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Review

Analyzing the Role of Renewable Energy in Meeting the Sustainable Development Goals: A Bibliometric Analysis

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Abstract: Academic contributions regarding the Sustainable Development Goals (SDGs) and renewable energy have been steadily increasing, given their essential relevance to economic, societal, and environmental progress. This research aims to examine the structure of scientific knowledge on the connection between SDGs and renewable energy by utilizing bibliometric methods and analyzing 3132 articles published between 1992 and 2022. Results indicate a sharp rise in the production rate since 2015, Environmental Sciences as the most prevalent area of study, and the leading role of publishers Elsevier, MDPI, and Springer in the publication of papers related to the subject. Consequently, this research may prove useful for both novice and veteran researchers who wish to further their understanding of the academic production regarding the SDGs and renewable energy.

Keywords: sustainable development goals; renewable energies; bibliometric analysis; VOSViewer; Web of Science

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1. Introduction

The Sustainable Development Goals (SDGs) can be a key tool to boost renewable energy development [1]. Indeed, Goal 7 of the SDGs focuses on ensuring access to affordable, safe, sustainable and modern energy for all [2]. This means that countries, companies, and individuals are committed to promoting the development of renewable energy, such as solar, wind, and hydropower [3]. These goals were established in 2015 by the United Nations (UN) and set out an agenda for global action to promote peace, sustainable development, and social justice [4]. These goals are based on the principles of equality, equity, and shared responsibility, based on respect for human rights, environmental protection, and the fight against climate change [5].

In today's free market paradigm, companies are able to have a significant impact on environmental, social, and financial systems, often on a global scale [6]. After the Rio Earth Summit in 1992, several efforts were made to help organizations become more sustainable, both on a theoretical and practical level [7]. In this context, concepts such as Corporate Sustainability (CS) or Corporate Social Responsibility (CSR) were intensified at the business level and subsequently at the academic level [8–14]. The SDGs offer a singular opportunity for businesses to capitalize upon, consisting of a global set of objectives with governmental, social, and corporate support, all of which can be used to provide a long-term plan of action for the purpose of policy, investment, and innovation. Furthermore, this framework provides a unified language of communication concerning social, environmental, and economic issues, allowing for improved dialogue and coordination [15].

Renewable energy is a clean and sustainable energy source that can be used to meet energy needs [16]. Its use is important as it reduces environmental impacts, contributes to the fight against climate change, provides clean and safe energy, and reduces the cost of electricity production [17]. The use of clean energy contributes to the reduction of carbon dioxide emissions in the atmosphere, which contributes to the fight against climate change [18]. This is largely because renewable energies do not emit greenhouse gases, such as carbon dioxide, when generating electricity [19]. This means that this type of energy generation is an important part of reducing the world's carbon dioxide emissions [20]. Renewable energy offers a host of benefits that can help countries, businesses, and individuals achieve the SDGs [21]. These energy sources are clean, safe, and affordable, which means they can help reduce the harmful environmental impact of burning fossil fuels [22]. Furthermore, these types of energy are an inexhaustible source of energy and do not have to be refueled like fossil fuels. Therefore, the SDGs can be a key tool to boost the development of renewable energies [23].

It is important to explore the linkages between the SDGs and renewable energy because this can help countries improve the quality of life of their populations and achieve sustainable development [24]. Renewable energy can improve SDG adherence in several ways. First, it can help reduce levels of greenhouse gas emissions, thereby contributing to SDG 13 to take action to combat climate change and its effects. This will help achieve SDGs 1 and 2 of eradicating poverty and hunger and improving food security. In addition, renewable energy can contribute to SDG 7 to ensure access to modern, affordable, safe, secure, and sustainable energy services for all, facilitating energy access for people in all parts of the world. Furthermore, the transition to renewables can have a positive impact on employment through the creation of direct and indirect jobs in areas such as infrastructure construction and equipment production. This can contribute to SDG 8 of promoting sustainable economic growth, full and productive employment, and decent work for all.

The critical analysis of the state of the art on SDGs and renewable energies is a highly relevant topic today. This is because the SDGs are a set of universally accepted goals that prioritize environmental protection, human well-being, and social equity [4]. Renewable energy is seen as a promising solution to mitigate climate change and reduce dependence on fossil fuels [7]. Studies on SDGs and renewable energies are constantly evolving, with various researchers trying to better understand the impacts of their implementation, from cost-benefit analysis of different technologies to broader approaches to resource management [18–25].

Studying this connection can help to understand how increased investment in clean, safe, and affordable energy can contribute to reducing the harmful environmental impact of burning fossil fuels, energy security, and poverty reduction [26]. Despite the importance of this relationship, to the best of our knowledge, there are no previous studies that have reviewed SDGs and renewable energy together using bibliometric methods. To fill this research gap, this research conducts a bibliometric analysis to understand the knowledge structure of the academic literature that has addressed the link between the SDGs and renewable energy. Bridging the research gaps in the joint study of the SDGs and renewable energy is important to better understand how the scientific output that has analyzed the contribution of renewable energy to the achievement of the SDGs is structured. This will enable decision-makers to better understand how renewables can help achieve the global goals and how they can be used to address specific problems in areas such as climate change, food security, energy access, and economic development. Similarly, this information will enable policymakers to take more effective actions that contribute to the generation of basic research in the areas of the SDGs and renewable energy and the SDGs.

There are several reasons for the originality of this study. First, it contributes to the body of knowledge concerning the scientific production that has been focused on the study of the SDGs and renewable energies. Notably, few bibliometric reviews have sought to analyze this topic. Secondly, it provides researchers with the means to identify the leading institutions and geographical regions for research stays and/or joint projects on the topic under analysis. Third, it enables academics to create new networks of collaboration between related institutions and to establish contacts with other researchers for the purpose of conducting joint research or organizing conferences. Fourth, it assists authors in identifying the main journals and publishers for disseminating the results of their research. Fifth, it assists authors in having an understanding of the main theoretical references when conducting research, improving the understanding of the field of study, and generating the theoretical underpinning. Sixth, it allows authors to be aware of the multidisciplinary nature of the subject, as well as existing and new research gaps that could help generate new knowledge on the SDGs and renewable energies. Lastly, it highlights the importance of renewable energies for the achievement of the SDGs and, consequently, for economic, social, and environmental well-being.

This research aims to utilize a bibliometric review to gain an understanding of the knowledge structure of the academic literature that has dealt with the relationship between the SDGs and renewable energies. To accomplish the proposed objective, the study is structured in the following manner: after this introduction, Section 2 elaborates on the research gap to be analyzed; Section 3 outlines the methodology used to conduct the bibliometric analysis; Section 4 presents the results; and Section 5 provides the main conclusions, limitations, and potential future lines of research.

2. Literature Reviews in the Field of SDGs and Renewable Energies

The increasing volume of scientific output on the role of renewable energies in meeting the SDGs has necessitated the collection, classification, and analysis of active research fronts in the area. Table 1 presents the publications in journals that review the literature on the topic, listing the authors, journal, objective, type of review, period, and number of articles analyzed. There are only 21 research papers indexed in the WoS core collection that have reviewed the literature, demonstrating the need to progress the state of the art of the discipline. All articles were published in the last four years (2019–2023) and 11 are bibliometric, four are systematic, and the remaining six use both bibliometric and systematic methods.

As can be seen, only Martinho's research [27] establishes the same objective as the one pursued in this research, since the rest, despite addressing the SDG–renewable energies link, focus their analysis on other aspects, such as: green storage [28], electricity grids [29], supply and demand of complementary renewable energy systems [30], awareness of radical changes [31], sustainable development agenda [32], renewable energy technologies [33], green investments [34], renewable energy sources [35], biofuels [36], economic growth and development [37], sustainability [38], energy efficiency [39], transition to clean energy [40], supply chain activities [41], smart city facilities [42], artificial intelligence [43], deep learning models [44], African countries [45], environment [46], and sustainable energy trends [47]. Likewise, of the 21 literature reviews, only seven analyzed more than 1000 documents.

The literature reviews conducted on the topic under investigation have identified several gaps that must be addressed. To begin with, there has been an increasing interest in the role of renewable energy in attaining the SDGs, yet the number of research studies that have reviewed the literature is still low, with only 21 reviews being identified that focus on this goal. Furthermore, only three reviews have included the year 2022 in their review period, necessitating the reviews to be updated up to the present time. In addition, the number of publications examined in each review is mostly fewer than 1000 documents, meaning that a more extensive review of the literature on SDGs and renewable energy is required in order to gain a more comprehensive perspective of the topic. To address these shortcomings, this study aims to conduct a literature review using bibliometric methods, analyzing more than a thousand records, with 2022 being the last year of analysis, with the intention of continuing to expand the knowledge structure of the study of SDGs and renewable energies.

Thus, the originality of this study lies in three main factors. First, the linkage analyzed (SDGs and renewable energies) deserves special attention because its study is necessary to advance the economic, social, and environmental well-being of countries and the people and organizations that comprise them. Second, this section illustrates the scarcity of bibliometric reviews on the subject under study, making its analysis necessary to structure the existing scientific knowledge on the field. Third, the study updates the bibliometric analysis up to the present time, allowing awareness of the new fronts of research on the subject.

Table 1. Reviews indexed in the Web of Science core collection on linking the SDGs and renewable energies.

Authors	Journal	Research Objective	Type of Review	Period Analyzed	Papers Analyzed
Bartolini et al. [28]	*Journal of Cleaner Production*	This paper provides an overview and classification of existing research on green storage and renewable energy within the framework of the SDGs.	Bibliometric and systematic review	2006–2018	38
Hache and Palle [29]	*Energy Policy*	This article studies the integration of variable renewable energy sources into electricity grids with the aim of achieving the SDGs.	Bibliometric analysis	2015–2018	2119
Gan et al. [30]	*Sustainable Futures*	The aim of this paper is to summarize research on the relationship between supply and demand for complementary renewable energy systems within the scope of the SDGs.	Bibliometric and systematic review	1998–2019	473
Ziabina and Pimonenko [31]	*Virtual Economics*	The aim of the article is to analyze the literature to identify public awareness of radical changes in the economic and ecological spheres, with special emphasis on the development of renewable energies to achieve the SDGs.	Bibliometric analysis	1999–2019	337
Belmonte-Ureña et al. [32]	*Ecological Economics*	The study examines current academic research on advancing the sustainable development agenda as expressed in the targets of the SDGs, focusing its analysis on renewable energy.	Bibliometric analysis	1992–2019	3270
Bortoluzzi et al. [33]	*Renewable and Sustainable Energy Reviews*	The aim of this article is to identify patterns in the literature on the use of key performance indicators and multi-criteria decision-making models in the analysis of renewable energy technologies, as well as their contribution to the SDGs set by the United Nations.	Bibliometric analysis	1988–2019	142
Chițimiea et al. [34]	*Sustainability*	The aim of this study is to examine the importance of the implementation of green investments in organizations, including investment in renewable energy, and their contribution to the SDGs.	Bibliometric and systematic review	1990–2020	444
Jabeen [35]	*International Journal of Energy Economics and Policy*	This study aims to analyze the renewable energy sources most examined by researchers over the last decade, as well as their links to the SDGs.	Systematic review	2010–2019	2868
Nazari et al. [36]	*Environment, Development and Sustainability*	The research aims to explore the relationship between biofuels and the SDGs, seeking to present the main challenges, perspectives, and current developments being discussed.	Systematic review	2015–2019	942

Table 1. *Cont.*

Authors	Journal	Research Objective	Type of Review	Period Analyzed	Papers Analyzed
Oliveira and Moutinho [37]	*Energies*	This research aims to provide a systemic review of renewable energy, economic growth, and economic development within the framework of the SDGs.	Systematic and bibliometric review	2008–2021	111
Sanak-Kosmowska and Wiktor [38]	*Energies*	This paper aims to identify media debates on renewable energy sources and their contribution to sustainability and, as a consequence, the SDGs.	Bibliometric analysis	2019–2021	2443
Tang et al. [39]	*Sustainability*	This study aims to present a systematic and bibliographic overview of the literature on improving the energy efficiency of smart city facilities, thereby contributing to the achievement of the SDGs.	Bibliometric analysis	1990–2021	1864
Zhang et al. [40]	*PLOS One*	The research analyzes the transition to clean energy and its link with the achievement of the SDGs.	Bibliometric analysis	2000–2019	2191
Agrawal et al. [41]	*Business Strategy and the Environment*	The research examines the relationship between the SDGs and supply chain activities, as well as their effect on renewable energy deployment.	Bibliometric analysis	2015–2021	144
He et al. [42]	*Sustainable Computing: Informatics and Systems*	This study aims to present a systematic and bibliographic overview of the literature on improving the energy efficiency of smart city facilities, thereby contributing to the achievement of the SDGs.	Bibliometric and systematic review	2017–2022	1370
Martinho [27]	*Environments*	The main objective of this research is to conduct a systematic review of renewable and sustainable energy and its link to the SDGs.	Bibliometric analysis	1990–2021	743
Nikseresht et al. [43]	*Environmental Science and Pollution Research*	This study aims to analyze the effect of artificial intelligence on the SDGs, highlighting the importance of renewable energy.	Bibliometric analysis	2007–2021	534
Ying et al. [44]	*Journal of Cleaner Production*	This article provides a detailed literature and bibliometric review of deep learning models for effective renewable energy forecasting and thus for improving SDG compliance.	Bibliometric and systematic review	2016–2021	276
Gyimah et al. [45]	*Journal of Cleaner Production*	This study aims to systematically review the existing literature on the achievement of the SDGs in African countries, with an emphasis on the role played by renewable energies to this end.	Systematic review	2015–2022	200

Table 1. *Cont.*

Authors	Journal	Research Objective	Type of Review	Period Analyzed	Papers Analyzed
Pestisha et al. [46]	*Energies*	This study provides a comprehensive review of trends in renewable energy, environment, and agricultural publications within the framework of the SDGs.	Systematic review	1988–2022	894
Kemeç and Altınay [47]	*Sustainability*	The study systematically presents publishing trends related to sustainable energy, as well as their link to sustainable development and the SDGs.	Bibliometric analysis	1980–2022	1498

Source: own elaboration.

3. Materials and Methods

The following research offers a bibliometric analysis through the use of the WoS database. For this purpose, Boolean operators, proximity operators and markers were used, using only WoS as it is one of the most restrictive in the acceptance of articles [47], which ensured the quality and rigor of the works analyzed. Specifically, the following indexes from the main WoS collection were utilized: Science Citation Index Expanded (SCI-E), Social Sciences Citation Index (SSCI), and Emerging Sources Citation Index (ESCI).

SCI-E is a multidisciplinary citation index covering scientific and technological journals since 1900, covering more than 8000 scientific journals, as well as 12,000 conference and press journals [47]. SSCI covers more than 3000 social science journals, including press and conference journals [48]. ESCI is a citation index that includes emerging science journals as well as some press and conference journals. It is designed to reflect the diversity of scientific publications, including those from developing countries, covering more than 5000 journals [49].

After determining the use of the WoS core collection, it was necessary to search for papers that were pertinent for the analysis of the topic. Following several attempts to examine the most pertinent results, as well as the least significant ones to eliminate potentially unrelated results, it was concluded that the optimal search equation among those being considered was the following:

TS = (((sustainab* development goal$) AND (renew* energy OR clean* energy OR green* energy)))

It can be observed from the search equation that the search was divided into two groups: SDGs and renewable energies. In order to take into account all possible searching options for these two groups, all potential synonyms of the discussed concepts were examined using the Thesaurus dictionary. In this manner, all terms that could provide relevant results were included. Additionally, the AND operator was utilized, which restricted the valid papers to those that presented results from both groups concurrently [48]. Simultaneously, the wildcard (*) was employed to include possible word variations in the valid results [49]. Finally, it is worth noting that, within the groups, the Boolean operator OR was used when synonyms were involved. Boolean operators are a fundamental tool for conducting a bibliometric review as they allow users to construct complex and specific queries, helping them to gather more relevant information for their research [48]. They can be used, among other purposes, to broaden or narrow the scope of the search to specific topics, publications of certain years or types of documents, allowing researchers to obtain the most relevant results while reducing search time [48]. The parameters were applied to the theme, encompassing the title, abstract, and keywords provided by the author, in addition to the keywords included by WoS itself, until the final full year of 2022.

Following the application of the search algorithm on 25 October 2023, a total of 4330 articles were accepted. The "Preferred Reporting Items for Systematic Reviews and Meta-Analyses" (PRISMA statement) was chosen for the analysis of the scientific output in a sequential manner due to its capacity to enhance the reliability and reproducibility of the reviews, the comprehensive nature of the method, and its pervasiveness in bibliometric studies [50–52]. The PRISMA methodology is a useful tool for improving transparency and communication between authors and readers, helping to ensure that the results presented are reproducible and reliable [50]. Its use is recommended to improve the quality of research studies and readers' understanding of the results, helping to reduce the risk of bias and errors in data collection by allowing information to be collected systematically [51]. The data were filtered to only include articles as the accepted scientific output format and duplicates were removed, resulting in a decrease from 4330 to 3132 documents (see Figure 1).

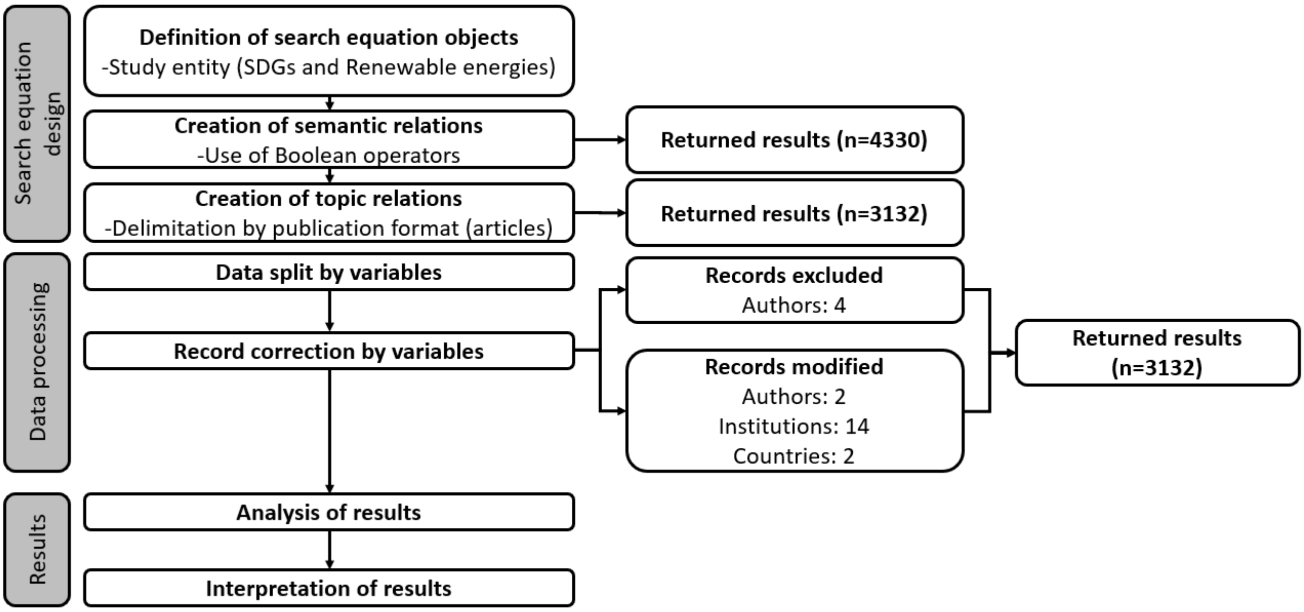


Figure 1. Flow diagram about the bibliometric review procedure developed. Source: own elaboration based on PRISMA guidelines.

Selection of several classificatory variables was made in order to comprehend the knowledge structure of the scientific production studied. In order to determine the interest in the subject over time, the records were divided according to the year of publication in the corresponding journals. This made it possible to observe the time of initial results and the moment when the topic began to garner significant attention, as well as its current state. Additionally, the records were differentiated in accordance with the area or areas of knowledge to which they corresponded. For this purpose, the WoS classification system (known as WoS Categories) was employed. A network map was also generated with the help of the VOSviewer tool in accompaniment to the analysis.

This software application enables the construction and visualization of bibliometric networks [53], which can incorporate journals, researchers, and individual publications, based on citation, bibliographic linkage, co-citation, or co-authorship relationships [54]. The authors of the records were identified, and their influence in the field was evaluated by number of publications and citations. Additionally, a bibliographic coupling map was generated with the VOSviewer application to analyze the connections between the authors. Furthermore, the institutions (known in WoS as affiliations) associated with the authors were examined. Lastly, the main journals, volume of records, publisher, and geographic classification by countries and regions of scientific production were analyzed.

For the generation of bibliometric maps, keyword co-occurrence analysis and bibliographic linkage by country and author were used. Keyword co-occurrence analysis is a useful tool to identify emerging themes and patterns in the literature. This can help researchers to better understand the topics that are related to a specific research topic and help them identify new areas of research, as well as provide an overview of the current state of research and allow researchers to establish new lines of research [54]. On the other hand, bibliographic linkage analysis, both by authors and by institutions, is a useful tool to analyze the links between documents published by the same author or a group of authors. This tool helps to identify the number of collaborations between authors and the direction in which research is developing, provides an overview of the patterns of collaboration between authors and the related topics they are researching, and allows the researcher to identify the main contributors to the field of study and to determine whether there are topics that require further investigation [53].

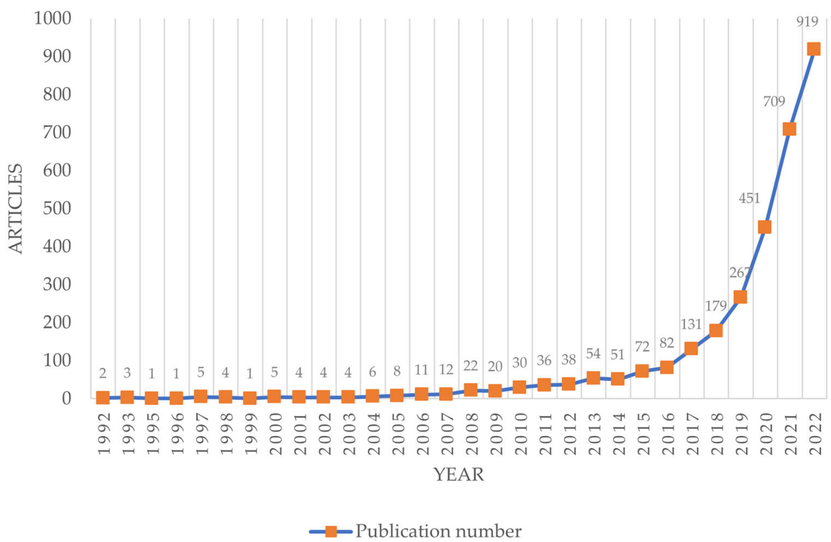
There are different motivations for conducting a bibliometric review, as opposed to a narrative and systematic review. These include: (1) a bibliometric review can provide a broader and more generalized view of the topic, as it is based on a wide range of published materials; (2) it allows to identify trends in a field of research, detect areas of interest, and establish relationships between different papers and authors; (3) it provides an objective assessment of the research conducted in a particular field and can be useful to establish priorities for future research; (4) it studies the evolution of a topic through a follow-up of the publication of papers in a particular field; (5) it reduces the time required to perform a manual literature review; (6) improves coherence and consistency when evaluating scholarly output; (7) a bibliometric review provides an idea of the importance of a topic with a visual representation of published articles; (8) it helps to visualize the structure and connection of the available literature on a given topic; (9) it offers a quick and easy way to check citations and references for all articles related to a topic; (10) it can help researchers identify and evaluate works published by an author or a group of authors [53].

4. Results and Discussion

Scientific production related to the SDGs and renewable energies began to intensify from 2015. This is evidenced by a 1176.38% increase in articles from 2015 to 2022, going from 72 to 919 (see Scheme 1). This is attributed to the United Nations' approval of the SDGs in 2015, which marked the beginning of research centered on sustainability with the SDGs as its framework [55].

Nevertheless, as depicted in Scheme 1, although the SDGs were adopted in 2015, the historical series of scientific production analyzed commences in 1992. This is due to the UN Conference on Environment and Development which took place in Rio de Janeiro, which had already begun to discuss the concept of devising a prospective Agenda 21 to address the issues that the planet would face in the 21st century, with a particular emphasis on the significance of fostering renewable energy [56].

It should be duly noted that there was a moderate augmentation in the production of scientific output in the latter half of the opening decade of the 21st century, leading to exponential growth up to the present day. This can be attributed to two primary factors. In 2000, the Millennium Summit saw the establishment of the MDGs, thereby forming a foundational blueprint for bettering economic, social, and environmental sustainability with the implementation of targets [57]. Subsequently, in 2012, the United Nations launched the SD21 project, with the intention of furthering the cause of sustainable development in the modern century, wherein renewable energy plays an essential role in realizing this objective [58].



Scheme 1. Scientific production analyzed by year of publication. Source: own elaboration based on WoS.

Regarding the distribution of scientific output by research field, Table 2 shows that the top ten fields in terms of scientific output on SDGs and renewable energy are Environmental Science (1157), Sustainable Science and Technology (923), Energy Fuels (811), Environmental Studies (614), Environmental Engineering (283), Economics (209), Chemical Engineering (118), Thermodynamics (90), Regional Urban Planning (79), and Management (78). This reflects the fact that the literature analyzed is mainly in environmental, energy, and business management studies.

This highlights the multidisciplinary nature of the study of the SDGs and renewable energy, since, among other aspects, the literature reviewed can improve the understanding of the possible aspects that can enhance the environment (Environmental Sciences, Environmental Studies, and Development Studies) the diversification of energy sources at the country, organizational, and personal levels (Energy Fuels, Engineering Environmental, and Engineering Multidisciplinary), or the improvement of profitability and business productivity (Economics, Management, and Business). Furthermore, some of these research fields exhibit a considerable capacity to expand upon the knowledge of the research topic addressed in this paper. For instance, those areas focusing on the field of geography and urban studies can aid in enhancing knowledge regarding regions where renewable energy can be pursued, while simultaneously facilitating financial prosperity and encouraging the realization of the SDGs.

A keyword co-occurrence analysis was conducted in order to supplement the analysis of the correlation between the Sustainable Development Goal (SDG) field and renewable energy, as well as other fields. This analysis allowed us to recognize the affiliations between keywords, as demonstrated by their adjacency on the map in Figure 2. As can be seen, the main keywords used in the scientific production analyzed, apart from SDGs and renewable energies, are sustainable development and sustainability (these being two approaches under which to study the field of SDGs and renewable energies), economic growth (the economic dimension being one of the three on which the SDGs are based), and CO_2 emissions (the reduction of CO_2 emissions being one of the main objectives of renewable energies).

Table 2. Number of results by research fields (Top-30).

Nº	WoS Categories	Records	Nº	WoS Categories	Records
1	Environmental Sciences	1157	16	Ecology	55
2	Green Sustainable Science Technology	923	17	Multidisciplinary Sciences	52
3	Energy Fuels	811	18	Materials Science Multidisciplinary	50
4	Environmental Studies	614	19	Meteorology Atmospheric Sciences	50
5	Engineering Environmental	283	20	Engineering Multidisciplinary	49
6	Economics	209	21	Engineering Electrical Electronic	47
7	Engineering Chemical	118	22	Biotechnology Applied Microbiology	44
8	Thermodynamics	90	23	Water Resources	42
9	Regional Urban Planning	79	24	Public Environmental Occupational Health	40
10	Management	78	25	Urban Studies	40
11	Business	76	26	Geography	38
12	Construction Building Technology	74	27	Chemistry Physical	36
13	Engineering Civil	60	28	Public Administration	31
14	Development Studies	56	29	Social Sciences Interdisciplinary	31
15	Chemistry Multidisciplinary	55	30	Geosciences Multidisciplinary	29

Source: own elaboration based on WoS.

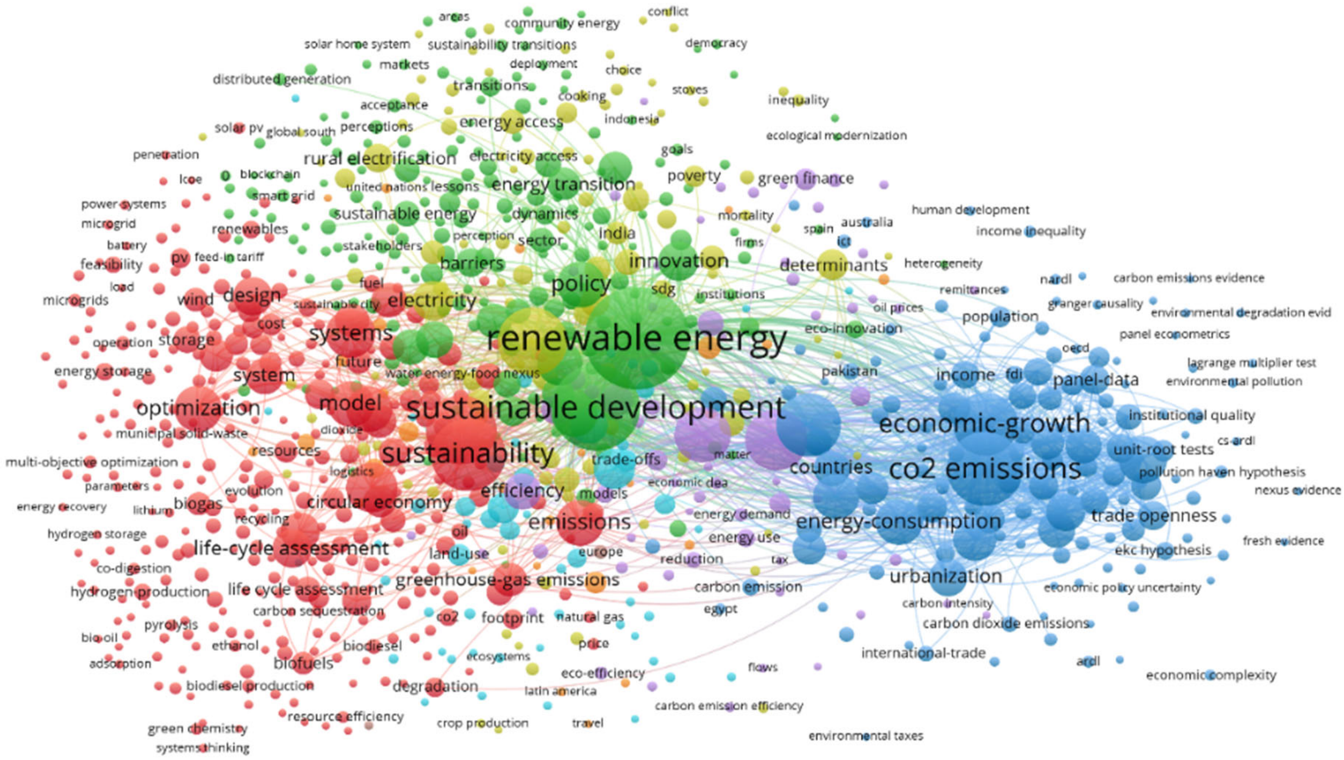


Figure 2. Network map on the co-occurrence of keywords. For practical reasons, we have included those keywords that appear at least 5 times in the records considered. The size of the nodes is proportional to the number of times the keyword appears. Source: elaborated on the basis of WoS and VOSviewer.

The results of Table 3 indicate that Festus Victor Bekun is the main author researching the analyzed topic, with 28 records. This is followed by Andrew Alola (24 records), Avik Sinha (22 records), Muntasir Murshed (17 records), Mahmood Ah-mad (16 records), and Umer Shahzad (15 records). A difference of 21 articles is evident between the first author and the 30th author, Samuel Asumadu Sarkodie (1570), Andrew Alola (1502), and Festus Victor Bekun (1339). Furthermore, it is evident that seven of the top 30 authors are affiliated with Chinese organisations, six to Turkish institutions, and three to Cypriot ones.

Although the content of Table 3 reflects the main authors in the field, it is also necessary to look at the relationships between them in order to understand their influence on the development of the analyzed field. To this end, Figure 3 shows an author-based bibliographic linkage analysis. Bibliographic coupling is a measure of similarity that uses citation analysis to establish a similarity relationship between documents [59]. It occurs when two works reference a common third work in their bibliographies [60]. According to the linkage analysis, Festus Victor Bekun, Andrew Alol, Avik Sinha, Muntasir Murshed, Umer Shahzad, and Khalid Zaman appear as the most influential in the research area analyzed by having the highest proportion of linkage among the literature analyzed. This is in line with the results in Table 3, as they are the authors with the highest scientific production in this area.

Table 3. Number of records, citations, work impact, and affiliation country for each main author (Top-30).

Author	Registers	Citations	Ratio	Institution	Country
Festus Victor Bekun	28	1339	47.8%	Istanbul Gelisim University	Turkey
Andrew Alola	24	1502	62.6%	University of Vaasa	Finland
Avik Sinha	22	1170	53.2%	Goa Institute Of Management	India
Muntasir Murshed	17	442	26.0%	North South University	Bangladesh
Mahmood Ahmad	16	467	29.2%	Shandong University of Technology	China
Umer Shahzad	15	460	30.7%	Anhui University of Finance & Economics	China
Tomiwa Sunday Adebayo	14	316	22.6%	Cyprus International University	Cyprus
Bright Akwasi Gyamfi	14	213	15.2%	Istanbul Ticaret University	Turkey
DaliaStreimikiene	14	304	21.7%	Lithuanian Energy Institute	Lithuania
Dervis Kirikkaleli	12	436	36.3%	European University of Lefke	Cyprus
Khalid Zaman	12	161	13.4%	Hazara University	Pakistan
Samuel Asumadu Sarkodie	11	1570	142.7%	Nord University	Norway
Edmund Ntom Udemba	11	80	7.3%	Istanbul Gelisim University	Turkey
Zahoor Ahmed	10	212	21.2%	Cyprus International University	Cyprus
Abdelmohsen Nassani	10	146	14.6%	King Saud University	Saudi Arabia
Rafael Alvarado	9	395	43.9%	Universidad Nacional de Loja	Ecuador
Muhammad Khalid Anser	9	197	21.9%	Xi'an University of Architecture and Technology	China
Ahsan Anwar	9	268	29.8%	ILMA University	Pakistan
Tomas Balezentisç	9	208	23.1%	Lithuanian Institute of Agrarian Economics	Lithuania
Buhari Dogan	9	333	37.0%	Suleyman Demirel University	Turkey
Yong Liu	9	113	12.6%	Beijing University of Chemical Technology	China
Yang Zhang	9	118	13.1%	Hunan University of Technology & Business	China
Mehmet Altuntas	8	159	19.9%	Nisantasi University	Turkey
Sinan Erdogan	8	163	20.4%	Mustafa Kemal University	Turkey
Yao Li	8	45	5.6%	University of Electronic Science & Technology of China	China
Haider Mahmood	8	168	21.0%	Prince Sattam Bin Abdulaziz University	Saudi Arabia
Arshian Sharif	8	396	49.5%	Sunway University	Malaysia
Farhad Taghizadeh-hesary	8	401	50.1%	Tokai University	Japan
Syed Ahtsham Ali	7	38	5.4%	Shanghai Jianqiao University	China
Raja Jayaraman	7	123	17.6%	Khalifa University	United Arab Emirates

Source: elaborated on the basis of WoS.

With regard to the main institutions that support research on SDGs and renewable energy, Table 4 reveals that the Chinese Academy of Sciences is the leader in terms of the number of articles with 62 articles, followed by Istanbul Gelisim University (50 articles), the Egyptian Knowledge Bank Ekb, and the Indian Institute of Technology System Iit System (both with 49 articles). Additionally, China is the nation with the highest number of institutions in the top 30 for scientific production on the subject, which is consistent with the results seen in Table 3, given that the country has the most academics on the topic of this study. Moreover, it is noteworthy to emphasize the role of the United States, United Kingdom, and the Netherlands, each of which has two institutions. This analysis is supplemented by the study of bibliographic coupling by institutions shown in Figure 4, where it is observed that the two main nodes and therefore the two main institutions by bibliographic coupling are the Chinese Academy of Sciences and Istanbul Gelisim University, both of which have the largest scientific production on SDGs and renewable energies.

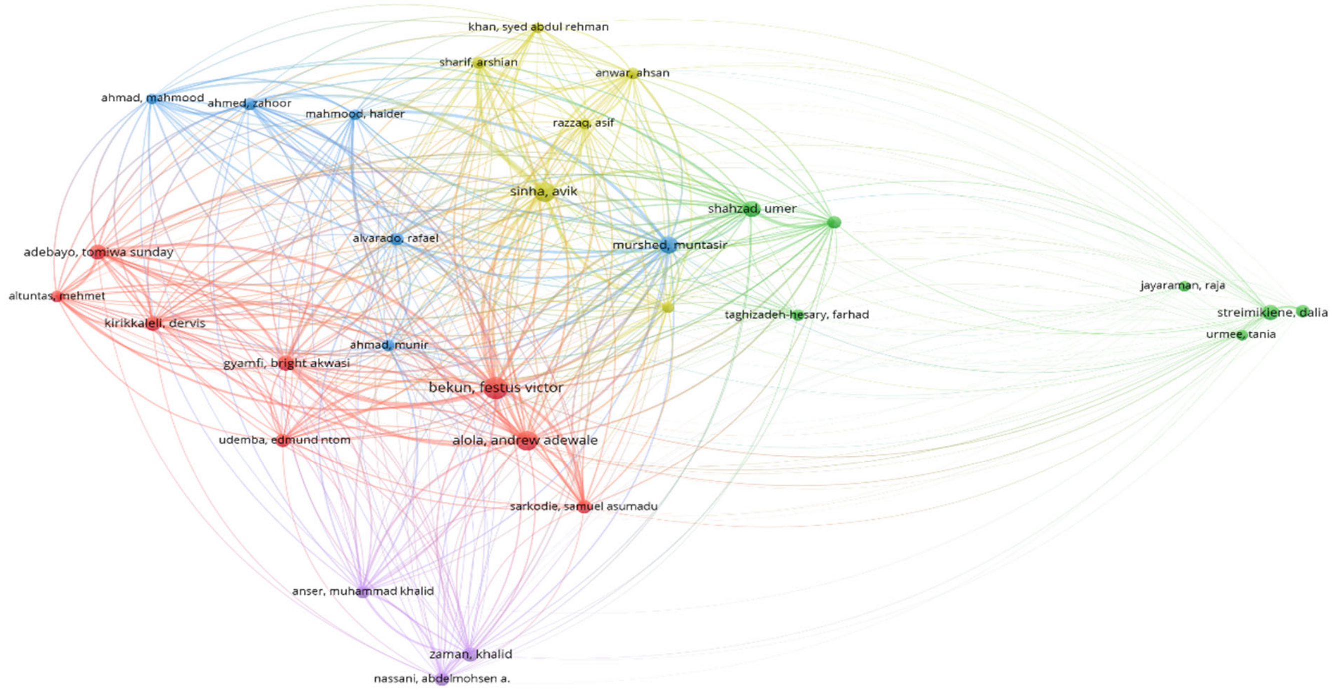


Figure 3. A bibliographic linkage map by authors with at least 30 citations using citation analysis software VOSviewer. Source: elaborated on the basis of WoS and VOSviewer.

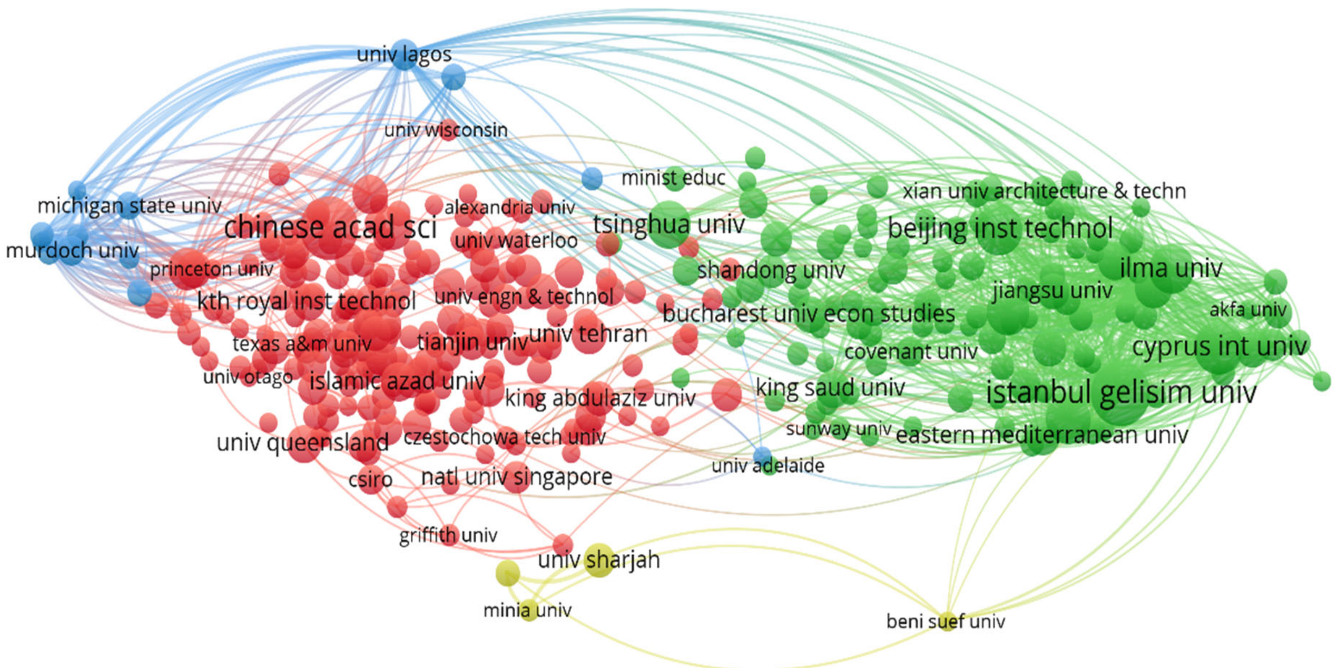


Figure 4. Bibliographic linkage map by authors with at least 30 citations. Source: elaborated on the basis of WoS and VOSviewer.

Table 4. Institutions by number of records and region (Top-30).

Institutions	Records	Region
Chinese Academy of Sciences	62	China
Istanbul Gelisim University	50	Turkey
Egyptian Knowledge Bank Ekb	49	Egypt
Indian Institute of Technology System Iit System	49	India
Cyprus International University	35	Cyprus
Beijing Institute of Technology	32	China
Ilma University	30	Pakistan
Tsinghua University	30	China
South Ural State University	29	Rusia
International Institute for Applied Systems Analysis Iiasa	28	Austria
Ministry of Education Science of Ukraine	28	Ukraine
University of London	28	United Kingdom
Anhui University of Finance Economics	27	China
University of California System	27	United States
Helmholtz Association	26	Germany
Royal Institute of Technology	25	Sweden
Utrecht University	25	The Netherlands
Islamic Azad University	23	Iran
Norwegian University of Science Technology Ntnu	23	Norway
University of Chinese Academy of Sciences Cas	23	China
Bucharest University of Economic Studies	22	Romania
GOA Institute of Management	21	India
United States Department of Energy	21	United States
Beijing Normal University	19	Norway
King Saud University	19	Saudi Arabia
State University System of Florida	19	United States
Universiti Teknologi Malaysia	19	Malaysia
University College London	19	United Kingdom
University of Tehran	19	Iran
Wageningen University Research	19	The Netherlands

Source: Own elaboration based on WoS.

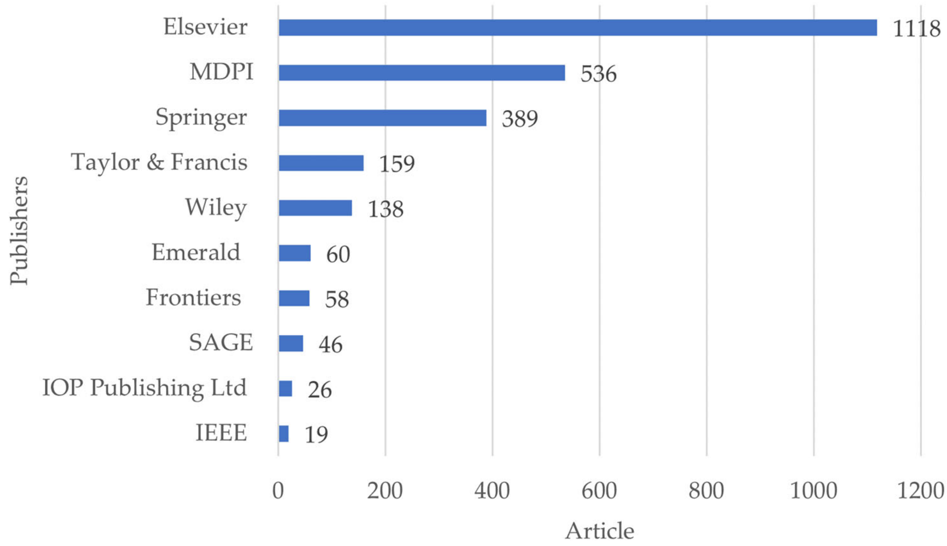
Regarding the main journals that disseminate research results, Table 5 shows that *Sustainability* is the leader with 262 publications, followed by the *Journal of Cleaner Production* (181) and *Energies* (167). It is noteworthy that the top 30 journals have a Journal Impact Factor (JIF), which is a measure used to assess journals that are considered to have sufficient quality and research impact [61,62]. Of these, 20 are in the first quartile of their respective categories, while eight are in the second quartile, indicating they are in the top 25% and 50% of the journals deemed to have sufficient quality and impact, which are mostly specialized in environmental research and, to a lesser extent, business studies. Scheme 2 demonstrates that Elsevier is the most prominent publisher in terms of academic publications, with 1118 publications, followed by MDPI (536), Springer (389), Taylor & Francis (159), and Wiley (138).

Table 5. List of journals by number of records (Top-30) and their 2021 Journal Impact Factor (JIF) quartile.

Journals	Records	Highest 2021 JIF Quartile	Publishing Houses
Sustainability	262	Q2	MDPI
Journal of Cleaner Production	181	Q1	Elsevier
Energies	167	Q3	MDPI
Environmental Science and Pollution Research	134	Q2	Springer
Energy Policy	82	Q1	Elsevier
Renewable Energy	74	Q1	Elsevier
Renewable Sustainable Energy Reviews	59	Q1	Elsevier
Energy	51	Q1	Elsevier
Applied Energy	50	Q1	Elsevier
Science of the Total Environment	41	Q1	Elsevier
Frontiers in Environmental Science	36	Q2	Frontiers
Journal of Environmental Management	34	Q1	Elsevier
Energy Reports	31	Q2	Elsevier
Energy Research Social Science	31	Q1	Elsevier
Environment Development and Sustainability	30	Q2	Springer
Environmental Research Letters	25	Q1	IOP Publishing
Sustainable Cities and Society	25	Q1	Elsevier
Energy Environment	21	Q3	SAGE
Sustainable Development	21	Q1	Wiley
Technological Forecasting and Social Change	21	Q1	Elsevier
Energy for Sustainable Development	20	Q2	Elsevier
International Journal of Sustainable Development and World Ecology	19	Q1	Taylor & Francis
Climate Policy	18	Q1	Taylor & Francis
International Journal of Environmental Research and Public Health	17	Q1	MDPI
Resources Policy	17	Q1	Elsevier
Applied Sciences Basel	16	Q2	MDPI
Clean Technologies and Environmental Policy	16	Q2	Springer
Energy Conversion and Management	16	Q1	Elsevier
Resources Conservation and Recycling	16	Q1	Elsevier
Energy Strategy Reviews	15	Q1	Elsevier

Source: Own elaboration based on WoS.

As for the geographical distribution of the scientific production analyzed, Figure 5 shows that China is the country with the largest contribution in terms of number of papers. A total of 677 publications are related to North American institutions, followed by the United States with 362 and the United Kingdom with 255. In fact, these three countries account for 23.76% of all existing scientific production on the subject. The role of India (227), Germany (217), and Turkey (193) also stands out in terms of scientific production, occupying fourth, fifth, and sixth place, respectively.



Scheme 2. Top publishers by number of publications. Source: Own elaboration based on WoS.

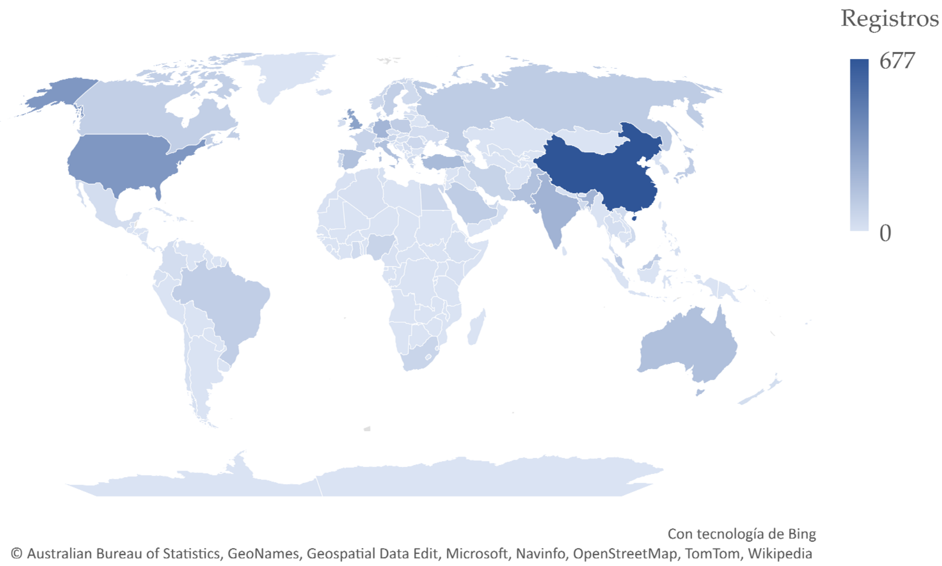


Figure 5. Number of records by countries. Source: Own elaboration based on WoS.

This research advances the study of the knowledge structure of the SDGs and renewable energies. First, despite the growing interest in the role of renewable energy in achieving the SDGs, the number of research studies that have reviewed the literature remains low, as only 21 reviews addressing this objective have been identified [28–47]. This highlights the importance of continuing to review the academic literature on the topic. Second, only three reviews include the year 2022 in their review period [42,45,46], so the present study aims to contribute to updating the literature reviews on the subject. Third, the number of publications analyzed in each review is mostly less than 1000 documents, with only one review with more than 3000 records [32], so it is necessary to review the literature on SDGs and renewable energies more broadly to obtain a more complete view of the subject. Through the present research, it is possible to analyze a vast amount of scientific production on the topic under analysis, exceeding the 3000 records analyzed.

5. Conclusions

This research allows to analyze the structure of knowledge on the study of the SDGs and renewable energies, and is therefore useful both for experienced academics in the field and for those who want to start researching the link between the two topics, as well as to know the evolution over time of scientific production on the subject analyzed.

Academics and practitioners can benefit from studying the link between renewable energy and the SDGs. The knowledge gained through studying this area will enable them to become more aware of the challenges the world faces in achieving the SDGs, while also helping them to better understand how renewable energy can contribute to the achievement of these goals. This means that they will also be able to apply these ideas and knowledge in their work and contribute significantly to the development of solutions to global problems.

SDGs most closely linked to renewable energy are Goal 7 (Ensure universal access to affordable, reliable, and modern energy servers) and Goal 13 (Take urgent action to combat climate change and its impacts). This linkage is due to the fact that the use of renewable energy sources is an effective way to reduce greenhouse gas emissions and mitigate climate change. The implementation of the SDGs can be seen as an optimal way to encourage the use of renewable energy. This can be achieved through the promotion of alternative energy projects, such as solar and wind energy, which are a good way to ensure that energy is produced in a clean and sustainable way. Investments in clean technologies, such as energy storage batteries and electric vehicles, should also be promoted, as they help to ensure that energy resources are used efficiently. In addition, governments should incentivize the use of renewable energy through subsidy schemes, reduced taxes, and education programmes for sustainable energy use. These incentives will help reduce the cost of renewable energy, which will make it more accessible to all, as well as promote research and development of new technologies to improve the efficiency and production of renewable energy sources.

A review of the academic literature that has examined the SDGs and renewable energy together is useful to help better understand the relationship between the two concepts. This is important to help decision-makers understand how renewable energy can contribute to the achievement of the SDGs, as well as to identify current challenges and opportunities in implementing renewable energy to improve energy access, reduce greenhouse gas emissions, and promote sustainability. This review of the academic literature on SDGs and renewable energy can also help to develop effective strategies for the energy transition to sustainability, identify regulatory and financial barriers to renewable energy deployment, determine the effects of renewable energy deployment on energy markets, the local economy, and everyday life, and serve as a starting point for developing local and regional action plans and global strategies to achieve the SDGs.

The research concludes that scientific production linked to the SDGs and renewable energies began to intensify from 2015, experiencing exponential growth until the last year analyzed (2022). One of the main reasons for the exponential growth of the academic literature analyzed since 2015 is the Paris Agreement. The Paris Agreement was signed in 2015 and is the first international agreement that obliges countries to reduce their greenhouse gas emissions. This obligation has driven interest in the search for clean and sustainable energy solutions globally. Other reasons include the growing concern about climate change, the urgency to accelerate the transition to clean energy, or the need to improve energy access for developing countries. These issues have attracted the attention of academics and experts from around the world, which has led to a significant increase in the academic research studied in this bibliometric review.

As for the distribution of scientific production by research field, the study shows that the top ten research fields in which scientific production on SDGs and renewable energies is framed are Environmental Sciences, Sustainable Science and Technology, and Energy Fuels. In terms of the main authors researching the topic analyzed, the bibliometric review shows that the main author is Festus Victor Bekun, followed by Andrew Alola, Avik Sinha, and Muntasir Murshed. Concerning the country of the institutions to which the top authors on the studied topic belong, it should be noted that seven researchers are affiliated with Chinese organizations, six with Turkish institutions, and three with Cypriot ones.

From these results stems China's interest in researching and developing renewable energy. China has ratified the SDGs, and is committed to reducing its greenhouse gas emissions by 2030. The Chinese government is investing in research on renewable energy and the SDGs to develop efficient and sustainable technologies. This has motivated Chinese academics to research and develop new solutions in this area. Furthermore, in addition to its commitment to the SDGs, China is also seeking to reduce its dependence on fossil fuels. This means that the Chinese government is looking to develop new ways of obtaining energy, including renewables. Similarly, there is great interest in renewable energy development because of its potential to contribute to the country's energy security and to reduce the cost of energy. Researchers in Turkey and Cyprus are also particularly interested in analyzing the academic literature on renewable energy and SDGs as these issues are directly linked to the economic and social development of both countries. On the one hand, in Turkey, the government has adopted ambitious energy development plans to boost the use of renewable energy in the country, as well as to reduce greenhouse gas emissions. On the other hand, the government of Cyprus has adopted a national policy to increase the use of renewable energy and improve its energy security. These initiatives require in-depth research on renewable energy and SDGs to better understand the challenges and opportunities they face.

Moreover, it should be noted that the main institutions supporting research on SDGs and renewable energy are the Chinese Academy of Sciences, followed by Istanbul Gelisim University, the Egyptian Knowledge Bank Ekb, and the Indian Institute of Iit System. Likewise, in terms of scientific production by country, China is the country with the highest number of institutions in the top 30 in terms of scientific production on the subject analyzed, followed by the United States and the United Kingdom. It is worth noting that the latter two countries are leaders in renewable energy technology, so there is much interest in investigating how renewable energy can be used to meet the SDGs, as well as in identifying how the SDGs and renewable energy can help improve the quality of life of citizens in these countries. As for the main journals that disseminate research results, *Sustainability* (MDPI) has the highest number of contributions, followed by *Journal of Cleaner Production* (Elsevier), and *Energies* (MDPI). These three journals are the leading journals for disseminating research on SDGs and renewable energy because they provide holistic coverage of research related to sustainable development and the SDGs. They specialize in topics related to the environment, sustainability, and renewable energy, such as natural resource management, green infrastructure, renewable energy, and air quality assurance, providing a platform for the publication of high-level scientific articles and serving as a forum for discussion on sustainable development issues. Along the same lines, in terms of the weight of importance of publishers by academic publications, Elsevier ranks first, followed by MDPI, Springer, Talylor & Francis, and Wiley.

Based on the scientific production analyzed, it can be stated that developing countries show the greatest interest in research on renewable energies and the SDGs. This can be explained for different reasons. First, these countries have an urgent need to address the climate crisis, as many of them depend on fossil fuels for energy and are experiencing the negative effects of climate change first-hand. Second, developing countries have limited resources to invest in clean and alternative energy, with research on renewable energy and SDGs in this context being an optimal way to make the best use of available resources. Thirdly, developing countries have the opportunity to become leaders in the fight against climate change. This is because these countries have greater flexibility to experiment with new technologies, allowing them to be at the forefront in the adoption of alternative energies, as well as to contribute significantly to the fight against climate change and help improve the quality of life of their population.

Linking renewable energy with SDGs is an urgent necessity for a better future. The use of renewable energies, such as solar, wind, and hydropower, is one of the main solutions to reduce greenhouse gas emissions. This measure contributes to the fight against climate change and to the reduction of air pollution, while at the same time helping to improve the quality of life of people living in areas affected by pollution. Renewable energies also contribute to improving the energy security of states. These clean sources not only renew themselves quickly, but are also cheaper than the use of fossil fuels. This means that governments can save money on their energy bills, allowing them to invest in education, health, infrastructure, and other essential services. In addition, renewable energies also contribute to job creation. The renewable energy sector requires many people to manufacture and maintain solar panels and wind turbines. This contributes to improving the quality of life of the population, while at the same time helping to reduce inequality. This is why the use of renewable energy is one of the most effective measures to achieve the SDGs. These clean sources contribute to reducing pollution and greenhouse gas emissions, improving the energy security of States, and creating jobs. It is therefore imperative that states adopt measures to boost the use of renewable energies.

The study has a number of theoretical and practical implications. First, the study advances the understanding of the scientific production that has focused its efforts on the study of SDGs and renewable energy. Second, the research can be used by researchers to identify the main institutions and geographical regions for research stays and/or joint projects on the analyzed topic. Third, it allows researchers to establish contacts with other researchers in case they wish to conduct joint research and even organize conferences on the topic under study. Fourth, through this study, academics can identify the main journals and publishers with which to disseminate their research results. Fifth, it enables authors to know the main theoretical references when conducting their research. Sixth, it allows authors to learn about the multidisciplinary and existing gaps in the examined subject matter, as well as to identify new research gaps that allow them to generate new knowledge on the study of SDGs and renewable energies. Research gaps in the study of renewable energy and the SDGs occur in all areas of sustainability, from technological to financial, social, environmental, and governance dimensions. Key research gaps include improving the understanding of the infrastructure needed to address environmental and social challenges, improving the efficiency of resource use, reducing the environmental impact of renewable energy production and consumption, and improving governance for the implementation of renewable energy-related policies and strategies. Seventh, it highlights the importance of renewable energy in achieving the SDGs and, as a consequence, economic, social, and environmental well-being.

This research can help identify policies that promote the link between renewable energies and the SDGs. First, an appropriate regulatory framework should be put in place to encourage investment in renewable energy. This would include adopting national renewable energy targets, guaranteeing long-term revenues for investors, and ensuring reliable market access. Second, fiscal and financial incentives for renewable energy investors, such as tax reductions, low-interest loans, and other financial instruments, should be provided. Third, research and development of renewable energy technologies can be encouraged through subsidies, incentives, and education programs. Fourth, compensation mechanisms could be set up for renewable energy users, such as tariff reductions, rebates, and other incentives. Fifth, support mechanisms for the inclusion of renewable energy in the economy, such as green investment funds and renewable energy funds, should be implemented. Sixth, collaboration between governments, industry, and civil society could be fostered to promote renewable energy and achieve the SDGs. Seventh, programs should be instituted to improve awareness and education on the importance of renewable energy in achieving the SDGs.

Despite the significant contributions of this bibliographic analysis, it has to be pointed out that the study also suffers from certain shortcomings. In this regard, it is worth noting the inherent limitation of bibliographic reviews, given that the scientific production is analyzed quantitatively but the content of the articles is not examined in depth. To overcome this limitation, a systematic review of the literature is suggested as a future line of research in order to identify the objectives, methodologies used, and conclusions of the published scientific output analyzed in this research. Likewise, the SDGs are only one of the possible frameworks for analyzing sustainability. For this reason, as a future line of research, we intend to analyze the link between renewable energies and sustainability, thus broadening the scope of the benefits that can be achieved through this type of energy.

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