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Article

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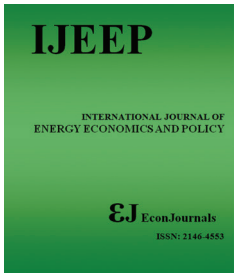

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Energy Financing in Colombia: A Bibliometric Review

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ABSTRACT

This article presents a bibliometric review on the researching topic "Contribution to the competitiveness of energy financing in the Colombian business sector," limited from 2011 to 2021. The review was carried out using the Scopus database, obtaining a set of 76 studies in Colombia within the 2609 documents analyzed. After having applied the different filters and search strategies, these studies were analyzed using the Bibliometrix package of the statistical software R. The results identified, for example, that the world production of publications shows an upward trend, with the largest number of scientific investigations presented in 2020. It was also found that one of the most relevant sources is the International Journal of Energy Economics and politics, with five published documents. On the other hand, the most cited local source is Energy Policy magazine, with 90 citations and that the most cited local authors are Cadavid L.

Keywords: Energy Financing, Competitiveness, Bibliometric Analysis
JEL Classifications: P18, Q40

1. INTRODUCTION

Currently, the energy sector is considered to be one of the most important sectors for the development of human activity, as well as for the assurance of quality of life. Therefore, this resource can be considered as the catalyst for the development of industry and economies as they are known today (Rohit et al., 2017). However, it must be recognized that, at present, the supply of energy systems in the world becomes an increasingly complex task due to the environmental crisis that the planet is going through, where non-renewable resources are increasingly scarce and endangered by exhaustion (Kazimierski, 2018); In addition to the high increase in the population rate that exists, leading directly to a situation where, the more people inhabiting a space, the greater the energy consumption and the greater the installed capacity of the energy sector must be to supply the needs of the population (Badii et al., 2020).

Such is the recognition of the importance of the energy sector today and the needs around it that in 2015, within the framework of the formulation of the sustainable development goals (SDG), the nations of the world, under the tutelage of experts, present a total of 17 objectives towards the achievement of sustainable development of humanity, in which objective 7 "Affordable and non-polluting energy" stands out; which is directly related to the expansion of the installed and technological capacity of an energy system that is capable of meeting the needs of society, without compromising the non-renewable resources present on earth (Altomonte, 2017).

In this way, it can be recognized that, from the efforts made by the various nations of the world, important steps have been taken towards the strengthening of efficient and sustainable energy systems hand in hand with financing options, allowing the implementation of these projects framed in technological development (Bobinaite and Tarvydas, 2014; Schwerhoff and Sy, 2017). However, it should be emphasized that these indicators have a greater impact in developed countries, which have the means and effective strategies for the development of this sector within the framework of sustainability (Donastorg et al., 2017).

Within the framework of the needs related to the effective empowerment of the energy sector, it is noted that in Colombia, in recent years, various strategies have been used to strengthen and develop the energy sector, highlighting financing within said sector as one of the most representative tools in the process. This is evidenced in the Sustainable Development Report (2021), which shows a significant level of improvement in Colombia's energy indicators, as shown below in Table 1:

Once the indicators shown above have been reviewed, it is certainly possible to recognize the important development shown by the Colombian nation in the development of a highly competitive energy system. Scientific evidence allows to demonstrate the application of new trends in the Colombian market towards energy efficiency (Martínez et al., 2020; Martinez-Sierra et al., 2019); in the same way towards the insertion of business models directed towards sustainable practices. However, it is essential to understand the dynamics of this sector, hand in hand with energy financing within the business environment of the nation. This is how a bibliometric analysis is carried out on the topic: Contribution to the competitiveness of energy financing in the business sector of Colombia, to delve into the following research questions:

- Q1: Which are the most relevant authors, countries and institutions in the field of energy financing competitiveness in the business sector in Colombia?
- Q2: Which are the most relevant authors, countries and institutions in the field of energy financing competitiveness in the business sector worldwide?
- Q3: Which are the most cited authors, documents and sources on the subject of energy financing competitiveness in the business sector worldwide?
- Q4: Which are the most cited authors, documents and sources on the subject of energy financing competitiveness in the Colombian business sector?

The other sections of this work are organized as follows: Section 2 describes the methodology used. In Section 3, the general information of the consulted studies is presented and in Section 4, the results obtained are described in terms of authors, countries, institutions and co-citation network.

2. METHODOLOGY

The methodological formulation is aimed at answering what has been the contribution to the competitiveness of energy financing in the business sector worldwide? To this end, the methodological design that underpins this research is based on a bibliometric analysis process, which is directed towards the recognition of the evolution of scientific knowledge in the area of energy financing. In this sense, bibliometric analysis is taken into account as a study tool due to its validation in multiple investigations (Li et al., 2014). Pritchard (1969) explains that this Type of research is directed towards the quantitative analysis of a variety of elements that can be located in texts of a scientific nature, which allows to recognize patterns or trends that occur in a specific time.

Thus, studies aimed at bibliometric analysis allow a quantitative validation of the sources of scientific information through mathematical and statistical processes (Thelwall, 2009), becoming an indispensable step for the qualitative analysis of academic data (Norton, 2001); and allowing to quantitatively purify the documentary sources for studies (Carvalho et al., 2013; Urquhart and Dunn, 2013). In this sense, we proceed to explain the methodological design used.

A systematic literature search was carried out in the Scopus database using the keywords "Energy," "Finance * 2," "Colombia," "Competitiveness," "Business sector," "problems" and "importance," limited initially by the year of publication, establishing as the lower limit the year 2011 and the upper limit the current year (both inclusive). The search equation was made up as follows: (TITLE-ABS-KEY (energy) AND TITLE-ABS- KEY (financ *) AND TITLE-ABS-KEY (colombia) AND TITLE-ABS-KEY (business AND sector) OR TITLE-ABS-KEY (problems) OR TITLE-ABS-KEY (importance) OR TITLE-ABS-KEY (competitiveness) AND PUBYEAR> 2010. The display of the previous equation generated 19 results without applying any filter, as the search did not obtain a considerable sample, as it was considered very small, a new search was carried out that generated the following equation: (TITLE-ABS-KEY (energy) AND TITLE-ABS-KEY (financ *) AND TITLE-ABS-KEY (colombia)) AND PUBYEAR> 2010 AND (EXCLUDE (DOCTYPE, "cr") OR EXCLUDE (DOCTYPE, "ed") OR EXCLUDE (DOCTYPE, "no") OR EXCLUDE (DOCTYPE, "re")) AND (EXCLUDE (LANGUAGE, "Portuguese")). As can be seen in the second search equation, the words used were energy, financ * and Colombia, and they were determined in this way, because the objective of the study is limited to this geographical area; in the equation it can also be analyzed that the Boolean search operator AND and the truncation operator (*) were used. All this with the purpose that the Scopus exploration engine with the AND would retrieve the documents that contained in it the 3 words used in obtaining the information and would use the truncation operator to search for words based on the root financ, such as finance, financing, etc. This operator is used to replace any ending of a word, which helps to broaden the search spectrum. With the results obtained, a filter was applied to exclude documents that were not relevant according to their type and language.

The results obtained after applying the filters were 75 documents, which were downloaded from Scopus in CSV format, to later be imported from the Bibliometrix package of the statistical

Table 1 : SDG7 – affordable and clean energy

SDG7 – Affordable and Clean Energy	Value	Rating
Population with access to electricity	99.9%	SDG achieved
Population with access to clean fuels and technology for cooking	91.8%	SDG achieved
CO2 emissions from fuel combustion for electricity and heating per total electricity output	0.9 (MtCO2/TWh)	SDG achieved
Share of renewable energy in total primary energy supply	26%	SDG achieved
Population with access to electricity	99.9%	SDG achieved

Source: Sustainable Development Report (2021)

Table 2: Main data information

Description	Results
Main information about data	
Timespan	2011:2021
Sources (Journals, Books, etc.)	62
Documents	76
Average years from publication	3.71
Average citations per documents	4.026
Average citations per year per doc	0.9184
References	3099
Document types	
Article	58
Book	2
Book chapter	1
Business article	1
Conference paper	14
Document contents	
Keywords Plus (ID)	586
Author's Keywords (DE)	292
Authors	
Authors	236
Author Appearances	247
Authors of single-authored documents	6
Authors of multi-authored documents	230
Authors collaboration	
Single-authored documents	6
Documents per Author	0.322
Authors per Document	3.11
Co-Authors per Documents	3.25
Collaboration Index	3.29

Main information of the data obtained from the search in the Scopus database.
Source: Own realization (2021) with data from SCOPUS

software R, which generated a diversity of indicators that allow to observe the number of documents that are published within a selected period of time, based on some keywords for the determination of the area of knowledge, with the authors of the largest number of publications, the dynamics of the sources, as well as the institutions and countries with the greatest trends in the area and the behavior of the citations. The general information of the consulted studies is presented in Table 2:

3. RESULTS

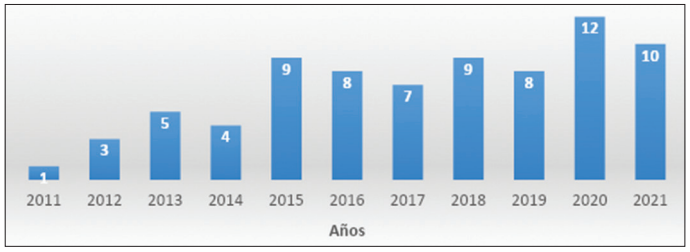
3.1. Productivity per Year

The design proposed in this research allowed the identification of 76 publications in the period from 2011 to 2021, showing a sustained growth with an upward trend in published studies associated with energy financing in Colombia in the last 10 years.

Figure 1 allows us to observe how the trend of publications associated with energy financing in Colombia has shown constant growth, where there have been various oscillations that have not had an effect on the growth of said production, in which there have been a total of seven publications on average during said period.

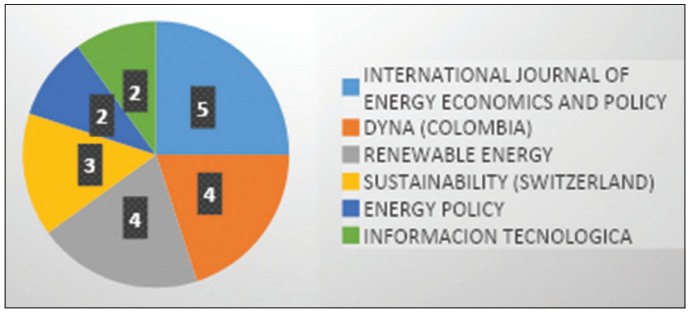
In Figure 2 you can see the journals that contribute the most research to the topic of interest of this report. Among the former are the International Journal of Energy Economics and Politics, Dyna, Renewable Energy and Energy Policy; together they provide most of the recovered documents. In the first journal, for example, one of the published studies deals with the evaluation of investment

Figure 1: Annual scientific production



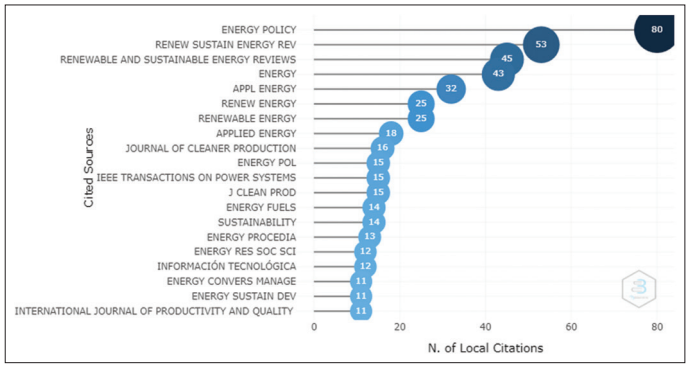
Source: Own realization (2021) with data from SCOPUS
The graph represents the annual scientific production of the last 10 years on the topic of energy financing in Colombia

Figure 2: Journals with the greatest influence



Source: Own realization (2021) with data from SCOPUS

Figure 3: Most cited local sources



Source: Own realization (2021) with data from SCOPUS
The country with the darkest blue color contributes more to scientific production

projects that have been carried out mainly through discounted cash flow analysis (DCF), whose financial viability measures have been based mainly on approaches such as the net present value (NPV) and the internal rate of return (IRR), which are widely discussed in the field of energy project valuation (Martínez-Ruiz and Manotas-Duque, 2021).

The first five most cited local sources, as can be seen in in Figure 3, correspond to the journals Energy Policy, Renew sustain energy review, Renewable and sustainable energy reviews, Energy and APPL Energy.

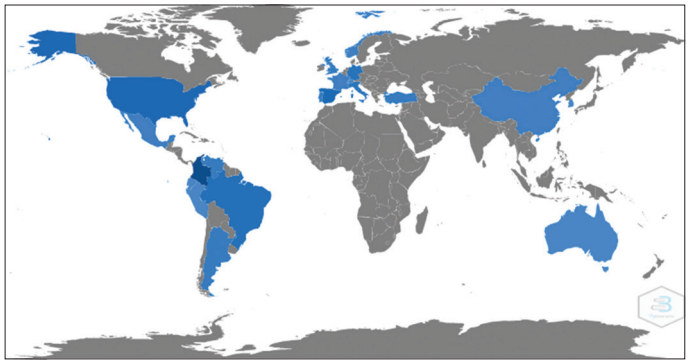
Analyzing the contributions made by each country, we can see in the Figure 4 that Colombia (149), the United States (19), Spain (16) and Brazil (9) are the countries that contribute the most in

the research area. In Colombia, for example, a study this year investigated renewable energies as an alternative to explore new business models in Colombia, especially when considering the new regulation associated with Law 1715 (Isaza-Cuervo and Arredondo-Orozco, 2021). At the same time, the United States is investigating one of the most efficient strategies to reduce energy consumption, which not only has a positive impact on reducing fuel consumption, but also shows improvements in both financial and technological efficiency (Avila, 2020).

Figure 5 shows the ranking of the most contributing institutions by publications within the bibliometric analysis. The institutions that contribute the most in this regard are the National University of Colombia with 15 publications, followed by the Technological University of Pereira (9). In third place, with the same number of publications, the Universidad Autónoma de Bucaramanga, Universidad del Norte and the Universidad Nacional de Colombia, Medellín headquarters (3).

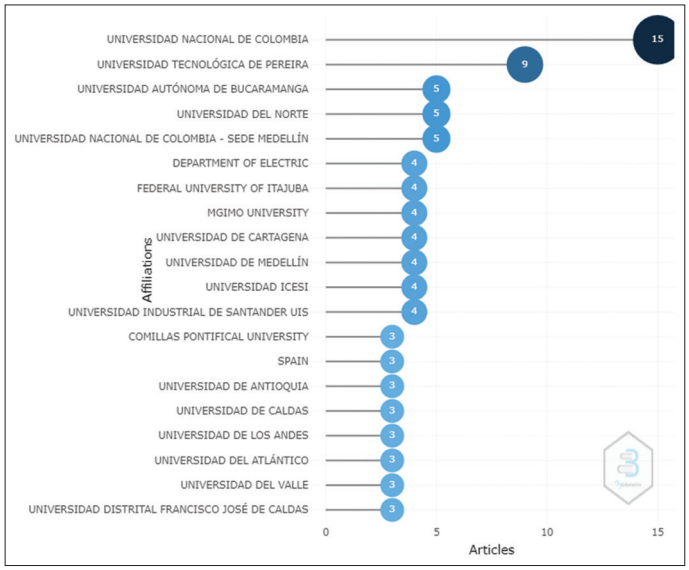
According to Figure 6, the most relevant authors in the field of research on energy financing in Colombia, with two publications each, are: Cadavid L., Castillo-Ramírez A.… and Tibaquirá J.E.

Figure 4: Scientific production by countries



Source: Own realization (2021) with data from SCOPUS
The country with the darkest blue color contributes more to scientific production

Figure 5: Most relevant institutions



Source: Own realization (2021) with data from SCOPUS

Among the studies by these authors, the one by Cano and Botero, where they propose a diversification analysis of power generation sources in Colombia, based on the Portfolio Theory, which has been traditionally used in the financial sector (Cano and Botero, 2012).

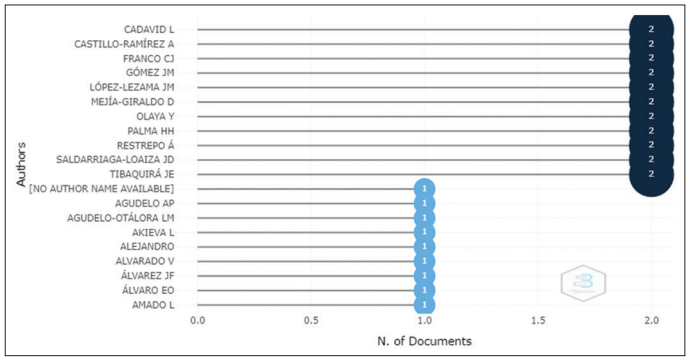
The general behavior in relation to the types of sources of published documents observed in Figure 7, shows a high tendency (76%) to publish mainly in the typology of articles, followed by products presented at conferences (19%), books (3 %) and finally book chapters (1%) and business articles (1%).

In Table 3, it can be seen that the most cited documents are found, firstly, in the APPL Energy magazine, by the author Colmenar-Santos of the year 2016 (25); secondly, in the International Journal Human Rights magazine, by the author McNeish of the year 2017 (24); thirdly, in the International Journal Environ Res Public Healt, by the author Hettiarachchi et al. of the year 2018 (18), etc.

The purpose of the most cited work in this section is to evaluate the economic impact resulting from the conversion of conventional stations to cogeneration plants connected to a heat and cooling distribution system. The analysis was carried out by means of a financial evaluation in order to evaluate the annual variations of all the expenses of the scheme (Colmenar-Santos and Rosales-Asensio, 2016).

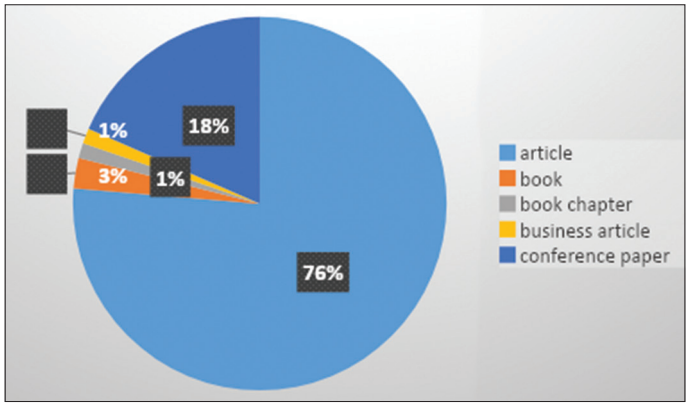
The most relevant terms produced by the bibliometric analysis can be seen in Figure 8, in which it can be seen that the most

Figure 6: Most relevant authors



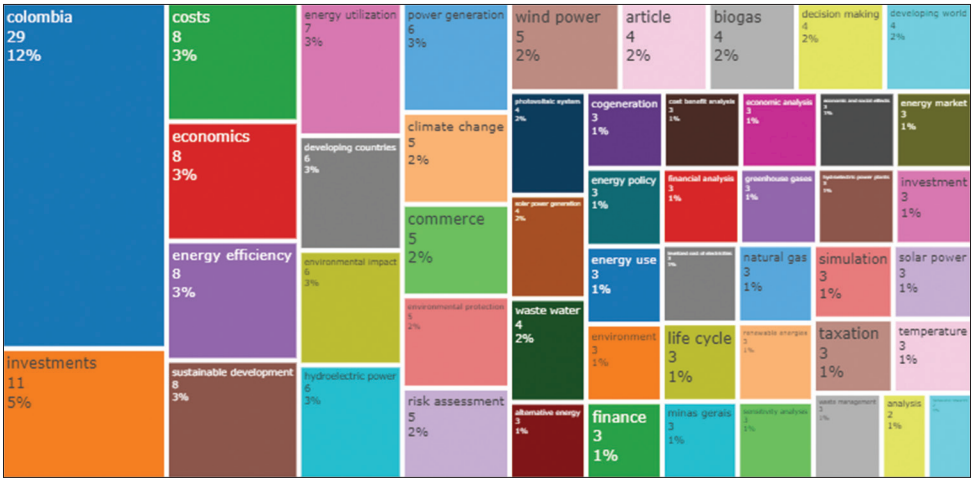
Source: Own realization (2021) with data from SCOPUS

Figure 7: Scientific production according to the type of source



Source: Own realization (2021) with data from SCOPUS

Figure 8: Most relevant terms



Source: Own realization (2021) with data from SCOPUS

Table 3: Twenty most cited documents

Documents	Doi	Cites
Colmenar-Santos et al., 2016, appl energy	10.1016/j.apenergy. 2015.10.161	25
Mcneish J., 2017, int j hum rights	10.1080/13642987.2016.1179031	24
Hettiarachchi et al., 2018, int j envir res public health	10.3390/ijerph 15112483	18
León-Vargas et a., 2019, renew energy	10.1016/j.renene. 2018.06.087	17
Taborda et al., 2017, energy convers manage	10.1016/j.enconman. 2017.05.055	15
Zabaloy et al., 2019, energy res soc sci	10.1016/j.erss. 2019.01.015	13
Osma et al., 2015, procedia eng	10.1016/j.proeng. 2015.08.524	13
Contreras J., 2016, renew energy	10.1016/j.renene. 2015.10.018	12
Sáenz et al., 2014, ecosyst serv	10.1016/j.ecoser. 2014.06.012	12
López et a., 2020, renew energy	10.1016/j.renene. 2019.10.066	11
Castillo-Ramírez et al., 2017, energy sourc econ plann	10.1080/15567249.2016.1276648	11
Ramírez et al., 2016, renew energy	10.1016/j.renene. 2016.06.047	11
Jiménez et al., 2014, dyna	10.15446/dyna.v81n188.42165	11
Valderrama et al., 2019, energy policy	10.1016/j.enpol. 2018.09.039	10
Meneses-Jácome et al., 2015, water sci technol	10.2166/wst. 2014.477	9
Mastropietro, 2017, econ energy environ policy	10.5547/2160-5890.6.1.pmas	8
Carvajal et al., 2013, energy policy	10.1016/j.enpol. 2012.10.041	8
Botta et al., 2016, economia politica	10.1007/s40888-016-0030-6	7
Goda et al., 2015, ensayos sobre polit econ	10.1016/j.espe. 2015.07.001	6
Otay and Yıldız, 2020, j intelligent fuzzy syst	10.3233/jifs-179452	5
Polanco, 2018, Energy Sustainability Soc	10.1186/s13705-018-0181-0	5
Agudelo et al., 2015, Inf Tecnol	10.4067/ S0718-07642015000600012	5
Saldarriaga-Loaiza et al., 2019, Inf Tecnol	10.4067/ S0718-07642019000100063	4
Castro et al., 2019, Int J Energy Econ Policy	10.32479/ijeep. 7587	4
Ríos and Olaya, 2018, Energy Effic	10.1007/s12053-017-9601-9	4
Gómez et al., 2018, Int J Prod Qual Manage	10.1504/IJPQM.2018.095651	4
Realpe et al., 2016, Int J Chemtech Res		4
Li F, 2018, Sustainability	10.3390/su10051599	3
Conde Máa, 2018, Ciriec Esp Rev Econ Publica Soc Coop		3
Zambrano and Olaya, 2017, Ann Oper Res	10.1007/s10479-016-2222-4	3

(Contd...)

Table 3: *(Continued)*

Source: Own realization (2021) with data from SCOPUS

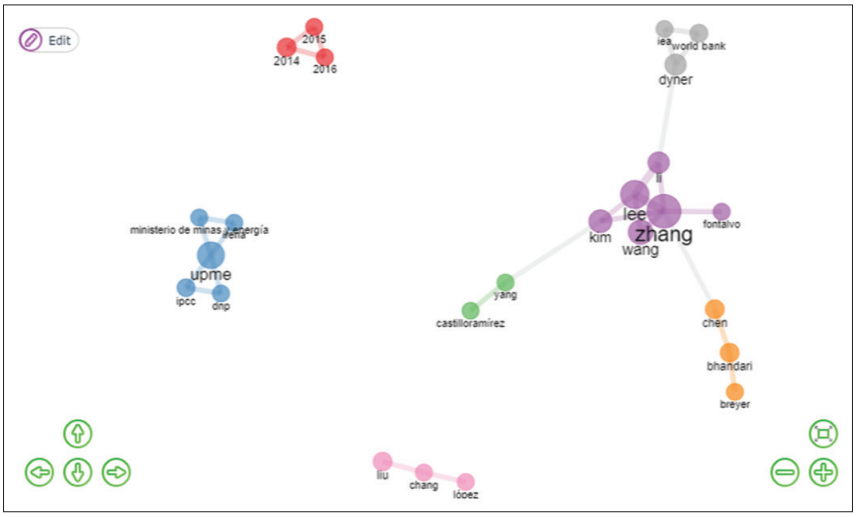
representative word with 12% was the word Colombia, followed by the word investments with 11%, cost, economics, energy efficiency and sustainable development with 3%. The other words that appear in the graph are very irrelevant with a percentage of 2-1%.

3.2. Analysis of Relationships and Co-occurrences

3.2.1. Analysis of the relationship and collaboration between authors

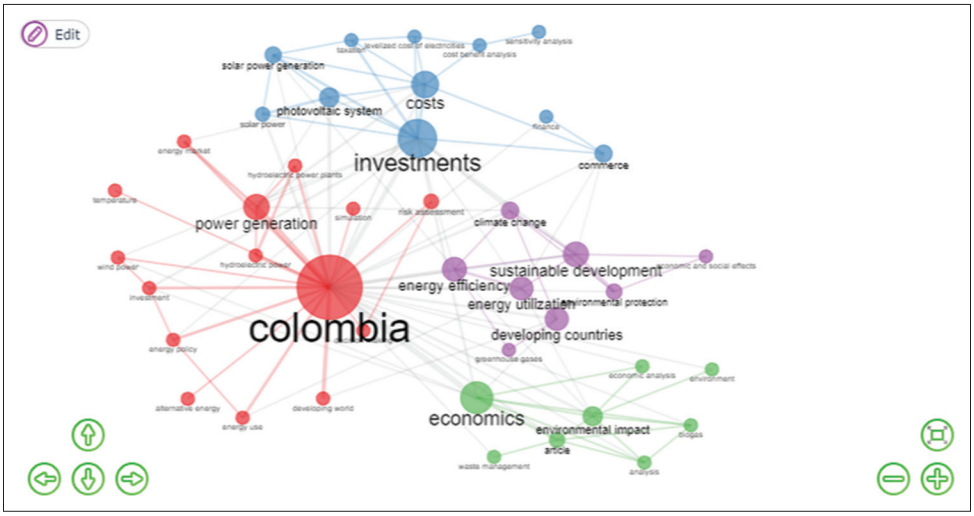
The process of identifying the relationships between the authors considered as most representative allows to expand the scope raised in the paper. In this way, a map of relationships and collaboration was carried out in the Biblometrix package of the statistical software R, in which the database previously used is taken into consideration for which the analysis of the "Co-authorship" that studies the authors as units through the process of "Full counting" is taken into account, which allows the construction of the map. In this sense, authors with at least three (3) publications are taken, where 58 authors are selected

Figure 9: Analysis of the relationship and collaboration between authors



Source: Own realization (2021) with data from SCOPUS

Figure 10: Analysis of co-occurrence of terms



Source: Own realization (2021) with data from SCOPUS

for the design of the same, this criterion is developed to allow the visibility of the graph.

Taking into account Figure 9, it can be seen that the relationship analysis carried out yielded 4 groups or clusters. The first group is made up of 5 authors: Zhang, Lee, Wang, Kin and Fontalvo; the second group is made up of 3 authors: Chen, Bhandari and Breyer; the third group is made up of 3 authors: Liu, Chang and López; and the last cluster is made up of 2 authors: Castillo Ramírez and Yang.

Figure 10 shows the keyword co-occurrence map. It allowed the identification of 4 clusters that involve the 76 documents analyzed. In the first cluster a group of words is grouped where the most relevant are Colombia, power generation, energy policy, among others; in the second cluster we find that the most relevant words are: Investments, costs, commerce, photovoltaic system, etc; in the third cluster words such as: Energy efficiency, sustainable development, energy utilization, etc; and in the last cluster words like: economics, environment impact, etc.

4. CONCLUSIONS

In the first instance, the empirical work carried out in this study allows us to conclude that the strengthening of sources of financing within the energy sector allows a development of innovation and incorporation that allow organizations and economics in general to direct themselves towards the fulfillment of the creation of a self-sustaining energy system. It is concluded in turn that it is essential to recognize the role of the energy system for humanity and how it should have a special emphasis on sustainability.

In this way, scientific production in high-impact sources around the study of energy financing in Colombia has had an important boom in the last decade (2011-2021), where it is important to highlight the increase in scientific production in the last 5 years (2016-2021)

that had an increase of 20% compared to the previous 5 years (2011-2015). This increase could be justified in the promulgation of the Sustainable Development Goals in 2015, which marked an important starting point. The general behavior in relation to the types of sources of published documents shows a high tendency (76%) to publish mainly in the typology of articles, followed by products presented at conferences (19%), books (3%) and book chapters (1%). It is also concluded that a high percentage (76%) of the analyzed publications come from scientific articles.

Authors with high relevance in the research topic are not presented. Those who contribute the most have a maximum of 2 publications. There is no strong relevance in the keywords related to the research topic, there is a lot of dispersion in the terms. Despite the fact that the subject was delimited by the geographical area of Colombia, a high percentage of participation in the contribution of scientific production can be seen in countries such as the United States and Brazil. Finally, it is recommended to continue expanding the lines of research related to the strengthening of the energy sector today; especially in relation to sources and financing mechanisms within developing countries, which still have a long way to go in the framework of energy efficiency and sustainability.

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