International Journal of Sustainable Development and Planning
Vol. 19, No. 2, February, 2024, pp. 457-467
Journal homepage: http://iieta.org/journals/ijsdp

Renewable Energy Research in Africa: A Bibliometric Review (1979-2022)

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https://doi.org/10.18280/ijsdp.190205

Received: 19 October 2023
Revised: 17 January 2024
Accepted: 3 February 2024
Available online: 28 February 2024

Keywords:
Africa, bibliometric research, scientific research African, renewable energy, RStudio, VOSviewer, Scopus database

ABSTRACT

This paper presents a bibliometric analysis of scientific research on renewable energy in Africa, a rapidly growing field driven by the need for sustainable and accessible energy solutions. It highlights Africa's role as a hub for renewable energy innovation, with local researchers collaborating with global institutions to address the continent's unique energy challenges. This synergy is enhancing energy access in African communities and contributing to the global advancement of renewable technologies. The study meticulously examines 3,109 scientific publications from the Scopus database, spanning from 1979 to 2022. It analyzes the evolution, geographical distribution, and impact of these publications, with a focus on international collaborations and scientific output. Findings indicate that South Africa leads in productivity with 962 publications and hosts the top affiliating institutions in this domain. The study also reveals an exponential increase in renewable energy research, particularly from South Africa, the United States, and the United Kingdom, emphasizing the need for more collaborative efforts and knowledge exchange globally. This analysis provides critical insights into the current landscape of renewable energy research and pinpoints areas ripe for further exploration and development in this vital sector.

1. INTRODUCTION

Africa, a continent rich in natural resources and diversity, is becoming a major player in the field of renewable energies [1-4]. African countries face significant energy challenges [5], including limited access to electricity in many regions, excessive dependence on fossil fuels, and the effects of climate change [1]. In this context, renewable energies emerge as a crucial opportunity to address these challenges while fostering economic and social development across the continent [6, 7].

Africa boasts immense potential in renewable energies [2]. With abundant sunlight over much of the continent, photovoltaic solar power stands out as a major energy source. Vast stretches of land also offer opportunities for wind energy, while hydrothermal, geothermal, and biomass resources are being harnessed in various regions [8]. One of the key features of renewable energies in Africa is their ability to provide electricity to remote areas where traditional grids are unavailable [9, 10]. Additionally, increasing investments in the renewable energy sector in Africa are driving technological innovation and creating local employment opportunities [11]. Governments and private enterprises are collaborating to implement policies and incentives aimed at encouraging the deployment of these clean technologies [12, 13]. Renewable energy projects also contribute to reducing greenhouse gas emissions, making Africa a key player in the global fight against climate change [10, 14, 15]. Furthermore, these projects serve as a vital engine for economic development, empowering local communities, and preserving the environment [6, 16].

Through its commitment to renewable energies, Africa is shaping a sustainable energy future for its inhabitants and becoming an inspiring example for the rest of the world [17]. The African continent, rich in natural resources, is not only an exceptional laboratory for innovation in renewable energies but also a fertile ground for exploring sustainable energy models tailored to local needs [15]. Research in this field has the potential to radically transform African energy systems,

creating jobs, stimulating economic development, and improving energy access for millions of people [10-12, 14, 18].

This bibliometric study delves into the complex and dynamic landscape of research on renewable energies in Africa. This bibliometric analysis is based on an in-depth examination of scientific publications extracted from various academic databases between 1979 and 2022. By focusing on scientific research in the field of renewable energies, this study offers valuable insights into the efforts made to promote clean and sustainable energy sources in Africa.

The primary objective of this study is to map trends, developments, and gaps in the scientific and technical literature regarding renewable energies on the continent. It aims to provide essential information to researchers and energy sector stakeholders, guiding strategic decisions, fostering international collaboration, and contributing to the development of effective and informed energy policies. Consequently, it encourages the development of renewable energies by urging researchers to find safe and environmentally friendly alternatives, thus enabling significant progress in this field over the years.

2. BIBLIOMETRIC ANALYSIS AND METHODOLOGY

The Bibliometric methodology is a quantitative and qualitative approach used to analyse scientific production within a specific field [19-22]. It relies on the statistical analysis of academic publications to assess trends, developments, collaborations, and the impact of research in a given domain. In this paper, we utilized bibliometric methods involving computer tools to extract, organize, and analyse bibliographic data. These data encompass information about authors, article titles, journals or conferences where they were published, citations between publications, and other bibliometric metrics, such as citation indices, in the field of renewable energies in Africa.

A research investigation was carried out by examining the title, abstract, and keywords sections of academic papers related to the field of renewable energy in Africa. The search was restricted to papers published between 1979 and 2022. All data retrieved was sourced from the Scopus database and meticulously analyzed using Excel. This analysis aimed to reveal publication patterns, information sources, affiliations, countries, notable phrases, and authors in the specific field of study. Furthermore, specialized software, VOSviewer, was employed to process the data, allowing for the identification of clusters of countries, scientific communities, and prominent keywords. This study, conducted on June 14, 2023, using the Scopus database, examines the progress made in the field of renewable energy in Africa between the years 1979 and 2022. Basic statistical analysis was conducted using Microsoft Excel to assess factors such as the number of records per year. Additionally, bibliometric maps, including co-citation networks and others, were visualized using VOSviewer software. In the initial step of identification, a set of keywords was utilized to search the Scopus database. To locate articles that covered both themes, search terms "Renewable Energy" and "Africa" were used. The search was restricted to the 'title' field of documents and was restricted to the years 1979–2022. The study comprised all document types (review papers, conference papers, book chapters, and original research publications...) written in the English language. On June 14, 2023, 3109 papers and 1134 sources in all were downloaded after filtering to do bibliometric analysis. The comprehensive methodology is depicted in Figure 1.

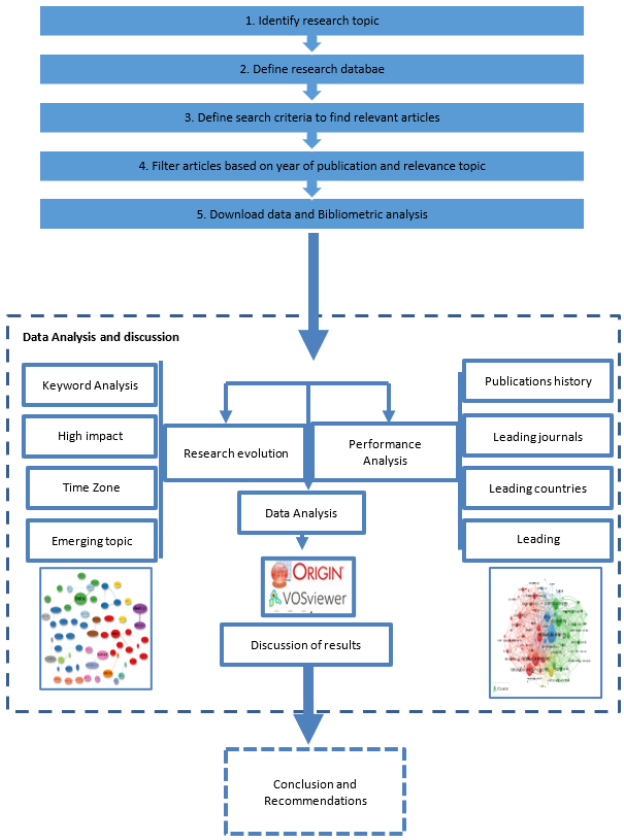

Figure 1. Methodology of work

3. RESULTS AND DISCUSSIONS

3.1 General information

Table 1 highlights the importance of bibliometric research on renewable energy research in Africa, portraying it as a vibrant and continually evolving field of study. The dataset included the publications, which were refined to 3109 publications by focusing on the period from 1979 to 2022. The significant number of sources (1134) and documents (3109) emphasizes its prominence in the field of research. Furthermore, the high annual growth rate of 13.39% suggests sustained interest in this subject.

Table 1. The main information on the survey

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	1979:2022
Sources (Journals, Books, etc.)	1134
Documents	3109
Annual Growth Rate %	13.39
Document Average Age	6.85
Average Citations per Doc	21.89
References	118420
DOCUMENT CONTENTS	
Keywords Plus (ID)	11029
Author's Keywords (DE)	6150
AUTHORS	
Authors	7095
Authors of Single-Authored Docs	548
AUTHORS COLLABORATION	
Single-Authored Docs	638
Co-Authors per Doc	3.04
International Co-Authorships	29.43
DOCUMENT TYPES	
Article	1861
Book	40
Book Chapter	218
Business Article	1
Conference Paper	641
Conference Review	31
Data Paper	4
Editorial	4
Erratum	6
Letter	3
Note	26
Retracted	1

The substantial average citations per document (21.89) underscore the significant impact of research in this field on the scientific community. Additionally, the extensive number of keywords (11029) and authors (7095) associated with a field of research publications reflects the substantial interest and commitment of numerous researchers in this area.

The bibliometric analysis covered various aspects, enabling the measurement of researchers' productivity, identification of key research areas, mapping of collaboration networks and academic institutions, and evaluating the influence of publications within the scientific community.

3.2 Annual growth production

The number of publications per year is an important parameter that reflects the importance of the field and its dynamicity. Figure 2 presents a bibliometric analysis showing the publication trends in publication from 1979 to 2022. The graph demonstrates a steady increase in the number of papers published, rising from 2 in 1979 to 445 in 2022. This upward trend can be attributed to the industry's acknowledgment of the significance of renewable energy research and the growing demand for practical solutions in the field of energy in Africa which boasts immense potential in renewable energies.

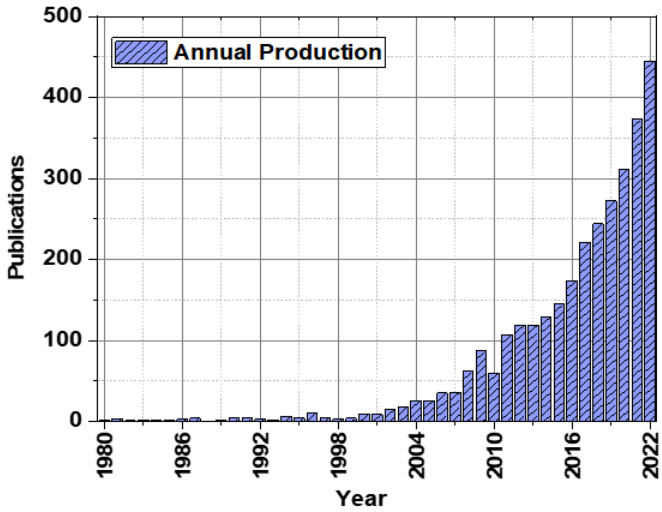

Figure 2. Growth of publications in renewable energy in Africa over the years (1979-2022)

3.3 Most relevant authors

In this section, Table 2 presents the top 10 most prolific authors in the field of this research, based on the number of peer-reviewed publications, utilizing data extracted from Scopus. Notably, authors such as Brent, Kusakana, and Kanzumba, specializing, emerge as highly productive in the area of research with a total production of orders of 37 and 28 respectively.

The table also includes the authors' H index, affiliations, country, and first year of publication. Furthermore, Table 2 indicates that South Africa boasts the highest number of affiliations in Africa concerning research on renewable energy, totaling six affiliations.

Co-citation analysis is a fundamental tool in bibliometrics used to explore the intellectual structure of a field by analysing the co-occurrence of different items. This analytical approach, introduced in 1973, examines how two items from previous academic works are cited together in subsequent publications. Co-citation analysis can be applied to various items such as authors, keywords, or sources.

In this section, author co-citation analysis (ACA) was employed as the basis, focusing on the frequency of co-occurrence among authors. The analysis utilized VOSviewer, setting a minimum threshold of 200 co-citations for an author. Out of 7095 authors, only 51 met this threshold, as depicted in Figure 3. The authors were categorized into four clusters based on their field of study. In the visual representation, the size of the circles indicates the number of co-citations for each author, and the connecting curves signify collaborations between authors. Authors within the same cluster demonstrate stronger collaboration, often sharing publications. The proximity of authors on the map reflects the degree of relatedness in co-citation. It is noteworthy that VOSviewer in co-citation analysis examines the frequency of cited works where an author appears as the first author in publications.

Table 2. List of the most prolific authors in research area extracted from VOSviewer (1979-2022)

Author Rank	Author	Total Productions	H Index	Total Citations	Current Affiliation	Country	Year of 1st Publication
1	Brent, Alan Colin	37	33	4808	Victoria University of Wellington, Wellington, New Zealand	New Zealand	2002
2	Kusakana, Kanzumba	28	28	2705	Central University of Technology, Free State, Bloemfontein, South Africa	South Africa	2008
3	Chowdhury, S. P.	18	22	2451	University Of Cape Town, Cape Town, South Africa	South Africa	2003
4	Mbohwa, Professor Charles	18	27	2807	University Of Johannesburg, Johannesburg, South Africa	South Africa	2002
5	Bekun, Festus Victor	17	55	9244	İstanbul Gelişim Üniversitesi, Istanbul, Turkey	Istanbul, Turkey	2016
6	Davidson, Innocent Ewean	17	17	1502	Durban University of Technology, Durban, South Africa	South Africa	1999
7	Bekker, Bernard	16	56	409	Stellenbosch University, Stellenbosch, South Africa	South Africa	2004
8	Lin, Boqiang	14	91	29023	Xiamen University, Xiamen, China	China	2010
9	Trieb, Franz	14	18	1146	Deutsches Zentrum Für Luft- Und Raumfahrt (DLR), Koln, Germany	Koln, Germany	1994
10	Thango, Bonginkosi A.	13	5	113	University Of Johannesburg, Johannesburg, South Africa	South Africa	2020

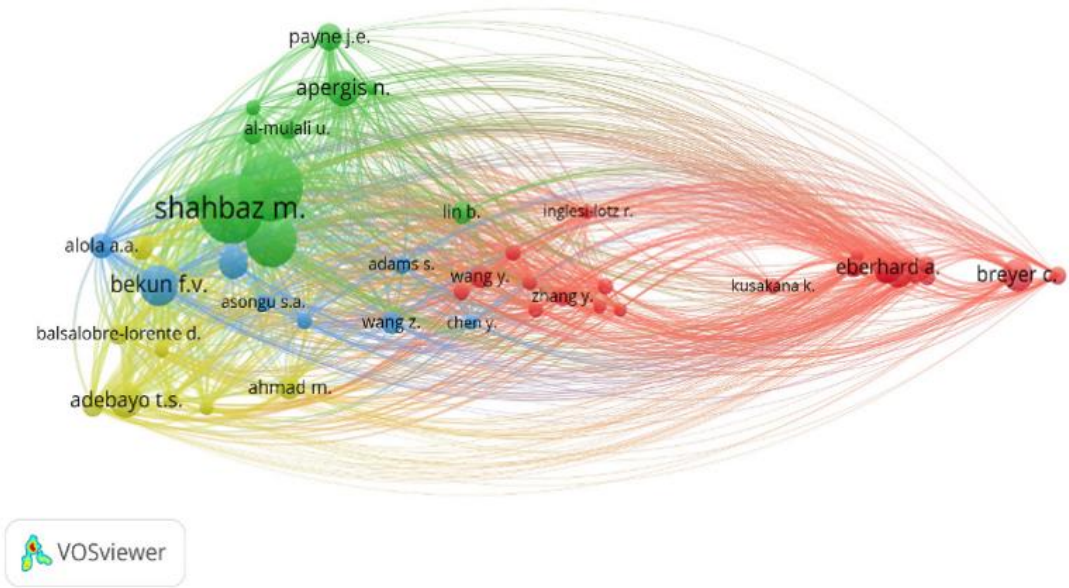

Figure 3. Co-citation map of authors in research area (1979-2022)

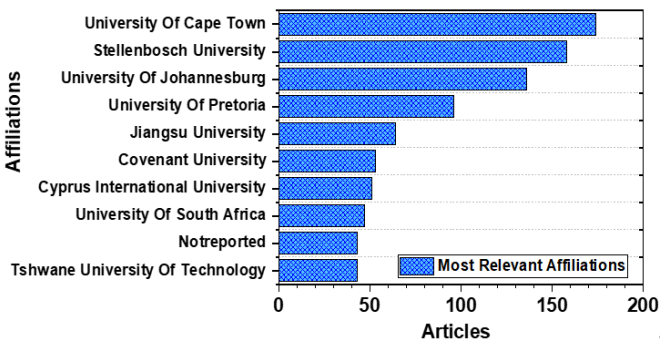

Figure 4. Most productive institutions in the research area (1979- 2022)

3.4 Affiliations analysis

From Scopus records, the analysis focused on the top 10 most productive institutions out of 1134 different ones, based on the number of publications during the period from 1979 to 2022, which are presented in Figure 3. Notably, the leading 10 institutions have contributed significantly, each publishing over 43 articles within this specified timeframe, a noteworthy observation is that a majority of these prolific institutions are located in South Africa.

In this section, we present the most affiliations productive and cited. Figure 4 shows the affiliations with the highest number of published papers in the field of renewable energy in Africa over the period from 1979 to 2022. the figure shows

that the top affiliation is the "University of Cape Town", South Africa with a total of 174 papers, closely followed by "Stellenbosch University of Netherlands" with 158 papers, the top 10 affiliations with 43 articles occupied by "Tshwane University of Technology of South Africa". Figure 5 presents the most cited affiliations, the figure shows that the "faculty of Economics Administrative and Social Sciences Istanbul Gelisim University, Istanbul, Turkey" with 1182 citations and an average citations /paper of order of 59 followed by 'Department of Economics, University of Pretoria, Pretoria, South Africa" with a total and average citations of the order of 55 and 455 respectively.

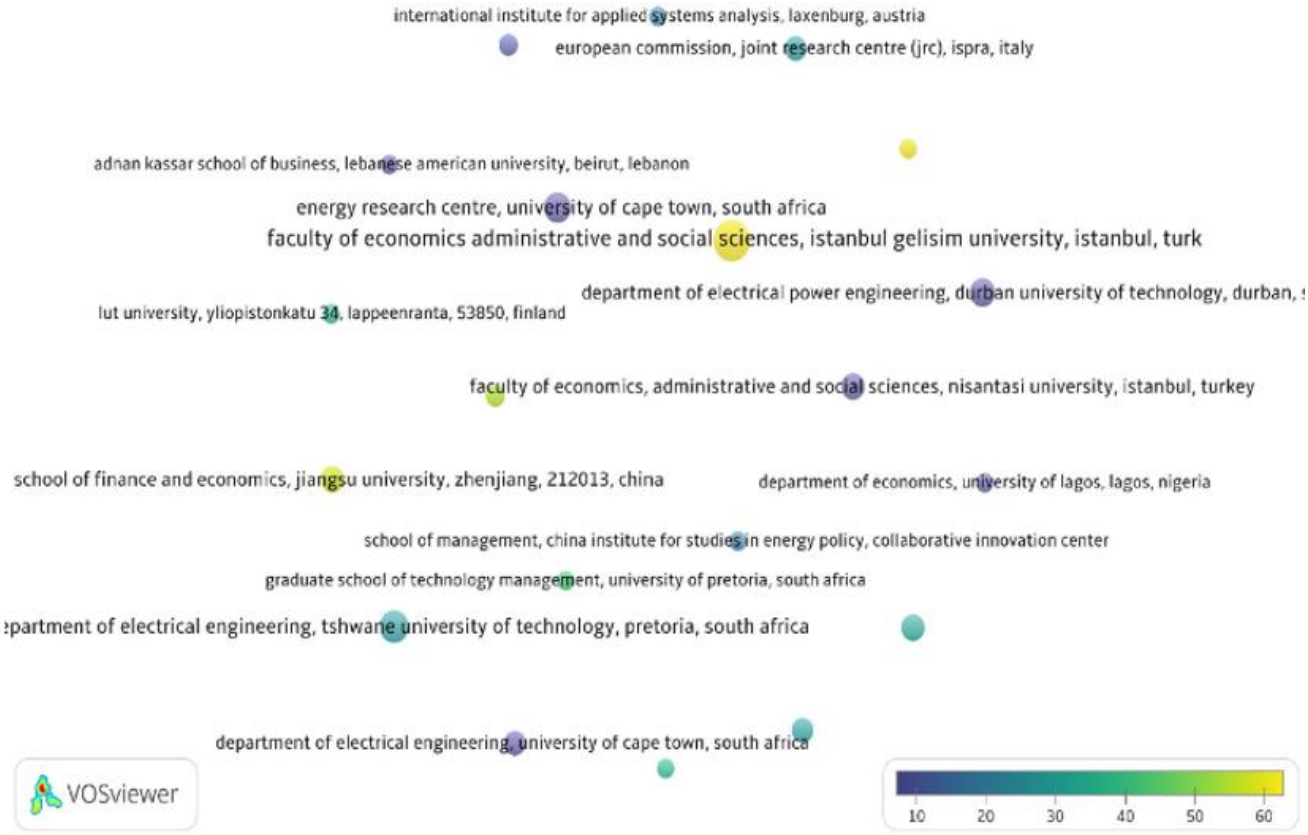

Figure 5. Top 20 most cited institutions in the research area (1979- 2022)

3.5 Countries analysis

Figure 6 and Table 3 illustrate the distribution of articles in the renewable energy field in Africa published by country and number of citations. The mapping presented in Figure 7 shows that South Africa leads with the highest production of papers, boasting 962 articles and a total citation of 11111 followed by the United States and the United Kingdom with respectively a total of documents 361 and 347 and citations of order 7981 and 9456 respectively. This analysis provides insights into each country's research interests and supported areas, directly reflecting their available resources and deficits.

Table 3. Top 10 most cited countries, number of publications and citations (1979-2022)

Rank Country	Country	Documents	Citations
1	SOUTH AFRICA	962	11111
2	USA	361	7981
3	UK	347	9456
4	GERMANY	299	7149
5	CHINA	278	7237
6	NIGERIA	263	5580
7	ITALY	201	3240
8	NETHERLANDS	140	3066
9	TURKEY	137	5373
10	FRANCE	114	2280

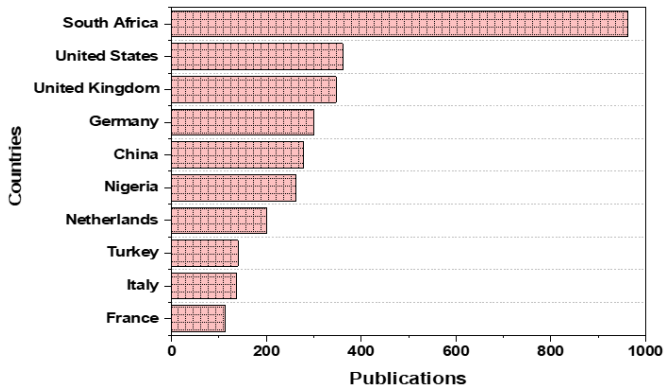

Figure 6. Countries with the highest productivity

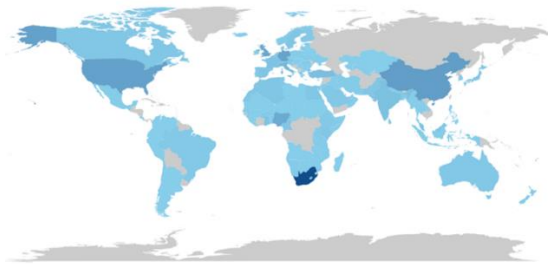

Figure 7. Mapping countries productivity

3.6 Most relevant sources

Figure 8 displays the leading journals in terms of published articles. At the forefront is the "Renewable and Sustainable Energy Reviews" with an impressive 125 articles, followed closely by the " Renewable Energy" with 117 articles and "Energy Policy" with 106 articles. Other noteworthy journals include the "Journal of Energy in Southern Africa," "Energies" "Environmental Science and Pollution Research," and "Sustainability (Switzerland)," which have played crucial roles in advancing research and making significant contributions to this field., publishing 88, 67, 65, and 58 articles respectively. This section also delves into high journal cited, furthermore, ranking papers based on their average citation in descending order was conducted in this section. Focusing on the frequency VOSviewer was utilized for the analysis, employing a minimum threshold of 200 co-citations for each journal, among 1134 sources, only 49 journals met this threshold. In Figure 9 we present the average citation of each journal as depicted in Figure 9 average citation varying between 10 to 60 citations, the journal most cited is " Renewable and Sustainable Energy Reviews" followed by "Renewable Energy" and "Energy Policy".

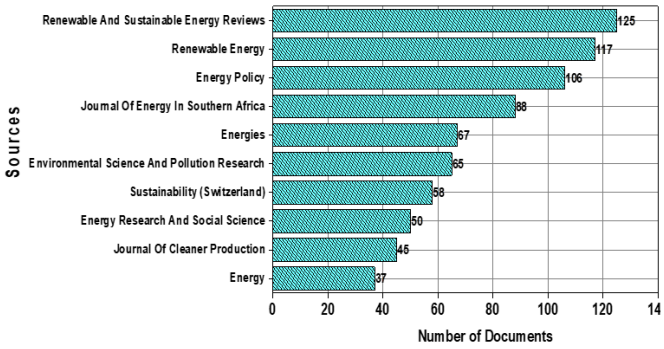

Figure 8. Highest productive journals

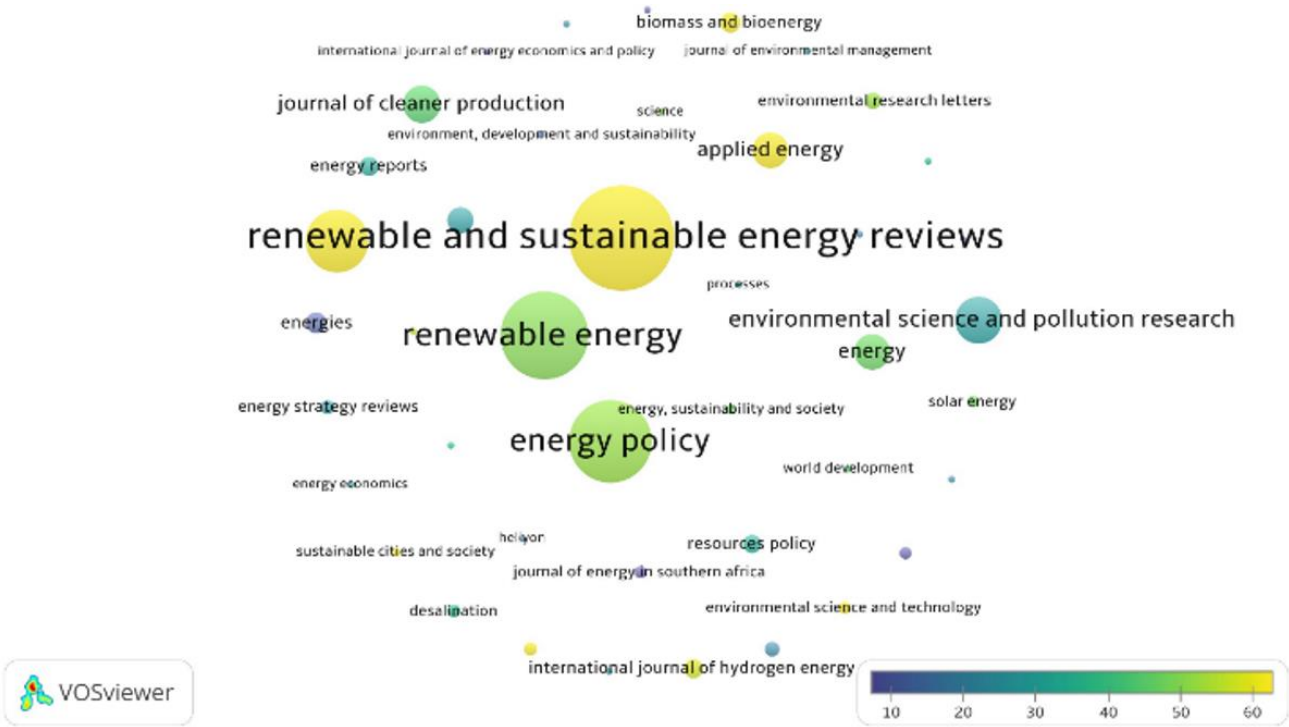

Figure 9. Highest cited journals

3.7 Most relevant documents

Table 4 reveals that the most cited papers in the field of research were published in esteemed journals like ‘’Reviews’’, highlighting the significance of these journals and their ability to attract top researchers and innovative work. However, it's crucial to acknowledge the presence of other high-quality journals in this field, as mentioned in Figure 8. Of special mention is the work by Wanner, Heinz, which has garnered a maximum citation of 1294 citations.

An intriguing observation is that the journal ‘’Science of the Total Environment’’ presents 3 papers of the top 10 most cited papers. Additionally, this section includes the citation graph of the most cited documents. Figure 10 was constructed using VOSviewer which is based on a minimum number of co-citations of authors of 200 citations only 46 authors met the threshold are shown in Figure 10.

3.8 Most relevant keywords

This analysis aids in pinpointing crucial areas of focus within a specific subject. Out of 3109 documents, 110029 keywords were identified. The most commonly occurring keyword was "Renewable Energy," mentioned 685 times, followed by "Renewable Energy Resources" (644), "South Africa" (561), and "Africa" (539). The remaining keywords are detailed in Figures 11 and 12.

Analyzing co-occurrence keywords can unveil the interrelation between research topics, providing insights into relevant and comprehensive research trends. This approach helps identify connections among specific terms, reveal lesser-explored terminology, and shed light on current and emerging themes in energy optimization research. In this study, a total of 11029 keywords, encompassing author keywords and those extracted from the titles and abstracts of 3109 documents, were analyzed.

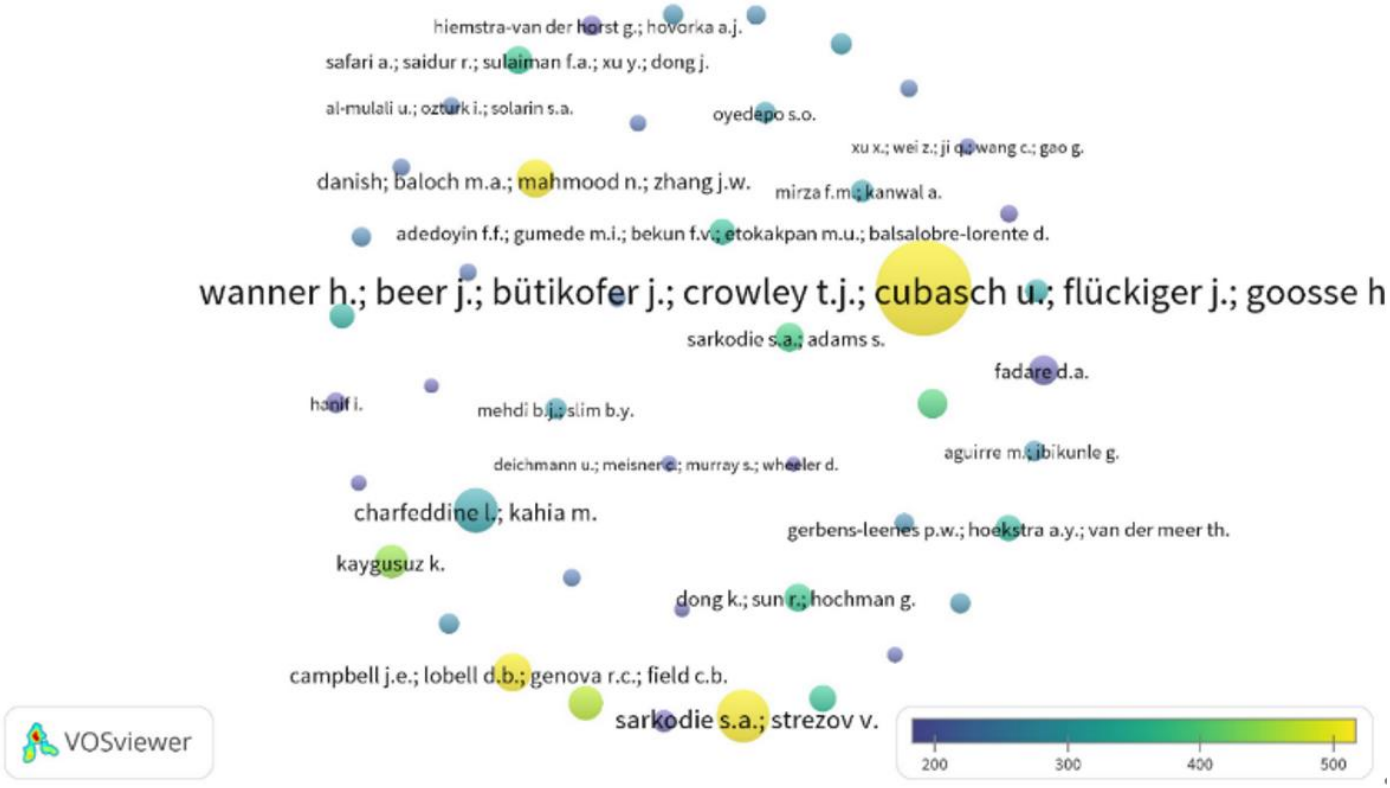

Figure 10. Highest cited authors

Table 4. Most cited documents on the field (1979-2022)

No.	Paper	Source 1979-2022	DOI	Total Citations	TC per Year	Ref
1	Wanner et al. "Mid-to Late Holocene climate change: an overview." Quaternary Science	Reviews 27.19-20 (2008): 1791-1828.	10.1016/j.quascirev.2008.06.013	1294	80.88	[23]
2	Sarkodie and Strezov. "Effect of foreign direct investments, economic development and energy consumption on greenhouse gas emissions in developing countries."	Science of the Total Environment 646 (2019): 862-871.	10.1016/j.scitotenv.2018.07.365	706	141.20	[24]
3	Charfeddine and Kahia. "Impact of renewable energy consumption and financial development on CO_2 emissions and economic growth in the MENA region: a panel vector autoregressive (PVAR) analysis."	Renewable energy 139 (2019): 198-213.	10.1016/j.renene.2019.01.010	568	113.60	[25]
4	Campbell et al. "The global potential of bioenergy on abandoned agriculture lands."	Environmental science & technology 42.15 (2008): 5791-5794.	10.1021/es800052w	504	31.50	[26]
5	Baloch et al. "Effect of natural resources, renewable energy and economic development on CO_2 emissions in BRICS countries."	Science of the Total Environment 678 (2019): 632-638.	10.1016/j.scitotenv.2019.05.028	503	100.60	[27]
6	Giglio et al. "An active-fire based burned area mapping algorithm for the MODIS sensor."	Remote sensing of environment 113.2 (2009): 408-420.	10.1016/j.rse.2008.10.006	456	30.40	[28]
7	Kaygusuz "Energy for sustainable development: A case of developing countries."	Renewable and sustainable energy reviews 16.2 (2012): 1116-1126.	10.1016/j.rser.2011.11.013	438	36.50	[29]
8	Inglesi-Lotz and Dogan. "The role of renewable versus non-renewable energy to the level of CO_2 emissions a panel analysis of sub-Saharan Africa's Big 10 electricity generators."	Renewable Energy 123 (2018): 36-43.	10.1016/j.renene.2018.02.041	392	65.33	[30]
9	Sarkodie and Adams. "Renewable energy, nuclear energy, and environmental pollution: accounting for political institutional quality in South Africa."	Science of the total environment 643 (2018): 1590-1601.	10.1016/j.scitotenv.2018.06.320	382	63.67	[31]
10	Dong et al. "Do natural gas and renewable energy consumption lead to less CO_2 emission? Empirical evidence from a panel of BRICS countries."	Energy 141 (2017): 1466-1478.	10.1016/j.energy.2017.11.092	370	52.86	[32]

Figure 11. Most relevant keywords in research area

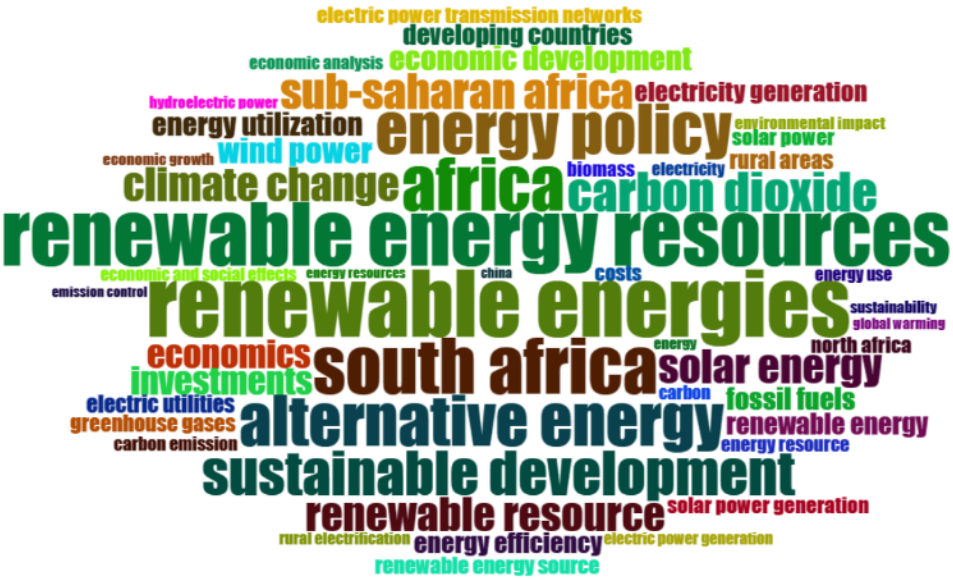

Figure 12. Word cloud of the most frequent keywords

3.9 Co-occurrence and collaboration network analysis

Consequently, a curated list of keywords with higher research significance was generated, highlighting the top 77 keywords in the co-occurrence network related to renewable energy in Africa, fixed keywords to 88 only 77 keywords met the threshold illustrated in Figure 13 and Table 5.

Also, for a better understanding of the scholars' collaborations, the contributing authors were taken as a unit for analysis. Using VOSviewer, the collaborative network among countries in the research area was examined. The analysis of publications revealed authors and affiliated institutions from various nations. Consequently, the participating countries were identified and differentiated by different colors in Figure 14, illustrating the collaboration network.

This analysis aids in visualizing international collaborations, offering insights into the network's dynamics. It serves as a valuable tool for researchers, enabling them to identify new collaboration possibilities and research avenues.

This analysis helps to visualize the collaborations between countries in the field of corrosion inhibitors and to understand the dynamics of the collaboration network, which can help researchers identify new collaboration and research opportunities. It is important to mention that a single publication might be associated with multiple countries due to collaborations between different institutions, a factor that has been duly accounted for in this study.

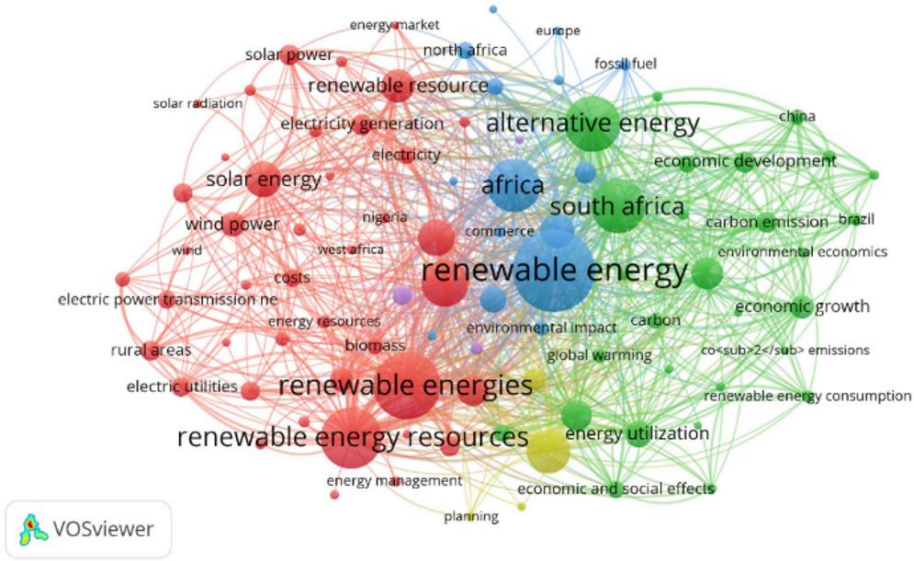

Figure 13. Co-occurrence of keywords

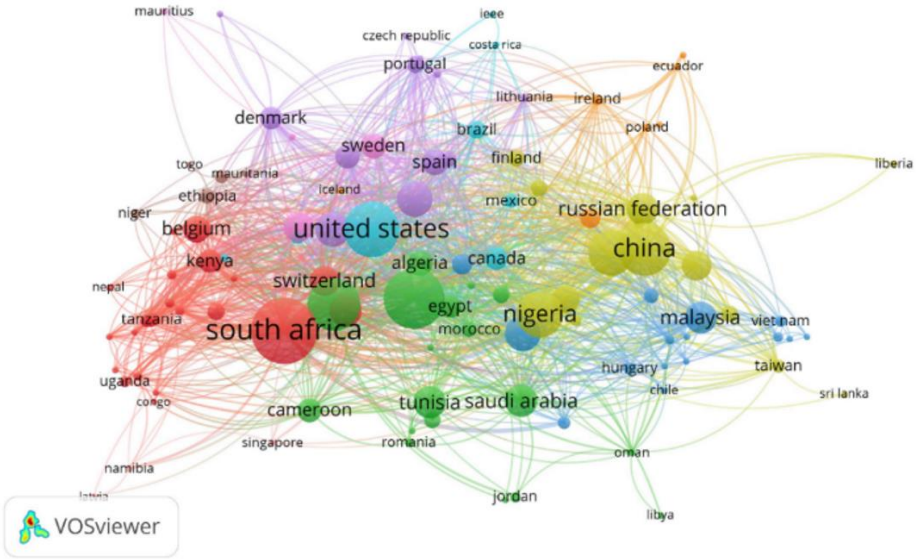

Figure 14. Co-authorship map

Table 5. Most relevant keywords on the field (1979-2022)

Terms	Frequency
Renewable Energies	685
Renewable Energy Resources	644
South Africa	561
Africa	539
Alternative Energy	514
Energy Policy	513
Sustainable Development	455
Carbon Dioxide	406
Sub-Saharan Africa	363
Renewable Resource	348
Climate Change	347
Solar Energy	347
Economics	288
Investments	286
Wind Power	262
Economic Development	251
Energy Utilization	236
Fossil Fuels	228
Renewable Energy	218
Energy Efficiency	211

4. CONCLUSIONS

The main objective of this research is to conduct an in-depth literature review on renewable energy in Africa using the Scopus database. The data collected covers various aspects of publications, including characteristics, journals, countries, affiliations, and authors. The study identifies Wanner, Heinz as the most influential author in this field, along with prolific researchers such as Brent and Alan Colin and Kusakana, Kanzumba. The results obtained in this bibliometric study show that South Africa is the most productive country in the field with 962 publications, and the best affiliations in the field belong to the same country. At the top of the highest productivity journals " Renewable and Sustainable Energy Reviews" with an impressive 125 articles, followed closely by " Renewable Energy" with 117 articles and " Energy Policy" with 106 articles the country presents journals like “Desalination”, with remarkable number of 762 articles published, and “Desalination and Water Treatment” made a significant contribution. Additionally, highly cited works have been featured in reputable journals such as Progress in Energy

and Combustion Science, highlighting their role in promoting innovative research.

However, it is essential to recognize the limitations of this bibliometric study. By relying solely on a single database, Scopus may overlook relevant researchers and work. To further investigate, it would be useful to conduct additional bibliometric analyses using various databases and extending periods. This approach would provide a more complete and precise understanding of the research area, thereby allowing deeper insight into its evolution. In summary, this study constitutes an important starting point, but further enrichment with additional bibliometric studies is imperative.

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