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Analysis of innovation and economic growth through the development of renewable energies

John Arturo Buelvas Parra[1], William Niebles Nuñez[2], León Arango Buelvas[3]

[1]*Administrador de Empresas- Abogado. Especialista en finanzas, Magister en Gestión de Organizaciones, Dr. En Ciencias Sociales Mención Gerencia. Docente Universidad de Sucre.*
Email: john.buelvas@unisucre.edu.co. https://orcid.org/0000-0003-1894-3712
[2]*Doctor en Ciencias Gerenciales, Docente de la Universidad de Sucre.*
ORCID: https://orcid.org0000-0001-9411-4583. Email: williamniebles@yahoo.com.mx
[3]*Economista. Doctor en Ciencias Económicas. Director Grupo de Investigación OIKOS. Docente Universidad de Sucre.*
ORCID: https://orcid.org000-0001-8198-1872. Email: leon.arango@unisucre.edu.co

Abstract

Sustainability has caused industries to generate new technologies based on renewable energy; resulting in innovation and development processes within the sector. From this panorama, this article is carried out in order to analyze the scientific production related to renewable or alternative energies as a source of innovation and economic development. At the methodological level, a bibliometric-based documentary study is proposed, which is carried out in the scopus database with a search equation that starts from the variables: "Economic development", "Renewable energies" and "Innovation". The results of the search carried out show a total of 674 documents in the time window of 1994-2023; and observing Environmental Science and Pollution Research, Renewable Energy, Journal of Environmental Management, Sustainability (Switzerland), Energies and Journal of Cleaner Production as main sources. It is concluded that scientific production has grown since 2015, possibly linked to subsequent programs to the sustainable development goals, and with an exponential peak since 2020. This is linked to the new achievements and findings of the energy industry in the field of sustainability.

Keywords: Sustainable development, SDG, Economic development, Renewable energies and Innovation.

Introduction

It is recognized by the scientific community and society that climate change is one of the most relevant issues today; directly causing the inability in the future of the subsistence of humanity to the depletion of non-renewable natural resources (Fedele et al., 2019). In this way, the so-called sustainability paradigm arises, which is fundamental in the Sustainable Development Goals promulgated by the United Nations in 2015 (Castro et al., 2022; García-Samper et al., 2022); which have served as a roadmap for the transformation of society and the economic model in search of a balance between man and his equal development and the environment (Sachs et al., 2019).

From this perspective, renewable energies appear as an alternative to conventional power generation models, a key factor for the development of the industry and the competitiveness of countries (Palma, 2020). These renewable energies are based on the use of non-finite resources and with a low environmental impact that allow them to present themselves as an alternative aligned to the aforementioned sustainability paradigm (Elavarasan et al., 2020).

However, these energies are still in a process of technological development towards the achievement of technical and economic feasibility that really allows conventional generation models to be replaced by this type of sustainable methods and processes (Palma, Casseres & Ravelo, 2022). From here, according to scientific evidence, an extremely interesting catalytic effect is generated in which sustainability as a requirement and necessity of humanity pushes the industry to search for and develop new innovative technologies that allow a transformation of the models current power generation (Wang et al., 2019).

In this sense, the states and organizations of the world propose strategies to encourage the processes of investigation and scaling of technologies towards a maturation that can be applied to the industry, through financial incentives, co-financing or technical support; in such a way that mechanisms aimed at innovation within the energy sector are generated (Hernández-Palma, H., Jiménez-Coronado & Mendoza-Casseres, 2022; Niebles-Nunez, Niebles-Nunez & Babilonia, 2022). From this, a panorama is observed that envisions how the exercise of technological maturation of the energy sector with a sustainable base directly permeates the generation of innovation and economic development of the countries; which seek to become the precursors and suppliers of the "new oil" worldwide.

In this way, it is considered essential to carry out scientific studies based on scientometrics that allow recognizing the state and characteristics of intellectual production related to renewable or alternative Energies as a source of innovation and economic development; recognizing the validity of this type of research due to the quality of the contributions they generate in the exploration of scientific knowledge (García et al., 2022).

Methodology

A systematic search of the literature related to the subject was carried out in the Scopus database in November 2022 with the keywords "economic development", "renewable energies" and "innovation"; below, in table 1 you can see the standardization of the keywords.

Table 1. Keyword standardization.

Keyword	Descriptors
Economic development	* economic growth
Renewable energies	* alternative energies * clean energies
Innovation	* innovation

Source: author.

The search equation based on Scopus was: (TITLE-ABS-KEY ("renewable energies ") OR TITLE-ABS-KEY ("alternative energies") OR TITLE-ABS-KEY ("clean energies") AND TITLE-ABS -KEY ("economic growth") OR TITLE-ABS-KEY ("economic development") AND TITLE-ABS-KEY ("innovation"); yielded 674 results related to renewable energies as a source of innovation and economic development and comprise a period of time between 1994 and 2023.

The results obtained were exported from Scopus in CSV format; To analyze said information, the Excel program, the Bibliometrix package of the R statistical software and the VOSviewer software were used. From this, a diversity of indicators was generated that allow analyzing the number of

documents published in a selected period of time, types of documents, authors with the largest number of publications, the dynamics of the sources, as well as the institutions and countries with the highest trends in the area and dating behavior. The general information of the consulted studies is presented in Table 2.

Table 2. Main information of the data obtained from Scopus.

Main information about data	
timespan	1994:2023
sources (journals, books, etc)	291
documents	674
annual growth rate %	2,42
document average age	3,27
average citations per doc	19,84
references	37638
Document contents	
keywords plus (id)	2696
author's keywords (de)	1661
Authors	
authors	1758
authors of single-authored docs	111
Authors collaboration	
single-authored docs	121
co-authors per doc	3,36
international co-authorships %	34,12
Document types	
article	516
book	10
book chapter	30
conference paper	73
conference review	2
editorial	1
erratum	1

note	2
review	37
short survey	2

Source: author using the R software based on information from Scopus (2022).

Table 2 shows the main information of the consulted documents, you can see a period of time from 1994 to 2023; In total, 674 documents were analyzed, of which it can be ruled out that the majority are articles with 516 followed by 73 conference documents.

Resultados y discusión

The results of the search carried out in the Scopus database were organized into three sections; first the laws of bibliometric productivity, second the different bibliometric indicators and finally the analysis of relationships and co-occurrences.

Laws of bibliometric productivity

It begins by showing the estimate of the coefficient of Lotka's law, explaining that there is a quantitative relationship between authors and the contributions produced in a given field over a period of time. A few authors produce most of the scientific production and a larger group of authors produces fewer articles (Alves, 2019).

Table 3 shows Lotka's law. The largest number of authors (1497), equivalent to 85.2%, are the ones with the least contributions with a single article, 9.1% have made 2 contributions, 2 7% have made 3 contributions, 1.4% have made 4 contributions, 0.6 have made 5 contributions, 0.4 have made 6 contributions, 0.3% have made 7 contributions and finally 0.1% have made between 8 and 22 contributions. From these it can be concluded that most of the contributions made are by researchers who carry out temporary or transitory research on the subject of study.

Table 3. Lotka's Law.

Written documents	Number of authors	Ratio of authors
1	1497	0,852
2	160	0,091
3	47	0,027
4	24	0,014
5	11	0,006
6	7	0,004
7	6	0,003
8	1	0,001
9	1	0,001
10	1	0,001

11	1	0,001
15	1	0,001
22	1	0,001

Source: author using R software based on information from Scopus (2022).

On the other hand, when applying Bradford's law in table 4 and figure 1, it is observed that 33.38% of the articles published are concentrated in the first 6 journals and that these belong to zone 1 of Bradford's law. , where a relatively small number of periodicals are concentrated and are the most productive (Vargas and Madrigal, 2011).

The first 6 journals are: Environmental Science and Pollution Research, Renewable Energy, Journal of Environmental Management, Sustainability (Switzerland), Energies and Journal of Cleaner Production.

Table 4. Bradford's Law.

Zone	**Number of magazines**	**Number of titles**	**Percents**
Zone 1	6	225	33,38%
Zone 2	63	227	33,68%
Zone 3	222	227	33,68%

Source: author based on information from Scopus (2022).

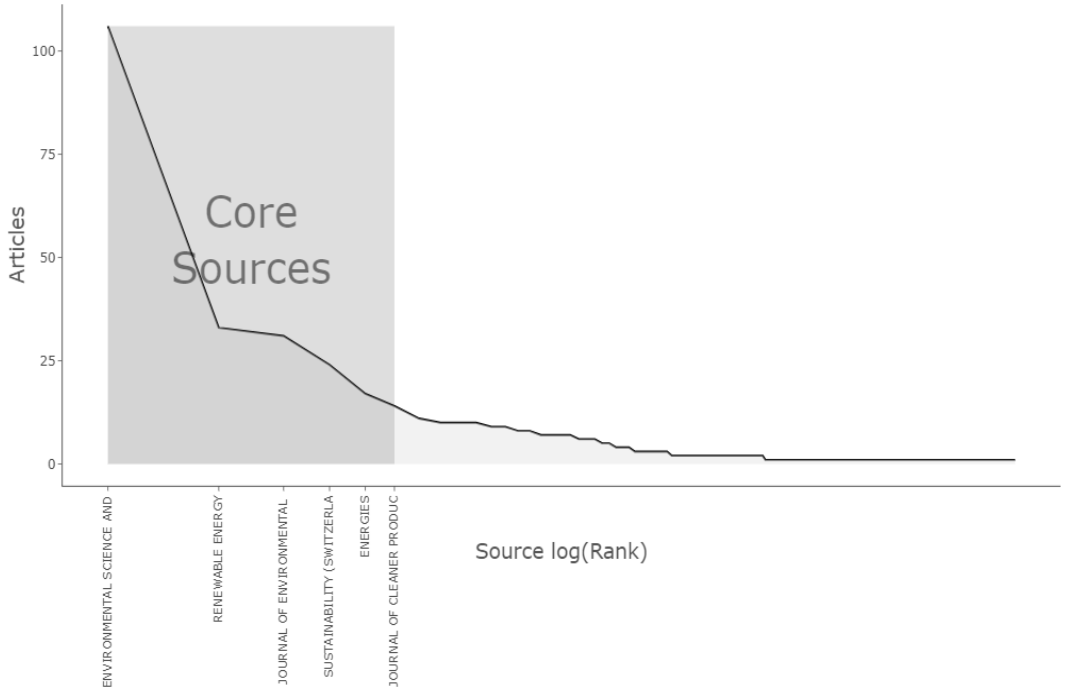

Figure 1. Bradford's Law, Source: author using R software based on information from Scopus (2022).

Bibliometric indicators

Figure 2 shows that the annual scientific production related to the research topic has been growing since 2010, especially in 2020, 2021 and 2022 where 63% of all the investigations carried out are concentrated; This indicates a growing interest in the research topic.

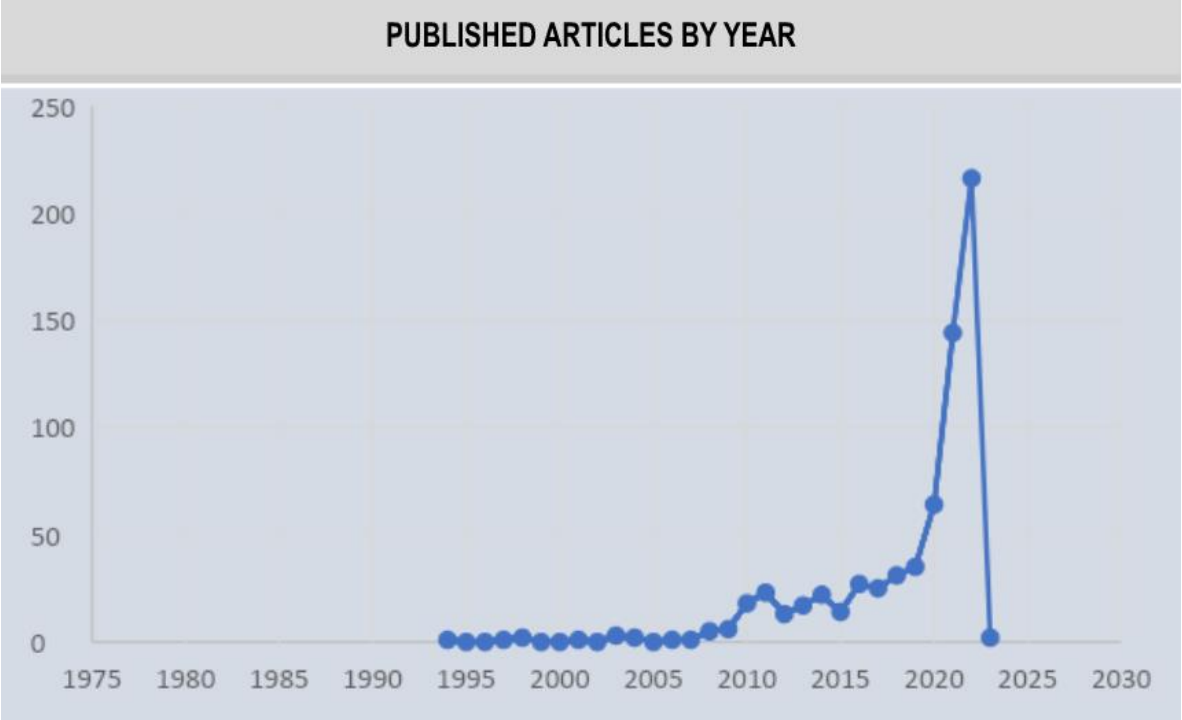

Figure 2. Annual scientific production. Source: author based on information from Scopus (2022).

A geographical analysis was carried out in order to know the countries in which more research is being carried out on the subject. In figure 3 we can see on the map the dark green countries are the ones that have the most research in this field, we can highlight China (275), Pakistan (82), Turkey (74), United States (69), United Kingdom United (49), Malaysia (34) and India (30).

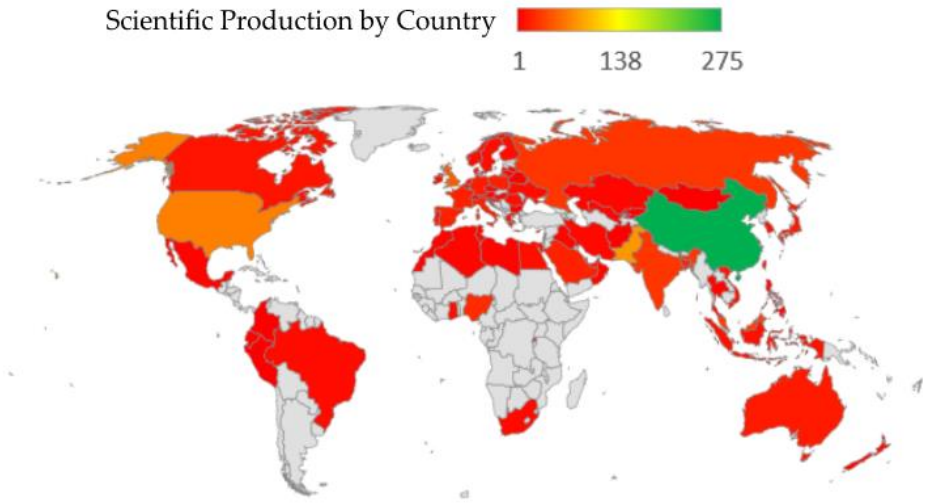

Figure 3. Scientific production by country. Source: author based on information from Scopus (2022).

China has research aimed at investigating the asymmetric influence of renewable energy and green innovation in reducing carbon emissions, and the role that innovation and renewable energy consumption play in reducing carbon dioxide emissions. (Sun et al., 2022; Azam et al., 2022; Khan et al., 2022; Amin et al., 2022).

For its part, Pakistan, which is the second country with the most research on the subject, addresses innovation as a mediator for innovative and ecological solutions to mitigate the negative effects of global warming (Fareed et al., 2022; Xie et al., 2022).

On the other hand, an analysis of the most relevant Sources in the research topic was carried out; Figure 4 shows that the six journals that publish the most on the subject are ENVIRONMENTAL SCIENCE AND POLLUTION RESEARCH (106), RENEWABLE ENERGY (33), JOURNAL OF ENVIRONMENTAL MANAGEMENT (31), SUSTAINABILITY (SWITZERLAND) (24), ENERGIES (17) and JOURNAL OF CLEANER PRODUCTION (14).

In the journal with the most publications on the subject, you can find several publications related to the link between financial development, technological innovation, foreign investment with renewable energies to reduce the emission of greenhouse gases (Ganda, 2022; Liu et al. ., 2022; Su & Gao, 2022; Zamir & Mujahid, 2022).

In the second journal with the most publications, you can find research related to green innovation in renewable energies, how through these you can mitigate carbon emissions and contribute to sustainable development (Habiba et al., 2022; Meng et al., 2022; Ostadzad, 2022; Zhou et al., 2022).

Production per author is moderate compared to the number of articles published from 1994 to 2023. As can be seen in figure 5, the 3 authors with the most published articles are Adebayo TS (22), Kirikkaleli D (15) and Ahmad M (11).

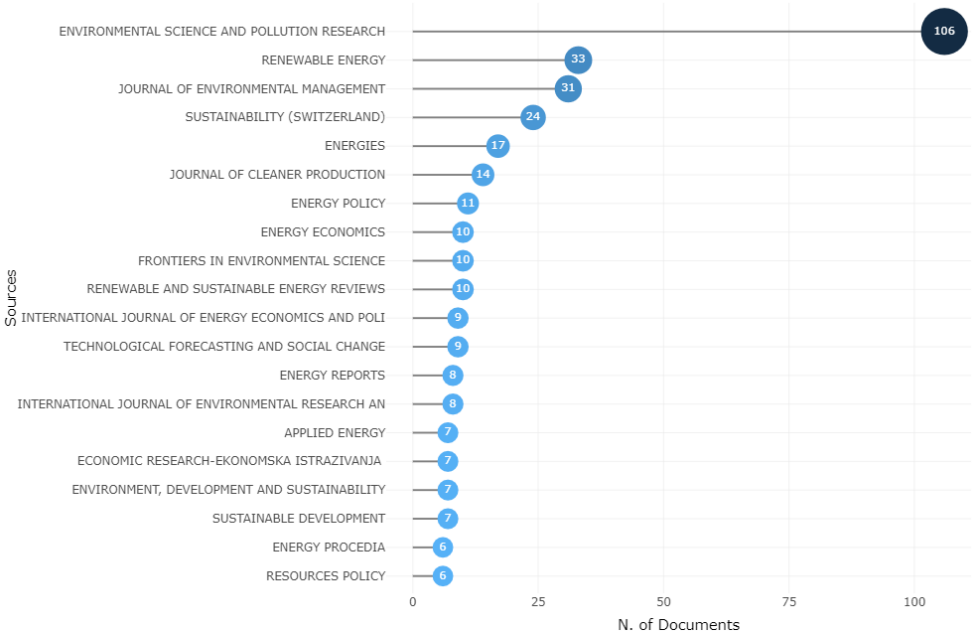

Figure 4. Most relevant sources. Source: author using R software based on information from Scopus (2022).

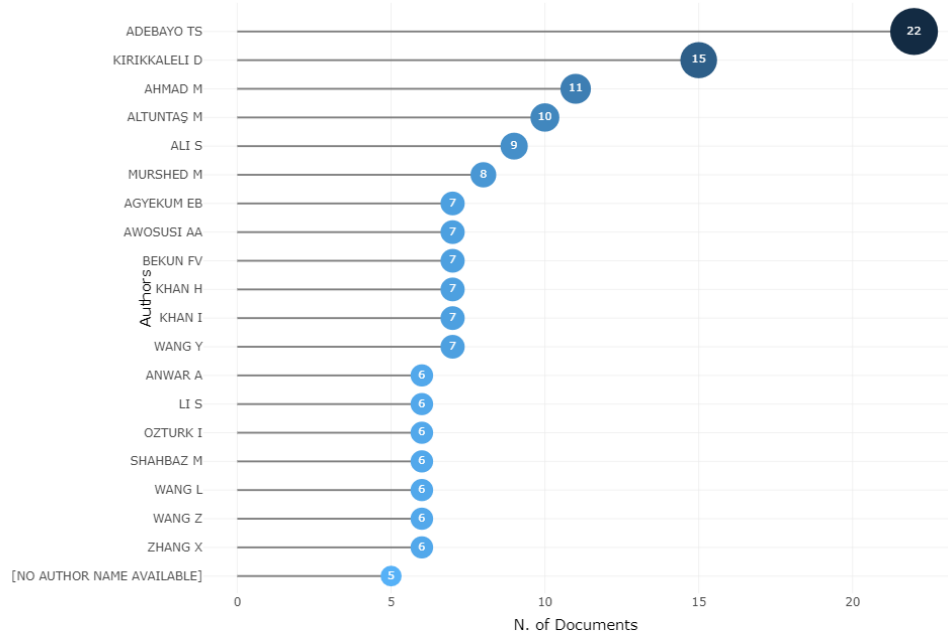

Figure 5. Most relevant authors. Source: author using the R software based on information from Scopus (2022).

The two authors who publish the most on the subject have several co-authored publications that deal with the consumption of renewable energies and how they influence financial development for environmental sustainability (Kirikkaleli & Adebayo, 2021; Kirikkaleli & Adebayo, 2021b).

Table 5. Most cited articles.

Articles	DOI	Total Citations
BALSALOBRE-LORENTE D, 2018, ENERGY POLICY	10.1016/j.enpol.2017.10.050	582
ALVAREZ-HERRANZ A, 2017, ENERGY POLICY	10.1016/j.enpol.2017.03.009	270
LIU X, 2018, J CLEAN PROD	10.1016/j.jclepro.2017.10.156	268
PEIDONG Z, 2009, RENEWABLE SUSTAINABLE ENERGY REV	10.1016/j.rser.2007.11.005	245
DOYTCH N, 2016, ENERGY ECON	10.1016/j.eneco.2015.12.010	203
TANG CF, 2016, RENEWABLE SUSTAINABLE ENERGY REV	10.1016/j.rser.2015.10.083	190

MENSAH CN, 2018, ENVIRON SCI POLLUT RES	10.1007/s11356-018-2968-0	189
TIWARI AK, 2011, ECON BULL		167
KHATTAK SI, 2020, ENVIRON SCI POLLUT RES	10.1007/s11356-020-07876-4	164
CHEN W, 2018, RENEW ENERGY	10.1016/j.renene.2018.02.026	163
ADEBAYO TS, 2021, ENVIRON DEV SUSTAINABILITY	10.1007/s10668-021-01322-2	151
IRANDOUST M, 2016, ECOL INDIC	10.1016/j.ecolind.2016.03.051	142
AL SHAQSI AZ, 2020, ENERGY REP	10.1016/j.egyr.2020.07.028	141
WANG H, 2019, ENERGY POLICY	10.1016/j.enpol.2019.03.007	141
DOĞAN B, 2021, SUSTAINABLE DEV	10.1002/sd.2125	139
KIRIKKALELI D, 2021, SUSTAINABLE DEV	10.1002/sd.2159	133
WANG R, 2020, J ENVIRON MANAGE	10.1016/j.jenvman.2020.111027	133
RAFINDADI AA, 2016, RENEWABLE SUSTAINABLE ENERGY REV	10.1016/j.rser.2016.05.028	125
CHENG C, 2021, J ENVIRON MANAGE	10.1016/j.jenvman.2020.111818	121
KOÇAK E, 2019, ENVIRON SCI POLLUT RES	10.1007/s11356-019-04712-2	119

Source: author using R software based on information from Scopus (2022).

Table 5 shows the 20 publications with the most citations, the five most representative are BALSALOBRE-LORENTE D, 2018, ENERGY POLICY (582), ALVAREZ-HERRANZ A, 2017, ENERGY POLICY (270), LIU X, 2018, J CLEAN PROD (268), PEIDONG Z, 2009, RENEWABLE SUSTAINABLE ENERGY REV (245) and DOYTCH N, 2016, ENERGY ECON (203). In turn, Table 6 contains a description of the ten most cited articles regarding the research topic.

Table 6. Ten most cited articles.

Highlight	Year	Source	Quote
Relationship between economic growth and carbon dioxide emissions, concludes that the consumption of renewable electricity, natural resources and energy innovation improve environmental quality.	2018	ENERGY POLICY	(Balsalobre-Lorente et al., 2018)
Renewable energies and energy innovation as a corrective measure for air pollution.	2017	ENERGY POLICY	(Alvarez-Herranz et al., 2017)
Cause-effect relationship between industrialization and carbon dioxide emissions.	2018	CLEAN PROD	(Liu & Bae, 2018)
Policy opportunities related to renewable energy in China for sustainable economic growth.	2009	RENEWABLE SUSTAINABLE ENERGY REV	(Peidong et al., 2009)
Relationship of foreign direct investment with the consumption of renewable energy and Source of innovation in energy efficiency.	2016	ENERGY ECON	(Doytch & Narayan, 2016)
Analysis of the relationship between energy consumption and economic growth in Vietnam, it was concluded that energy consumption, foreign direct investment and capital stock have a positive influence on economic growth.	2016	RENEWABLE SUSTAINABLE ENERGY REV	(Tang et al., 2016)
The effects of innovation on carbon dioxide emissions in OECD countries.	2018	ENVIRON SCI POLLUT RES	(Mensah et al., 2018)
Impact of income, innovation and the consumption of renewable energies on the emission of carbon dioxide.	2011	ECON BULL	(Tiwari, A. K. 2011).
Analysis of the dynamics of renewable energy consumption, economic growth and carbon dioxide emissions.	2020	ENVIRON SCI POLLUT RES	(Khattak et al., 2020)
Impact of renewable energies and technological innovation on economic growth.	2018	RENEW ENERGY	(Chen & Lei, 2018)

Source: author using based on information from Scopus (2022).

Análisis de relaciones y Co-ocurrencias

The analysis of relationships and co-occurrences is done using the VOSviewer software, taking as a parameter that the author has a minimum of two documents and a minimum of three citations.

The co-authorship analysis shows that of 1754 authors only 232 meet the parameters, of which 179 are connected with other authors; We can see this in figure 6, in which 18 clusters can be identified.

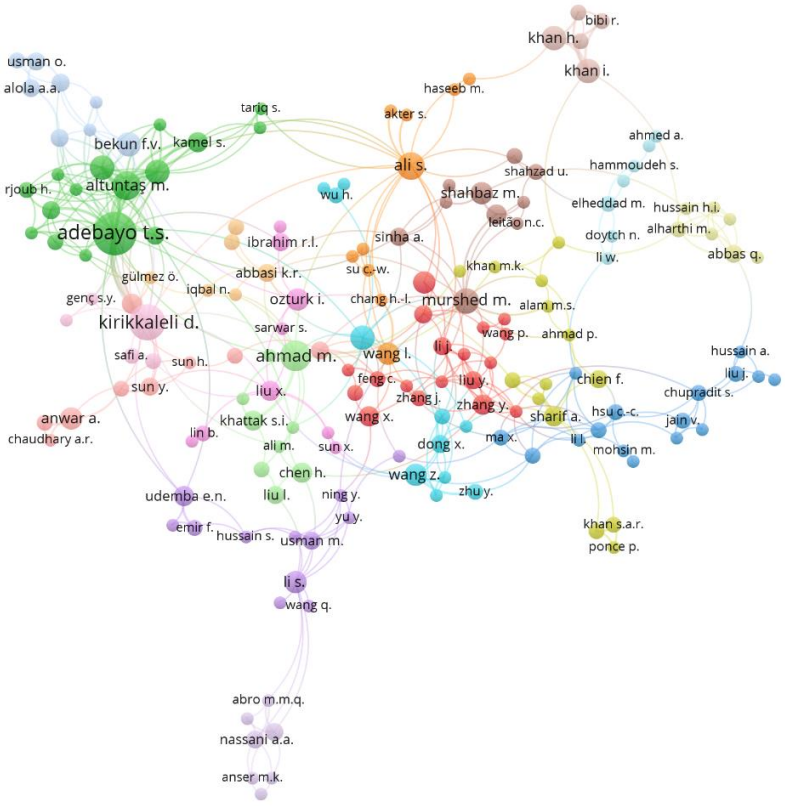

Figure 6. Co-authorship relationship. Source: author using the VOSviewer software based on information from Scopus (2022).

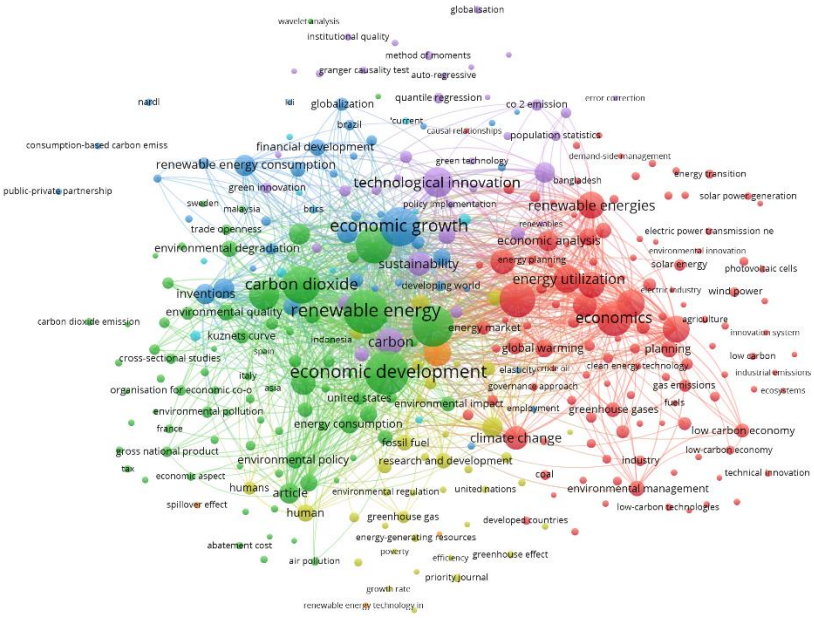

Figure 7. Co-occurrence of keywords, Source: author using the VOSviewer software based on information from Scopus (2022).

Finally, an analysis of co-occurrence of keywords was carried out, the parameter was that the minimum number of occurrences of a keyword is 5, of 3741 words only 330 meet the parameter, this can be evidenced in figure 7 where they identify 7 clusters; The words economic development, carbon dioxide, renewable energy, innovation, sustainable development, economic grow and alternative energy can be highlighted.

Conclusions

Of the 674 documents analyzed in this bibliometric study carried out based on the information obtained from the Scopus database on renewable energies as a source of innovation and economic development, it can be concluded:

77% of the documents consulted are articles, 11% are conference documents and the remaining 12% other formats. The scientific production analyzed in the period from 1994 to 2023 shows a growing trend, there is interest in this research topic, especially in the years 2020, 2021 and 2022, where 63% of all the publications carried out are concentrated. It can be concluded that this trend could be related to the development of recent new technologies and the plans resulting from the sustainable development objectives.

China, Pakistan, Turkey, the United States, the United Kingdom, Malaysia and India represent 91% of the twenty countries that generated the most publications in the field of research. On the other hand, the journals that publish the most on the topic Environmental Science and Pollution Research, Renewable Energy, Journal of Environmental Management, Sustainability (Switzerland), Energies and Journal of Cleaner Production, concentrate 34% of the publications, the rest of the publications is disseminated among different journals. In turn, the most productive authors are Adebayo TS, Kirikkaleli D and Ahmad M, each with eleven or more articles; this taking into account that 85% of researchers in this field are transitory. It is then concluded that the search carried out shows considerable growth and the participation of more and more authors in more parts of the world; which could be related to a future development of new technologies that are increasingly effective in the search for the total

replacement of non-renewable energies by sustainable energy generation and use systems.

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