations regarding the policies and applied energy tariffs.

Ilse et al. [26] warn about the issue of dirt at the panel's location, which causes a decrease in the efficiency of PV energy generation. The authors claim that a location closer to a source of dust generation has a greater risk of dirt. For them, locations close to cement factories, agricultural and livestock farms, dirt roads, or high traffic roads, for example, should be avoided when selecting the location.

Shading

The PV system produces electricity depending on the amount of solar radiation received by the modules. The shading effects on the panels can be caused by barriers such as objects, vegetation, proximity to buildings, and accumulation of dust, among others, which can reduce the energy production. According to Goswami et al. [23], the reliability and energy efficiency of the PV plant are determined by the performance rate and this rate depends, among other factors, on the shading of the PV panels. According to Yendaluru et al. [20], the sizing of the PV plant and the balance of the system (BoS) should be performed based on the shadow-free area.

Several authors in their feasibility analyses consider the shading effects as losses in the electrical generation by the PV system. For Ilse et al. [26], partial shading in a PV module can significantly degrade the energy production. In the same way, for Lopes et al. [24], the shading effects generate energy production losses of 2.3%.

3.3.2. Economic Factors

Energy Consumption

Energy consumption is determined by a standard average demand for electricity and is predicted in many studies in order to know the energy capacity that should be installed on the site. This capacity can influence many factors, such as the investment cost that depends on the installed capacity, power generation, and the required amount of storage (when considered), among others.

According to Das et al. [104], the average consumption of electric demand is predicted considering the pattern of use of household appliances in the area. In particular, it is possible to perform a probabilistic calculation to manage an electric demand profile. By knowing the consumption values, it is possible to predict the capacity of installing solar energy and to estimate the amount of surplus energy, which can be stored for self-consumption or even sold to the electricity grid. For Karimi et al. [3], energy consumption and production must be assessed to carry out the economic feasibility study and justify the use of PV systems. According to Espinoza et al. [43], different values of the NPV and internal rate of return (IRR) will be obtained in the feasibility analysis depending on the consumption profile, level of self-consumption, tariffs allocated to the sale of surplus PV energy, and savings on unconsumed electricity.

The level of energy consumption can also influence the energy tariff paid to the electric utility, depending on the established local policies. For Eshraghi et al. [35], the price of energy must be considered for each individual consumption plan. More specifically, Viana et al. [4] consider several categories of consumers, based on the hours of electricity usage during the day, observing the peak hours. Finally, for Anagnostopoulos et al. [105], the price of electricity by type of consumer varies to reflect as much as possible the real cost of generation and to reduce subsidies.

Investment Cost

The initial investment cost is the factor that appears most often in the sample articles. This expense often serves as the main parameter in the analysis of economic viability, in addition to being often a high and fluctuating expense, which generates a great financial impact. It is obtained in consultation with the manufacturer of the PV panels, and often includes costs such as transportation, labor, construction, and installation services. This expense can also vary significantly according to the manufacturer, the incentive policies established in the region (such as reduction or exclusion of sales taxes), the technology used by the manufacturer, or other influences.

The initial investment cost is the main factor used in most economic feasibility studies to determine whether the project is indeed financially viable. According to Al-Saqlawi et al. [60], for example, two criteria are used to assess the attractiveness of an investment: payback and IRR. Both criteria are based on the investment value to know if the business is viable. Payback measures the time needed to recover the cost of an investment. The IRR considers the value of money over time and determines the interest rate at which the NPV is equal to zero. For Talavera et al. [50], the economic profitability analysis is based on several criteria. One of them, the discounted return on investment time, provides information on the liquidity of the investment value, while the rest of the parameters deal with the project's profitability.

The value of the investment alone does not indicate whether the system is financially viable or not. Sometimes, a greater expense in the investment for the installation generates greater revenues during the project lifetime. In other cases, a smaller investment may be more financially viable, so each case must be assessed individually. According to San Miguel and Corona [64], the effect of capital expenditures (CAPEXs) on the viability of a PV energy project was studied, and a linear relationship between capital investment and NPV was reported. It was concluded that economic viability cannot depend only on reducing the capital costs, but also on reducing operating and maintenance costs and increasing the power generation capacity. Brunini et al. [54] concluded that the PV system had an investment cost higher than the others, however, the annual cost of electricity was zero, which demonstrated a better efficiency in the energy generation of this system in relation to other sources.

According to the IRENA report issued in 2019 [238], the average values of total installed cost (USD/kW) for residential and commercial solar PV plants are 1830.88 and 1604.25, respectively. Since 2010, these values decreased by 73.7% and 76.9% for residential and commercial applications, respectively.

Finally, it is important to note that the investment cost is a variable that the investor cannot control, although the investor can negotiate for better equipment prices. The behavior of this variable has uncertainties that are impacted by macroeconomic factors and the development of technology. In addition, investments in PV farms are capital intensive, that is, they require a large amount of capital to be carried out.

Operation and Maintenance Costs

The operation and maintenance costs (O&M) are considered to ensure that the PV system continues to operate in the best way and maintains the quality of electricity generation. These costs depend on factors such as the installed capacity and the power generation. According to Kharseh and Wallbaum [57], operation and maintenance represent expenses that occur after installation. For Lammoglia and Brandalise [47], the costs of operation and maintenance are included in the annual operating expense of power generation to cover periodic maintenance, cleaning the surface of the PV panels and other maintenance costs. Furthermore, for Adefarati and Bansal [91], the cost of maintaining the generator is considered proportional to the energy generated.

According to Gurturk [51], operating and maintenance costs can be divided into fixed and variable costs, and are composed of maintenance and repair costs, price of electricity produced by the solar power plant, and the amounts paid to employees. For this author, one of the most important advantages in terms of the costs of solar power plants is exactly the relatively low cost of operation and maintenance. The author explains that such plants do not need expensive maintenance operations, since they do not require complex components of machines and systems that consume a lot of energy, and this reduces the costs. In general, maintenance is divided into preventive and corrective maintenance. According to Peters and Madlener [106], the objective of the first is to maintain the functionality of an item and avoid failures beforehand, while the second happens after the occurrence of a failure and restores the functionality of the item.

According to Goswami et al. [23], the maintenance cost must be provided in an agreement for PV projects, and must be included in a maintenance contract. For them, the annual maintenance contract can be awarded for 5 years, also includes training of personnel for daily operations, and can be renewed every 5 years to maintain the health of the installation devices.

For some authors, the operation and maintenance costs must be considered as a percentage of the installation cost, or must be included in the installation contract. Patil et al. [90] consider the annual costs of operation and maintenance to be 2% of the total cost of the PV system. For Jo and Jang [34], this cost is 0.2% of the cost of investment, annually. Rocha et al. [87] consider that the system had annual operating and maintenance costs of 0.5% of the investment cost.

Despite being a variable that also has uncertainties and that can be influenced by non-systematic factors, it is a low-representative cost for the LCOE of PV farms when compared with CAPEXs.

Extra Investment Costs

Several authors also consider extra investment costs, such as cleaning costs, replacement costs for parts during the life of the project, project and labor, tax values, or fines, among others. According to Lopes et al. [24], in addition to the modules and inverters, the PV system needs to include extra expenses with support structures, electrical cables, control equipment, and safety, protection, and monitoring systems, in addition to costs related to engineering projects, licensing, and project facilities.

For Adesanya and Pearce [29], additional costs must be foreseen to cover a possible increase in operating and annual maintenance costs. Bimenyimana et al. [17] consider replacement costs, in addition to investment and maintenance costs, during the life of the installation. Babatunde et al. [19] studied investment in solar energy for public lighting and additional costs related to the battery of the PV module, the charging controller, and costs of LED lamps were forecast in order to save on the energy expenditure of the PV system. Haegermark et al. [115] say that the costs of the PV system include, in addition to the investment cost and operation and maintenance costs, inverter replacement costs and additional costs associated with the generation of PV electricity.

Residual Value

The residual value is the business value that remains in a component of the energy system after the complete depreciation of the system at the end of the project's useful life. Some authors consider this value in the cash flow of the economic evaluation of solar energy projects. Ajayi and Ohijeagbon [131] consider revenues in relation to embedded solar generation, including revenue recovered from sales to the grid, and revenue with any residual value that occurs at the end of the project's useful life. For Bhakta and Mukherjee [130], the residual value is considered in the cash flow at the end of the project, discounting the operating cost. According to Alsharif [119], the residual value collected at the end of the project's useful life is considered and reduces costs in the calculation of NPV.

According to Sarasa-Maestro [145], the cash flow in the last year is dramatically lower than in previous years, since it is assumed that at the end of the system's useful life, the remaining value of the components is obtained by selling them. As an example, they mention that if the generator has performed 50% of its useful life at the end of its project life, it is expected to obtain cash flow by selling it at 50% of its acquisition cost. According to Choi [85], it is common practice to assign a residual value of 15% to 20% of the initial cost for PV equipment that can be sold and reallocated at the end of its useful life. For Poonia et al. [63], the residual value can be considered 10% of the initial investment cost.

Avoided Energy Cost

The avoided energy cost enters the cash flow of the business as a gain in value. It is due to the amount saved from what would be spent on energy consumed from the electricity grid, according to the local tariff system, and is instead generated by the PV system for self-consumption. According to De Boeck et al. [158], one of the types of PV energy revenue comes from saving energy costs. A part of this savings in the electricity bill comes from the reduction in the demand for energy from the grid, as part of the PV production is automatically consumed, requiring less energy from the grid. According to these authors, in addition to self-consumption, the other part of the savings in the electricity bill comes from net metering schemes, present in some countries.

The avoided energy cost can be very beneficial in the PV system, due to high tariff prices charged by the electricity grid or the cost of other fuel sources, such as oil products. Reducing consumption costs when generating solar energy adds a revenue amount that will enter the project's cash flow in the economic analysis. According to Shaahid and Elhadidy [222], the percentage of energy fuel savings using the hybrid system decreases, with the aid of solar energy, compared to the conventional system. In addition, the avoided energy costs continue to increase as the capacity for generating solar energy increases. According to El-Nashar [232], the increase in the performance rate also increases the cost of investment of the plant, which is offset by the benefit obtained with energy saving.

As this variable is normally impacted by the retail price (price paid by the consumer for the energy supplied by a concessionaire) practiced in each market, the investor has no influence on the behavior of this variable.

Cost of Land

Sometimes it is necessary to consider a land cost in the solar energy project, either due to the rent for the installation of the panels, or due to the necessary services for this installation (such as land cleaning, landfill, leveling, among others). Mehang et al. [163] state that there is a fixed cost of capital, which consists of the cost of land allocation and is valued at a very low rate compared to the cost of the total installation. Napoli and Rioux [151] state that the land costs can be calculated separately, as the facilities generally require a large area. Moreover, Xue [116] states that the cost of the land refers to the rental rate of occupied land, and there is no additional cost for the PV system.

Sabo et al. [120] discuss the issue of land acquisition for the implementation of the PV installation. According to these authors, the land acquisition process remains an impediment, because, in addition to delaying timely installation, it also increases the cost of installation.

According to Okoye and Solyali [117], land costs can be considered as a percentage of the total cost of installation (or estimated when known) and in their research they consider it to be 20% of the total cost of the system. According to Kumar and Sundareswaran [178], when PV systems are installed on the roof or with building-integrated photovoltaic panels (BIPVs), the cost of land can be excluded, but in the case of a large-scale plant, the costs of land need to be included in the total investment. This reinforces the statement that in most plants this cost is approximately 20% of the investment. Already, according to Li et al. [182], the cost of land has the least effect of the parameters on the economic viability of the PV system, due to the cost of land representing only 0.1% to 1% of the total investment cost.

The above-indicated cases show non-convergence of the criteria, since some authors consider land rent as a variable not related to fixed O&M costs, while others consider this variable with the total O&M costs [238].

3.3.3. Political Factors

Energy Tariff

Without local energy production, the electricity bill refers to the consumption of electrical energy supplied from the electricity grid. The value of the electricity tariff has a great impact on the economy, in addition to varying with the annual rate of increase, and even with the profile of energy consumption. According to Al-Saqlawi et al. [60], the main benefit associated with a grid-connected PV system is an annual reduction of the energy bills, calculated using the electricity tariff structure. A system connected to the grid has the additional benefit of exporting the surplus electricity to the grid. In work by Ayadi et al. [72], the cost of the PV system depends on the agreed energy transfer period and the electricity tariff that will be charged to the end user. For Lee et al. [86], the higher the average retail price of electricity, the more remarkable the economic value of electricity generated by the PV system.

According to Cucchiella et al. [101], energy savings through internal consumption are evaluated based on the purchase price of electricity. This value is the price of energy per kWh for the final consumer, and its evolution over the years, is calculated by using the energy inflation rate. In work by Ramírez et al. [122], the price of energy depends on many parameters, including the geopolitical situation, import diversification, electricity grid costs, environmental protection costs, and weather conditions. Generally, the price paid by the end customer depends on the type of customer, such as commercial, residential, or industrial.

Noro and Lazzarin [74] affirm that there is an economic saving due to the electricity produced by the PV system that does not need to be bought by the network. This saving is calculated through two different tariffs: one is the traditional price applied to residences; the other is a new special fee, for electricity dedicated to private customers who use electric heat pumps as a heating source. Talavera [50] argues for the need to obtain different data on electricity tariffs to compare them with PV systems. This allows comparative cost analysis, in addition to considering significant variations in the price of electricity, depending on the amount of electricity consumption grouped into different consumption ranges.

Similar to the avoided energy cost, the investor has no influence on the evolution of the energy tariff. Indeed, future energy tariff scenarios could significantly impact on the convenience of using self-produced electricity, following the trend towards establishing local energy systems and energy communities.

Financing Conditions

One of the factors that can influence the financial feasibility of the project is the financing conditions provided for the location, which includes interest rates, the amortization and financing term, and the amount financed, among other items. According to Corona et al. [143], due to the high initial investment cost involved and the benefits of capital diversification, the construction of a PV plant is usually not fully covered by the investor, but could be co-financed by banks or other financial institutions. For the authors, this implies difficulties in applying the method of assessing financial viability, since the initial investment cost is distributed in annual payments. In Ellabban and Alassi's work [21], the annual cost of financing refers to the repayment of the loan for installation of the PV system, if any, and the annual payment of the loan must be included in the costs of the system. For the authors, obtaining financing offset by electricity exported to the grid increases the system's economy.

According to Chiaroni et al. [179], the financing options are analyzed with the scenario of equity (100% equity) and shared capital (75:25, 50:50, and 25:75 equity and debt: third party capital, respectively). For the authors, when modifying the financing mode by increasing or reducing the use of equity, the greater the initial investment cost in the zero year, the longer the return on investment. For Garcia et al. [82], the existence of financing programs, for those interested in buying their own microgeneration centers, would be of great importance. The creation of a national program aimed at introducing PV energy not only for residential use, but also for companies, would bring prosperity to the country.

In research by Holdermann et al. [185], equity financing was assumed because, according to the authors, there are no adequate financing programs available in Brazil, and a substantial change in the discount rate would be possible by introducing adequate financing options in the country. Concluding the research, the authors state that the results of the economic feasibility study demonstrate that, currently, PV systems are not economically viable in Brazil. It would be necessary to introduce financing options to make the PV system feasible, both in the commercial and residential sectors.

Public financing can be articulated as a way to subsidize RESs, reducing the cost of capital. In this case, it will depend on the regulatory and political framework of each jurisdiction for the RES market.

Discount Rate

The discount rate is applied to a future value to determine its equivalence in the present, and is used for the analysis of the return on investments. This rate indicates the level of minimum attractiveness of the investment, and its value can be calculated in several ways. The weighted average cost of capital (WACC) is one of the most used methods for this calculation.

According to Vale et al. [103], the discount rate varies mainly with the business risk, opportunity cost, and liquidity, and each company generally has its own economic parameter to analyze the project. The WACC was applied in Rocha et al. [87] to calculate the discount rate used in the feasibility analysis of the PV microgeneration system. Conversely, Okoye and Oranekwu-Okoye [78] use the risk-adjusted discount rate (RADR) method to incorporate the project risk in the capital budget decision process. The RADR method groups the value of money in pure time, represented risk-free rate, and a risk premium.

The discount rates considered are estimated in different ways and vary according to the study. For Hammad et al. [88], the discount rate assumed is equal to the bank's interest rate under bank lending conditions, considered to be 6.7%. In Schopfer et al.'s work [66], the defined discount rate was 4%. In research by Anagnostopoulos et al. [105], the selected discount rate was 5%, assuming that this rate is satisfactory for most investors in the economic situation in Greece, in which the interest rate is lower than the best alternative investments available. According to Macdougall et al. [69], the addition of the risk premium (from 1% to 3%) provides a risk-adjusted discount rate of 5% to 7%. For the authors, when evaluating a PV project using the internal rate of return (IRR), a reasonable discount rate for the owners is 3% to 7%, lower than the rates used for commercial projects (8% to 9%).

It is worth noting that the WACC is the most popular method for estimating the discount rate. The parameters for estimating the WACC should preferably be based on the market and economic context of each location. Still, this variable is seen as partially controllable by the investor, since financing decisions can be controlled, but the rate parameters cannot be controlled.

Sale of Energy

One of the main forms of incentives mentioned in the installation of PV systems is the possibility of selling energy, established by local incentive policies. This factor can generate revenue from the sale price of the energy generated in the PV project, supplied to the electricity grid, and make the investment viable. According to Ramanan et al. [27], the variation in the economic analysis of the PV system is due to the net metering policy. The generation of PV energy and sales to the grid increase simultaneously with the PV capacity. Yaqub et al. [196] state that long-term investment is considered viable if there is price stability in the long term, so that the concessionaire can continue to sell the electricity generated at a price that is higher than the costs.

Choi et al. [190] state that if an electricity sales policy is included, it can improve financial feasibility by selling surplus energy from the PV system. The authors conclude that the return on investment increases and the payback period decreases when the rate of sale of energy to the grid increases, improving the financial viability of the system. For Qoaider and Steinbrecht [213], the return period of the energy project developed depends on the electricity sales policy, where the return period will be inversely proportional to the value of the sale price. If the value of the energy sold is equal to the cost production, there will be no profit. Hoppmann et al. [180] state that if families are also able to sell their electricity in the wholesale market, an increasing number of families will move from being an electricity consumer to become an energy prosumer, increasing the interest and use of energy produced from solar sources.

For Goswami et al. [23], the present value of the cash inflow generated by the sale of energy injected into the grid is correlated with the incentives given by the government. In research by Barone et al. [32], different scenarios are investigated for the surplus of electricity produced. These scenarios include a standard electricity purchase and sale strategy, in which the electricity exported to the grid is sold at the single national price applied to all consumers, and an ideal net metering, where the surplus of produced electricity exported to the grid can be returned to the building when necessary.

Incentive Policies

There are different incentive policies applied around the world. The conditions provided by these policies can facilitate the return on investment in solar energy and attract investors. Many researchers pay attention to public incentive policies, as a means of making investment in PV energy more easily economically viable. According to Focacci [215], promoting the use of renewable energy sources must become an important objective of national energy policies after crises driven by oil shocks and environmental imbalances caused by the massive use of fossil fuels. For this author, the mechanisms adopted to support the PV sector were oriented in two main directions: (i) feed-in tariffs and (ii) capital incentives for the acquisition of PV equipment.

Lee et al. [137] analyzed the economic impact of state solar incentives in the USA, considering various scenarios based on tax incentives and cash incentives. Then, the authors propose improvement strategies for solar incentives, which include the offer of state income tax credit and tax exemption. According to Hirvonen et al. [172], without subsidies, residential PV systems have a long payback period. Boeck et al. [158] carried out a comparison of incentive policies in several countries. They concluded that the highest possible level of profitability is not always equal to the best policy, but a stable and consistent policy that reduces the ups and downs of investor demand, and leads to more manageable stable growth in the market. Zhang et al. [76] state that when incentive policies are applied, the return period of the PV system can be reduced at different levels, depending on the location and type of construction.

Farias-Rocha et al. [40] argue that the incentive policy can be improved by lowering the initial costs and/or the debt interest rate, and that this can be done through government grants, tax reductions for renewable energy equipment, incentives for equipment from local sources, and establishment of credit lines for PV development. It was also reinforced that the electricity export tax greatly affects the financial viability of a project. According to Rocha et al. [87], the tax exemption meets the objective of encouraging the development of productive sectors, such as the PV industry and, in addition, the subsidy indirectly contributes to improving the quality of life of the population, providing support for cleaner energy production.

Interest and Taxes

Interest rates and taxes charged on investing in solar energy can often have a significant impact on the business. These fees are charged by the government, often included in investment expenditures by manufacturers. One of the solutions suggested by researchers around the world is to reduce taxes and fees charged, in order to facilitate investment. For Varela et al. [228], the operation and maintenance costs must include the amount spent on annual installation insurance and the annual taxes paid for the installation, regardless of the electricity generated. Schmid and Hoffmann [227] deal with the import of equipment manufactured outside the country, and consider supply costs, including surplus transportation, taxes, and services.

In the analyses of economic viability, various scenarios are generally considered with conditions of interest and taxes. Haegermark et al. [115] argue that for the calculations, based on the NPV, three different scenarios of available financial incentives were assumed: (i) including a tax discount, (ii) including an investment subsidy, and (iii) including both a discount and a subsidy. Hoppmann et al. [180] point out that in addition to the electricity generation costs in the PV system, prices must include network fees, the concessionaire's profit margin, taxes, and the cost of feed-in tariff redistributed to the consumer. Li and Yu [148] analyzed the economic feasibility of the PV system before and after tax, as in calculating the index of the internal rate of return before tax on equity, and the internal rate of return after tax on equity. For Ramírez et al. [122], one of the main support policies implemented in the main countries of the European Union is the reduction of taxes, with lower rates of value added tax, or amortization schemes when considering loans.

The income tax credit, which offers tax credit for the cost of installing the PV system, can be categorized into federal and state income tax credit. The federal income tax credit is a solar incentive granted by the country to all states. The state income tax credit is a state-based solar incentive, and its implementation and the amount of credit differs by state. Tax exemptions, on the other hand, can generally be categorized as tax exemptions on properties and sales. The property tax exemption is an incentive that exempts the property tax charged for increasing the residential value due to the installation of the PV system. The sales tax exemption is a solar incentive that exempts sales tax from the cost of installing the PV system, as in Lee et al. [86].

Inflation Rate

The inflation rate is the average growth in the prices involved in the installation. This variation in prices must be observed. Inflation is generally considered by the authors on the prices of energy tariffs. According to Hammad et al. [88], the inflation rate is a percentage that should be considered as an interest rate in the increase in the electricity tariff, and as a reference for calculating the discount rate. For Rocha et al. [87], the cash flow is derived from variables such as the interest rate, the value of the energy sold to the concessionaire, and the cost of purchasing the equipment, which may vary during the life of the project. This variation brings uncertainty involved in each variable, and, when considered together, can increase the risk of the project, so it is proposed to include this uncertainty to evaluate the NPV.

Talavera et al. [50] state that the price at which the surplus electricity is sold to the grid, and the price of the electricity consumed, are usually equal to the retail electricity tariff. However, it is necessary to define an annual rate of growth in the price of electricity. This rate of growth is generally linked to the evolution of the electricity markets, which is difficult to predict. In the event of a lack of information, the rate of growth is set equal to the annual inflation value defined for each country. Choi et al. [85] use the rate of price inflation to forecast energy costs for the residential, commercial, and industrial sectors, at various levels of general rates. For these authors, the assumed average rate of inflation over the useful life of the PV system was 4%, considered as incremental retail electricity rates for PV systems to estimate future electricity tariffs. According to Okoye and Oranekwu-Okoye [78], the cost–benefit of the PV system is affected by the inflation rate, and this value changes with the location, affecting the economic viability of the system. For them, the inflation rate considered was 8.1%.

The price of electricity does not remain constant. Therefore, it is necessary to define an annual growth rate of the price of electricity. In any free market for electricity, the retail electricity tariff is usually a function of the supply and demand available and depends on the type of energy matrix existing in a country. Electricity prices are expected to continue to rise over the lifetime of the PV system [50].

As can be seen, this variable depends on the local macroeconomic context and in high inflation scenarios, it can increase the project's cost of capital.

3.3.4. Climatic and Environmental Factors

Solar Radiation

Solar radiation is the radiant energy emitted by the sun. It occurs directly from the source in all directions, and does not need a means to propagate. The average of this radiation varies according to the location. The relevant quantity for the energy system studies is the solar irradiance, measured in W/m^2. The solar irradiance is the power per unit area received from the sun as electromagnetic radiation. Its value also depends on the characteristics of the measuring instrument used, in particular, on the wavelength range captured by the instrument. The solar irradiance is important for the analysis of economic feasibility of PV systems, observing the capacity of electricity generation by the solar source in the region. A PV panel can receive both direct and diffuse solar irradiance. The solar irradiance can be measured on a horizontal surface of the particular region, or on a surface positioned in the same way as the PV panel considered. The solar irradiance is subject to many changes periodically, due to different climatic conditions and to the sun evolution over time.

The solar irradiance is directly linked to the production of electrical energy in the PV system. According to Barone et al. [32], the greater the solar irradiance, the greater the production of electricity by the PV modules. However, a non-linear change in production is detected due to the decrease in electrical efficiency caused by the overheating of the panels. Fereidooni et al. [80] establish a relationship between solar irradiance and energy output. In clear sky conditions, the maximum registered power occurs in the same period as the maximum registered solar irradiance.

Aderemi et al. [70] created a model of analysis of the PV system in which they simulated the conditions under the average ambient temperature and solar irradiance of the location. The results showed an increase in the production of PV energy as the solar irradiance increased, depending on the time of day. However, production decreased when there was an increase in temperature.

Temperature

The average ambient temperature of a location influences the generation of solar energy and can impact the efficiency of the modules of the PV system. The variation in this temperature can also be a problem and can cause degradation in the equipment.

Although a high level of solar irradiance is relevant to the power generated by using solar energy, high temperatures can affect the performance of the system, reducing its efficiency. Kang et al. [123] state that, in a given location, high solar irradiance generally increases the ambient and PV module temperatures. However, when the temperature of the module exceeds the standard test conditions used by the manufacturers for testing the PV modules, the efficiency of the PV module and the corresponding power generation decrease, due to the degradation related to the coefficient of temperature. For Sampaio and González [109], the efficiency of PV cells depends on temperature, solar irradiance, and dust. The temperature can drastically affect the cell's performance and, due to this fact, studies have focused on reducing the temperature by means of heat extraction, using heat for other purposes, such as heating water or heating air.

The temperature of the PV cell has a significant effect on the PV output power. For this reason, it is essential to establish an energy balance of the solar energy absorbed by the PV panels, the resulting electrical output, and the transfer of heat to the environment [89]. For Barone et al. [32], the operating temperature of PV cells affects the electrical efficiency. In their study, the electrical efficiency decreased from 16.4% to 14.8% as the PV temperature increases.

Energy Penetration Rate

In the PV generation system, not all of the energy captured is used for electricity generation. In fact, there are energy losses in the system, caused by several factors. The energy penetration rate considers how much of the electrical capacity will be produced by the PV modules.

In the assessment of the electricity generated by the PV system, the presence of further local generation systems has to be taken into account. Shaahid and El-Amin [218] analyzed the economic feasibility of a hybrid system with PV and diesel energy. The authors conclude that, as the penetration of the PV system increases, the operating hours of diesel generators decrease, which reduces the cost of energy and also the emission of greenhouse gases. For Hirth [176], the economic impact of the variability in the solar energy penetration rate is high. Some researchers warn of wasted electricity, which can be caused by high penetration of solar energy. For Yu [84], with a high penetration of PV energy, negative prices can be observed in the electricity markets, due to excess of electricity production in periods of time in which the electrical demand is lower than the available generation. These aspects have to be carefully taken into account in the design of future energy markets.

Soiling

External factors, such as dirt, can also affect the efficiency of a PV panel. Reasons that can cause dirt to accumulate on the panels, such as dust, organic materials, or microscopic organisms and other types of material, can prevent the passage of sunlight to the cells of the plates, affecting the production of electrical energy. According to Bianchini et al. [168], the accumulation of dirt can have a significant impact on the performance of the PV modules, and PV plants can have a power loss in the range of 1% to 7%, depending on the characteristics of the dirt and cleaning methods.

According to Askari and Ameri [200], one of the reduction factors in the PV system, which explains any discrepancy between the nominal performance and the real performance of the PV modules, is due to factors such as the dirt on the PV panels, including even the cover for snow. Sampaio and González [109] discuss the effect of dust on the efficiency of PV cells, and state that it is advisable that the PV surface is cleaned frequently to maintain performance, as the accumulation of dust can block irradiance in the PV modules, and reduce the efficiency of the PV cells. For Yendaluru et al. [20], the PV panel's dirt depends on the area where the PV system is installed. Dirt can occur in an area with many trees and due to bird droppings. Ilse et al. [26] suggest the inclusion of an additional cost for dirt mitigation. According to them, the dirt mitigation technology can become more profitable compared to the standard cleaning cost.

For Dagtekin et al. [188], the dirt from the PV panel is similar to the shading effect, and can cause losses of around 3%. Kang et al. [123] confirm that the losses of the PV system include losses in the inverters, dirt, shading, snow, mismatches, wiring, connections, light-induced degradation, nameplates, availability, etc. For them, the total reduction losses in the system must be in the range of 15% to 35%.

3.3.5. Technical Factors

Frequency Level

The frequency level (in Hz) is generally considered when the PV system is connected to the electricity grid. The PV system must work in combination with the public electricity distribution network, and, therefore, must behave exactly like an ordinary power plant, operating at nominal frequency, and inside a specified voltage range. The electricity generated from PV arrays flows in only one direction, and is converted by the PV inverters to suitable voltage and frequency. It is possible to verify that the PV plant is in good operational mode by observing the measured tracks of energy supply in the national electricity grid, the frequency, and the voltage.

According to Dagtekin et al. [188], it is necessary to use PV inverters to convert the alternating current and control the frequency because the PV modules generate direct current from the sunlight, while the public power distribution networks use alternating current. According to Munoz-Cruzado-Alba et al. [152], weak networks have a relatively small number of loads compared to a conventional national power grid, so any unexpected load change can vary the voltage and frequency of the system and, consequently, will lead the PV system to reduce the output production. For Khouzam [233], the PV systems connected to the grid must use standardized inverters, designed with fixed frequency and voltage trip configurations, according to the applicable codes and requirements.

It is necessary to maintain the frequency of the network. For this purpose, the network operators must be able to accurately predict how strongly the sun would shine. However, an accurate forecast is almost impossible. The loss of sunlight or the deviation of clouds over a PV plant can significantly reduce its energy production. If the PV plant is supplying a significant portion of the grid energy, this rapid loss of energy could result in the decrease of the grid frequency well below 50 Hz, causing possible network instability, or even a blackout, as reported by Hairat and Ghosh [113].

Energy Storage

Energy storage basically consists of saving the energy produced for later use. Energy storage technologies make it possible to adjust the temporal and geographical differences between electricity supply and demand. In addition, combining different energy sources in the same generation system increases the efficiency of the system, where one energy source compensates for the weaknesses of the other in production. The energy storage system requires an additional cost in equipment, such as batteries.

According to Adesanya and Pearce [29], the financial economy increases with the addition of batteries for the PV system coupled to hybrid systems. Storage makes it easy to provide a way to increase the penetration of solar energy, which reduces the use of other energy sources, improving the financial benefits. Eshraghi et al. [35] claim that the use of storage devices generally results in higher costs and less production, but that does not make the use of these devices unfounded. Generally, the use of storage improves the quality of the output and can cause considerable cost savings to meet a certain demand. These authors also conclude that, in addition to technical and economic conditions, other factors are involved in the attractiveness of investment in storage technologies, including ensuring the system's useful life, even when it will not be used for a long period.

Adesanya and Pearce [29] state that the sizing of the battery system is usually chosen to absorb the excess energy produced by the PV modules, which can be used when sunlight is not available. According to these authors, the batteries must be at the same operational level in terms of type, validity, manufacturer, and temperature of the system. According to Bimenyimana et al. [17], in energy storage systems, batteries are connected to store the energy to be used by demand, as long as there is no irradiance or sunlight available.

Hoppmann et al. [180] investigated the conditions under which battery storage would be economically viable in residential PV systems without policy support, showing that investments in battery storage are already profitable for residential systems. The system and size of storages improve over time, so that families become electricity prosumers if they have access to the energy market. Developments that lead to an increase in the sale price of energy further contribute to the economic viability of storage.

Efficiency

The efficiency of PV panels is directly related to the amount of energy captured from the sunlight that the panel converts into electrical energy. This efficiency can be affected by several reasons, as has already been discussed in other factors, and the drop in efficiency of PV modules causes loss in the quality of energy production, which can make the project financially unfeasible. According to Sampaio and González [109], research on PV cells aims to increase the efficiency of the conversion of solar energy. The total energy production of a PV cell depends on its efficiency and useful life, and these factors affect the value of an energy production system based on PV technology.

According to Kazem et al. [102], the efficiency of the inverter in the PV system is very important for the system. In their study, an amount of 7.4 kWh was produced for the grid with an efficiency of 4.1% to 8% of the system. According to Cuchiella et al. [11], the energy produced by a PV plant decreased from the first year of operation to the twentieth year due to a factor of efficiency reduction. For Mostafaeipour et al. [52], the smaller the amount of energy losses, the greater the efficiency of the PV system, because less energy is wasted in the system.

Chiacchio et al. [41] argue that the main efficiency degradation process depends on meteorological factors, such as wind speed, passing clouds in PV units, incident irradiance, and ambient temperature. Higher daily energy production of PV plants, due to the increase in efficiency, causes a greater return on investment [23].

Finally, Wang et al. [44] show how energy efficiencies affect the total cost of the system over its useful lifetime, and report that high energy efficiency has a high level of cost savings. In their research, the payback period is around 3 years when efficiency is 90%, and increases to 4 and 5 years when efficiency drops to 80% and 70%, respectively. When efficiency reaches 52%, the payback period becomes 9 years. That is, the greater the efficiency, the faster the return on investment, making the project more economically viable.

Energy Generation

The amount of energy generated by the PV system directly affects the costs, since the PV panels are installed to generate energy that meets the demand, and cuts expenses that would come from the purchase of energy from the conventional electricity grid. For this reason, it is important to evaluate the generation of energy produced by the PV system. Some authors propose methods for calculation of annual PV energy production, for example, Rocha et al. [87].

Ellabban and Alassi [21] state that most of the revenues from the PV system depend on the energy produced. The useful energy generated by a PV system depends on many factors, such as the installed power, solar irradiance, orientation of the PV panels, environmental conditions (shading, temperature, dirt, snow, etc.), and the different efficiencies of the system components. According to Viana et al. [4], the use of the PV system would result in a reduction in the daily demand that would be contracted by the electricity grid, which, in turn, would generate savings, treated as financial income in the project's cash flow. This premise constitutes the effect of the decrease in demand due to the generation of electricity by the PV system.

Moreover, Mehrpooya et al. [22] state that the generation of hybrid solar electricity depends mainly on the solar irradiance, and is affected by the position of the sun during the day, environmental conditions, and wind speed. High values of hybrid solar electricity generation can be obtained when the solar irradiance and the ambient temperature are high enough. Still, according to Jamali et al. [42], the climatic situation has a significant influence on energy production, with increased wind speed and reduced ambient temperature, leading to increased energy generation.

Operation and Maintenance Time

The time of operation is the period in which the system is in fact operating. Conversely, the maintenance time is the period in which the system is stopped by some event, such as for maintenance, repair, replacement, or cleaning of the equipment. Some studies consider this time in the economic feasibility analysis, impacting the costs of the project, such as Mohammadi et al. [65].

Bimenyimana et al. [17] believe that the storage costs of the system also depend on the operating time of the batteries. For them, the batteries operate 4380 hours a year, and have a range of 17.5 hours and an expected life of 10 years. San Miguel and Corona [64] advise the hybridization of the PV system, allowing more hours of functional operation and, therefore, greater energy generation and revenue. Hybridization would also improve unavailability, which would allow plant operators to adapt generation to hourly periods when market prices are higher, thereby increasing the monetary income.

According to Wang et al. [44], a long period of operation of the PV system causes a reduction in the consumption of other energy sources, which also significantly reduces the operating costs. A reduction in the use of other energy sources also results in a decrease in the amount of gas emissions released.

Lifetime

The equipment of the PV system must operate in perfect condition to guarantee the quality of power generation. However, like any tool, they wear out over time, due to the frequency of use, environmental factors, aging, etc. For this reason, an estimate of the time in which this equipment can be used without losing its essential characteristics must be considered. This time estimate is determined by the manufacturing companies, and is supplied to the buyer. The system's useful lifetime is used as a cash flow assessment period in the economic feasibility analysis. It is in this period that cash inflows and outflows will be considered in the analysis of the project.

Previous studies on the economic analysis of PV systems have established the useful lifetime of the PV system between 20 and 40 years. If the actual service life of the system exceeds the warranty time, the performance of the PV panel cannot be guaranteed, due to degradation. In addition, due to the increased operating and maintenance costs, the PV panel reaches the end of its economic life. Thus, the warranty period determined by the manufacturers of PV panels is generally the time used as the service life of the PV system [86].

Ouedraogo and Yamegueu [28] used methods of economic feasibility analysis based on the useful lifetime of the system. According to them, the calculation of LCOE can be defined as the sum of all costs discounted during the project's useful lifetime, divided by the units of discounted energy produced. The NPV calculation considers all costs and revenues incurred during the life of the project and the value of the investment cost, all discounted at the zero date. Chiacchio et al. [41] state that the useful life of equipment varies depending on the environment and how they are operated. For Talavera et al. [50], an increase in the life of a PV system can mean important improvements in the cost competitiveness of the PV system, because it produces energy for a longer time. Analyzing the LCOE produced over the entire duration of the system, with an increase in useful lifetime from 20 to 35 years (75%), a 17% improvement in economic viability can be expected.

Panels Degradation

In PV systems, there is a decline in their technical performance over time, in which equipment loses quality, and its acquisition value depreciates. Degradation is a factor that takes into account the wear and tear on the PV panels. There are several causes of PV panel degradation, such as overheating, natural aging, accumulation of dirt, etc.

It is important to determine and assume the rate of degradation of the system to perform feasibility analyses [86,125]. The degradation factor is considered in the studies as a rate of reduction in the efficiency of electrical generation, and also in the values of the PV system as a form of depreciation. Therefore, it is necessary to define an annual rate of degradation in the efficiency of the PV modules.

The degradation of the panels causes an increase in the electricity costs of PV generation. For Hammad et al. [88], the cost of electricity increases with time over the life of the system, as the total production decreases with the annual degradation of the modules. Tervo et al. [10] argue that in any economic analysis the results depend on the component costs, financing methods, efficiency, and the degradation rates determined for the PV system model.

According to Choi et al. [85], PV modules degrade in performance due to aging over their lifetime and, as a result, the future energy generation of the system is estimated using the normalized energy generation in the first year and then decreased annually to consider performance degradation due to aging. For San Miguel and Corona [64], the degradation of the components of the PV system causes a cumulative reduction of 0.2% per year in energy generation, which is considered to determine the net energy production over the useful life of the system. McTigue et al. [61] conclude that in addition to the battery, the components of the PV plant suffer degradation over time, and some equipment needs to be replaced. They consider a rate of 1% degradation and replacement of parts, but if the plant is operated ineffectively, the rates of degradation may be higher.

Tilt Angle

For many authors, the slope on which the PV panels will be installed will directly influence the capture of energy from the sun and, consequently, the profitability of the project. Therefore, to extract the maximum performance from the system, an ideal inclination of the panels must be studied. However, the sunlight is not constant throughout the day, therefore, the ideal inclination at a certain time is different at another time. Several researchers are studying the best slope, where the panels will be more efficient most of the day, or even the possibility of changing the slope of the panels throughout the day as the sunlight changes direction.

According to Xu et al. [46], PV panels are tilted to increase the efficiency of solar irradiance on them, and it is necessary to maximize the solar energy yield to determine the ideal angle of inclination. For the authors, by adjusting the panels to the ideal inclination angle, the solar energy yield can be increased according to the location. According to Asif et al. [49], the output of a PV system is greatly influenced by the orientation and angle of inclination of the installed panels. Awan [7] warns that too high a slope can cause shade between the panels. For him, the inclined PV modules have an automatic shading effect that decreases the performance efficiency of parallel PV arrays, but this efficiency can be improved by increasing the distance between the parallel arrays.

Finally, according to De Lara Filho [55], it is necessary to determine the angles of inclination of the panels to maximize the generation of solar energy. However, to ensure that the panels are installed at this angle, it would be necessary to invest in support structures for the panels and, therefore, it is usually decided to use the existing structure (of the roof, as in the case) that has a fixed slope. Khalid and Junaidi [194] suggest that the PV plant has a fixed slope installation, as it is expected that the fixed slope plant has low operating and maintenance costs, as it does not use components with moving parts, such as trackers. However, regular cleaning of the panels in these installations is necessary, as well as occasional replacement of the inverters.

4. Conclusions

This research has been developed with the purpose of identifying and studying factors that can influence the economic viability of PV energy projects. Analyzing the main characteristics of a sample of studies selected with the systematic literature review criteria, it has been possible to notice the growing interest in this area of research, through the rapidly increasing number of articles per year of publication. In addition to the relevance of these studies to the literature, through the general number of citations it has been possible to observe that, from 2015 to 2019, there was an increase of approximately 54% in the number of citations. From the list of publications, it has been possible to identify the regions most interested in this study area, in which Brazil, Italy, and Spain stand out.

In our study, 29 factors were identified, which impact in some way on the economic feasibility of PV energy projects. These factors were separated into five classes, according to the corresponding points of view: location, economic, political, climatic and environmental, and technical factors. Among the factors identified, the initial investment cost has been the most prominent, present in 219 works in the sample, followed by power generation and operation and maintenance costs, identified in 210 and 196 works, respectively. Moreover, important terms are solar radiation (cited in 191 studies), lifetime (191), energy tariff (186), efficiency (184), electricity consumption (147), and interest and taxes (140).

Some factors vary widely from region to region, such as solar radiation, energy tariffs, temperature, and incentive policies, among others. Each factor ends up being influenced by another one, which reinforces the need to analyze all possible parameters for each case study. When compared to the places of publication, it can also be noted the diversity of the studies, as the factors considered in each study often vary greatly according to the region.

The initial investment cost is considered in most methods as a reference for the economic evaluation of projects. However, the investment cost alone is not enough to know whether a project is financially viable or not, as there are other factors that influence this viability. In this work, the other 28 parameters were addressed as well, because of their importance in the feasibility analysis.

In addition to the factors identified, which in some way can be predicted or calculated, there are non-financial factors that can greatly influence the decision to install PV energy systems, and which have been some of the biggest reasons for encouraging the production of solar energy. There are socio-environmental factors, such as the reduction in the emission of gases in the atmosphere; the reduction of environmental impacts caused by the electricity generation; the improvement of the quality of life; etc. Researchers are working to translate these factors into numbers, making it possible to include them in the financial analysis. These factors must be considered when designing incentive policies. Determining such factors, and the way they are treated in the literature, can be extremely relevant in helping investors and researchers, so that they can identify and consider the most appropriate variables for their studies.

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