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Evaluating the Global Research Landscape on Renewable Energies in the Context of Climate Change: A Bibliometric Analysis

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ABSTRACT

This study provides a bibliometric analysis of the global research landscape on renewable energies in the context of climate change, covering the period from 2013 to 2023. Utilizing the comprehensive Scopus database, it examines 3,195 research documents to identify trends in publications, key contributors by country, influential journals, and prominent authors. The analysis reveals a marked increase in renewable energy research, particularly peaking in 2020, with a notable rise in citations in 2021, reflecting the growing global urgency of addressing climate change through sustainable energy solutions. China and the United States are identified as leading contributors, with significant, impactful research also emerging from countries like India, highlighting the global nature of the field. The study employs VOSviewer for data visualization, revealing "climate change" as a pivotal theme within a dense network of interconnected research topics. Key journals such as "Renewable and Sustainable Energy Reviews" and "Science of the Total Environment" are identified as significant outlets for disseminating influential research. Authors like Shahbaz M. and Ozturk I. emerge as significant figures within the research community, contributing extensively to the discourse. The findings underscore the importance of supporting diverse and comprehensive research in renewable energies and advocate for integrating these insights into policy development for effective climate change mitigation and renewable energy implementation strategies.

1. INTRODUCTION

The impetus for a transition to renewable energy sources is driven by the imperative of mitigating the adverse effects of climate change, a global challenge that a broad consensus of scientists and policymakers has recognized. The seminal work of the Intergovernmental Panel on Climate Change (IPCC) has accentuated the critical role of renewable energies in reducing greenhouse gas emissions [1, 2]. With the increasing global demand for energy, exploring renewable resources has emerged as a critical theme in energy policy and climate change mitigation strategies [3].

Bibliometric analyses have been instrumental in mapping the landscape of academic research, identifying leading trends, and highlighting the most influential contributions in various fields [4]. Within renewable energy research, such analyses reveal a significant growth in scholarly output, reflecting the escalating priority of sustainable energy solutions in response to climate change [5]. The complex relationship between renewable energy technologies and policy measures has been explored extensively, with studies emphasizing the role of governmental intervention in fostering innovation and adoption [6].

The corpus of renewable energy literature encompasses diverse technologies, including wind, solar, hydro, and bioenergy, each with its challenges and opportunities. For instance, the proliferation of wind energy research has been particularly notable, with contributions from Ahmad et al. [7] examining the socioeconomic impacts of wind farm developments. Similarly, the photovoltaic potential of solar energy has been a focal point of studies by Kumar and Sudhakar [8], who have delved into efficiency improvements and cost-reduction strategies.

Climate change considerations are intrinsically linked to the discourse on renewable energies, with authors such as Ozturk and Acaravci [9] and Warsame et al. [10] exploring the implications of energy policies on carbon emissions and environmental sustainability. The complex dynamics between economic growth, energy consumption, and renewable energy investments have been analyzed in the works of Shahbaz et al. [11], highlighting the multifaceted nature of the energy transition challenge.

The relationship between technological advancements, market forces, and policy frameworks is critical to understanding the renewable energy landscape. As Bekun et al. [12] asserts, the successful integration of renewable technologies into the energy mix is contingent upon supportive regulatory environments and the scalability of technologies.

Moreover, the socioeconomic aspects of renewable energy deployment, such as job creation and public acceptance, are vital considerations addressed in research by authors like Adebayoet al. [13], Dogan et al. [14], and Ali et al. [15].

In this bibliometric analysis, we aim to synthesize the wealth of research on renewable energies and climate change, employing a comprehensive approach to evaluate the global research output. This study seeks to provide a nuanced understanding of the field's current state and future directions by systematically examining the contributions of pivotal authors and the evolution of research themes.

2. MATERIALS AND METHODS

2.1 Research approach

This study engages in a bibliometric analysis, a method by Ali et al. [15] describe as highly beneficial in scholarly endeavors. It offers a global view of scientific efforts on specific subjects and delivers essential data supporting decision-making within the academic sphere [16]. Additionally, a bibliometric approach yields a wealth of data regarding research findings' progression, exposure, and organizational structure [17-19]. The primary goal here is to assess the scientific output, influence, and origins of research within the chosen domain.

2.2 Search strategies

The methodology for identifying relevant literature began by selecting two essential keywords from the UNESCO thesaurus. In the second week of January 2024, the research was conducted using the Scopus database provided by Elsevier, which encompasses a diverse range of over 36,000 titles across various disciplines, including the physical sciences, health sciences, agriculture, and social sciences [20-22]. This database hosts a variety of scientific materials, including articles, books, and book chapters. The selected keywords were searched within the database's search functionality using a combination of logical operators as part of the following search string:

TITLE-ABS-KEY (renewable energy consumption) AND TITLE-ABS-KEY (climate change) AND PUBYEAR > 2013 AND PUBYEAR < 2024.

2.3 Inclusion and exclusion criteria

Specific criteria for inclusion and exclusion were established to conduct the bibliometric analysis. The analysis was confined to a time frame spanning from 2013 to the late part of 2023, thereby excluding any articles published outside of this window. To maintain a comprehensive and international scope, the study did not limit the inclusion of articles based on the publication language. Additionally, the research did not impose any geographical limitations, ensuring that no particular country, ethnicity, or culture was given precedence or faced exclusion in the assessment.

2.4 Data processing

Following the protocol outlined by Alcayde et al. [23], this research examined various elements, including document types, publication language, scholarly output, leading nations in the domain, international collaborations, key authors, and the development of keyword usage over time. The study utilized VOSviewer software, available at (http://www.vosviewer.com). It was accessed on January 4, 2024. It is a no-cost tool for creating and displaying bibliometric networks, with data sourced from searches conducted on the Scopus database.

Figure 1 shows the process followed during this research to perform the bibliometric analysis.

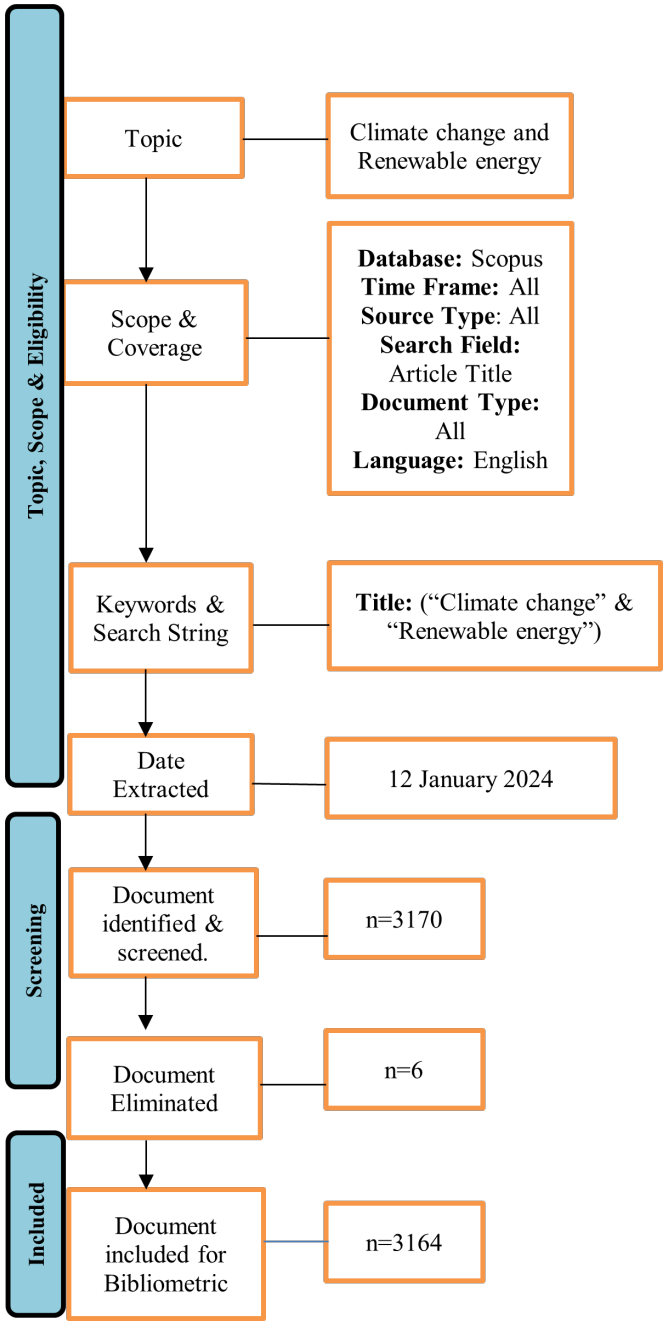

Figure 1. Methodology used in the bibliometric analysis

First a comprehensive search was conducted using three specific fields on Scopus: TITLE-ABS-KEY for both "renewable energy consumption" and "climate change," with a publication year filter set from 2013 to 2023. The retrieved data were then exported into a .csv file compatible with Excel, capturing details such as publication year, authorship, document type, country of origin, citations received, publishing source, and institutional affiliations.

After the data was received analysis of bibliometric data was carried out individually for each data point using the capabilities of Excel software, allowing for a nuanced examination of the respective categories.

Finally, the clustering phase involved aggregating the data related to authors, countries, and keywords. This step utilized VOSviewer® software, version 1.6.19, to synthesize the information. The clustering provided insights into the collaborative networks within the scientific community, highlighted the contributions of different countries, and identified research trends via keyword frequency and association analysis.

3. RESULTS

3.1 Yearly citations and publications

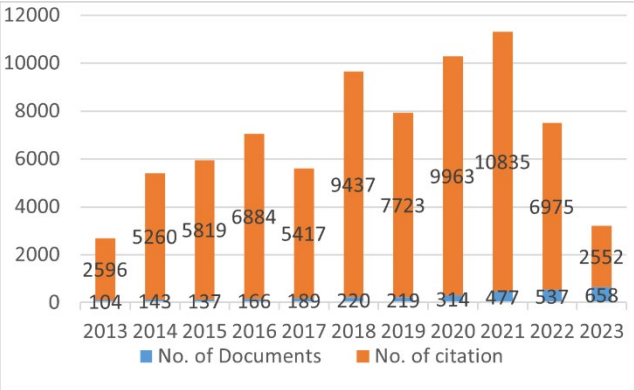

Figure 2. Yearly citations and publications

The bar graph in Figure 2 offers a detailed overview of the publication trends in renewable energy research in the context of climate change from 2013 to 2023. Over the years, there has been a clear upward trajectory in the number of documents published, with a particular surge noted up to 2020. This consistent increase reflects a burgeoning scholarly attention to renewable energies, indicating the sector's rising importance in academic and scientific discourse.

Regarding citations, the graph reveals a general increase over time, yet the pattern differs from that of publications. Notably, citations peaked in 2021 despite the number of publications not being the highest in that year. This peak suggests that the research content produced around that time significantly impacted the field, resonating strongly within the academic community. Moving forward to 2023, there is a marked decrease in both published documents and received citations, suggesting various potential factors, such as changes in research focus, field maturity, or a lag in the academic citation process for newer publications.

3.2 Top 15 leading countries

The line graph of Figure 3 portrays a comparative analysis of different countries' contributions to the field of renewable energy research within the context of climate change as part of a bibliometric study. It contrasts the total number of publications against the total citations received for each listed country. From the data, China leads with the highest number of publications and also tops the chart in citations, indicating a robust research output that is both voluminous and influential. The United States follows, with many publications and citations, but with a lower count on both fronts than China.

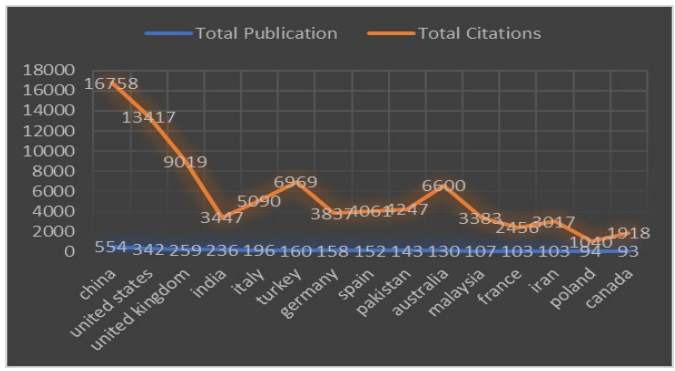

Figure 3. Contribution of 15 leading countries in the field of renewable energy and climate change

China and the United States exhibit several characteristics in their academic output that warrant further discussion. Firstly, both countries demonstrate a significant investment in renewable energy research, reflected in their high publication counts and citation frequencies. This indicates robust funding support, advanced research infrastructure, and a conducive academic environment. Moreover, their research output tends to cover a broad spectrum of topics within renewable energy, ranging from technological advancements to policy analysis and socioeconomic implications. This multidisciplinary approach fosters comprehensive solutions to the challenges posed by climate change and energy transition.

However, while China and the United States lead in research quantity and citation frequency, their academic outputs also reveal certain weaknesses and challenges. One notable weakness is the potential imbalance between basic and applied research. Despite their high publication counts, these countries may face criticism for prioritizing quantity over quality, leading to a lack of groundbreaking innovations or transformative solutions. Additionally, issues such as intellectual property rights protection and data transparency may pose challenges to the credibility and reproducibility of research findings, potentially affecting the global research landscape.

A closer examination reveals that while there is a general trend that countries with more publications tend to have more citations, there are notable exceptions. For instance, with fewer publications than the United Kingdom, India has garnered more citations, demonstrating strengths in producing impactful research despite their comparatively lower publication counts. This suggests a focus on high-quality, high-impact research that addresses specific challenges or niche areas within renewable energy. These countries may prioritize interdisciplinary collaborations, leverage indigenous knowledge and resources, or capitalize on emerging technologies to enhance the relevance and applicability of their research outputs.

Conversely, despite having a considerable number of publications, countries like Italy and Germany see a relatively lower citation count, hinting at a disparity between research output and its subsequent academic influence.

The graph also underscores the competitive nature of research in renewable energies and the varying degrees of impact different countries' research has on the global stage. Smaller countries like Malaysia and Iran, while contributing

fewer publications, show a commendable citation count, suggesting that the quality of research could be high or of particular interest to the global research community. Conversely, countries such as Poland and Canada have a relatively low number of publications and citations, which could reflect different national priorities, levels of investment in research, or focus areas within the renewable energy sector. This bibliometric snapshot highlights the prolific nature of research outputs from specific regions. It underscores the importance of citation impact as a measure of influence and relevance in the scientific community.

3.3 Leading journals in the domain

Table 1 provides a detailed bibliometric analysis of various academic journals on renewable energy and climate change. It lays out several key metrics that gauge the quantity and impact of the research published within these journals. Total publications (TP) and total citations (TC) serve as raw indicators of productivity and influence. In contrast, the Citation per publication (CPP) provides a more nuanced measure of the average impact of each article published in the journal.

Table 1. Journals

Journals	TP	TC	CPP	Cite-Score	SNIP	SJR	Publisher
Renewable and Sustainable Energy Reviews	90	8042	89.35556	26.3	3.631	3.232	Elsevier
Science of the Total Environment	44	4702	106.8636	16.8	2.026	1.946	Elsevier
Journal of Cleaner Production	98	3525	35.96939	18.5	2.379	1.981	Elsevier
Environmental Science and Pollution Research	126	3327	26.40476	7.9	1.214	0.944	Springer Nature
Energy Policy	58	3259	56.18966	15.2	2.155	2.292	Elsevier
Renewable Energy	60	3195	53.25	16.1	2.146	1.815	Elsevier
Energies	158	2104	13.31646	5.5	1.025	0.632	MDPI
Energy	47	1977	42.06383	14.9	2.132	1.989	Elsevier
Applied Energy	50	1877	37.54	21.1	2.907	2.758	N/A
Journal of Environmental Management	44	1703	38.70455	1.8	0.374	0.233	L & H Scientific Publishing, LLC
Sustainability (Switzerland)	98	1489	15.19388	5.8	1.198	0.664	
Energy Reports	32	823	25.71875	5.6	1.542	0.973	Elsevier
Environment, Development and Sustainability	33	459	13.90909	7.2	1.291	0.835	Springer Nature
ENERGY PROCEDIA	33	370	11.21212	N/A	1.07	0.519	N/A
IOP Conference Series: Earth and Environmental Science	32	57	1.78125	0.8	0.255	0.197	N/A

"Renewable and Sustainable Energy Reviews" leads in terms of total citations (TC) with 8042, which is significantly higher than other journals, indicating that its articles are widely referenced and presumably influential in the field. However, when considering the Citation per publication (CPP), "Science of the Total Environment" stands out with an impressive score of 106.8636 despite having fewer total publications and citations than "Renewable and Sustainable Energy Reviews." This suggests that the average article in "Science of the Total Environment" is fundamental to the field, potentially shaping current research and policy discussions.

Regarding the CiteScore, a metric reflecting the average citations per document that a title receives over three years, "Renewable and Sustainable Energy Reviews" again tops the list with a score of 26.3, corroborating its leading position in the field. The SCImago Journal Rank (SJR) further supports this, holding an SJR of 3.232. Conversely, journals such as "IOP Conference Series: Earth and Environmental Science" and "Energy Procedia" have lower CiteScores and SJRs, which could be attributed to these journals possibly publishing more niche or specialized articles that attract a smaller, more specific audience.

The SNIP (Source Normalized Impact per Paper) metric allows for comparing the impact of journals in different fields, normalizing for differences in citation practices. Here, "Applied Energy" has the highest SNIP of 2.907, suggesting that the impact of its papers is high relative to the global average in this subject area. The diversity in publishers, with Elsevier leading with multiple high-performing journals, indicates that this publisher is a significant player in disseminating influential research in renewable energy and climate change. Smaller publishers, like L & H Scientific Publishing, LLC, with lower citation metrics, may reflect a focus on specialized topics or emerging fields within the broader discipline.

3.4 keywords

3.4.1 The link between Climate change and renewable energy

The intrinsic connection between "climate change" and renewable energy lies at the heart of sustainable environmental practices and global efforts to mitigate the impacts of climate change. Renewable energy sources, such as solar and wind power, offer a compelling solution to reduce greenhouse gas emissions, the primary drivers of climate change (IPCC, 2018). As emphasized by Smith et al. [24], the transition to renewable energy is pivotal in achieving a low-carbon economy, providing a viable alternative to traditional fossil fuels that contribute significantly to atmospheric CO_2 levels. This symbiotic relationship is further underscored by the fact that the deployment of renewable energy technologies not only mitigates climate change but also addresses energy security concerns [24-26].

On a theoretical level, the link between "climate change" and renewable energy can be expounded through the concept of carbon neutrality. The works [27-30] underscore that transitioning to renewable energy systems is pivotal for achieving carbon neutrality and, consequently, combating the adverse impacts of climate change. Renewable energy technologies not only minimize the carbon footprint associated with energy production but also contribute to ecosystem resilience, aligning with broader climate change adaptation strategies (UNEP, 2019). Empirical evidence, as highlighted by Wang et al. [31], showcases the effectiveness

of renewable energy initiatives in mitigating climate change-induced challenges, including extreme weather events and rising sea levels.

3.4.2 Keyword network

Figure 4, a network visualization created using VOSviewer, illustrates the interconnectedness of various keywords within the global research landscape on renewable energies in the context of climate change. The nodes (or circles) represent keywords, with the largest node colored red and labeled "climate change," having occurred 1,911 times, indicating its central role in the research landscape. This keyword also boasts a high total link strength of 14,141, demonstrating numerous connections to other terms and illustrating how climate change is a pivotal topic that ties together diverse research strands. The density of connections around this node suggests that a wide array of research on renewable energies directly addresses or relates to climate change.

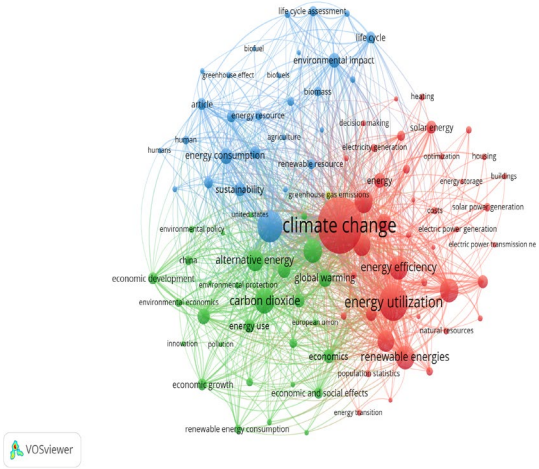

Figure 4. Network of keywords

The green nodes, which cluster around the keyword "carbon dioxide," reflect research on greenhouse gas emissions and their mitigation. "Carbon dioxide" has 611 occurrences and a total link strength of 5773, indicating a strong academic focus on understanding and reducing CO_2 emissions to tackle climate change.

In the blue cluster, "renewable energy" is a prominent node, with 858 occurrences and a total link strength of 6,806, surrounded by related terms like "solar energy," "wind power," and "biofuels." This cluster highlights a concentration of research on alternative energy sources that are pivotal in transitioning away from fossil fuels to mitigate the impacts of climate change.

The yellow cluster, featuring "greenhouse gas emissions" and associated terms, underscores another critical aspect of the discourse. It has 217 occurrences and a total link strength of 2,319, focusing on greenhouse gas sources, impacts, and reduction strategies. This cluster is heavily linked to the red and green, indicating a cross-disciplinary dialogue between the general phenomena of climate change, the specific issue of carbon dioxide, and broader greenhouse gas concerns.

The network also shows smaller nodes and thinner lines, indicating more niche topics or emerging research areas. For example, "energy storage" is a smaller node with 76 occurrences and a link strength of 747, suggesting it is a developing field within the renewable energy sector.

Overall, the visualization captures the complexity of the research on renewable energies and climate change, highlighting established and emerging focus areas. The connections between the nodes, some with hundreds or even thousands of links, underscore the multidisciplinary nature of addressing climate change, encompassing technological innovation, policy development, and environmental impact assessment, among other areas.

3.5 Most cited authors

Figure 5 presents a bibliometric network visualization highlighting the citation relationships among researchers in renewable energy and climate change. At the epicenter of this network is Shahbaz M., an author whose work commands considerable attention within the academic community. Represented by one of the largest nodes in the visualization, Shahbaz M. has the highest citation count in the dataset, with 1,142 citations and an impressive total link strength of 36,647. This dominant presence indicates that Shahbaz M.'s research contributions are extensively referenced and broadly impact the field.

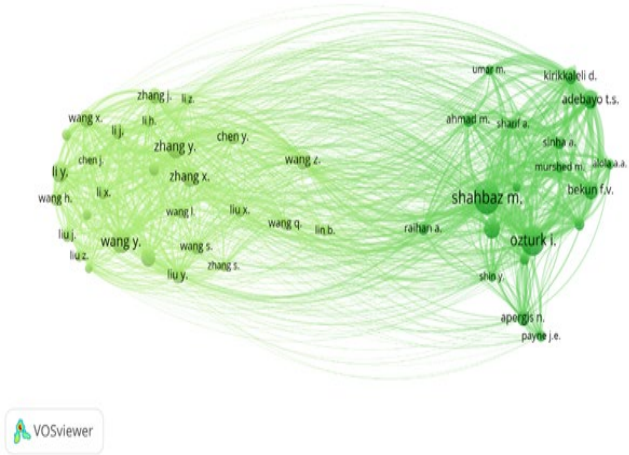

Figure 5. Result of the co-citation analysis by cited sources

In comparison, Ozturk I., a significant contributor, has a slightly lower total link strength of 31,447 and 1,009 citations. Ozturk's work is pivotal, strongly influencing the discourse on renewable energy. Nevertheless, it does not quite match the Citation reach and network centrality of Shahbaz M. This distinction points to the nuances in academic influence, where different authors may lead in either the breadth or depth of their research impact.

Another notable researcher in the network is Bekun F.V., who also has a substantial academic footprint with a total link strength of 23,600 and 601 citations. Bekun's work is widely acknowledged and suggests a cross-disciplinary appeal, connecting various thematic areas within the larger field of study.

On the other hand, Kumar A. presents a contrasting profile with a total link strength of 3,649 and 253 citations, indicative of a more focused sphere of influence. Although Kumar's citations and link strength are modest relative to the authors above, his research is integral to developing specialized topics within renewable energy and climate change.

These authors, with varying citation counts and link

strengths, illustrate the diverse scholarly contributions shaping the understanding of renewable energies and their role in addressing climate change. Their interconnectedness in the network underlines the collaborative nature of research, where studies often build upon and reference peers' work, weaving a complex tapestry of knowledge in the field.

4. CONCLUSIONS

This comprehensive bibliometric analysis, "Evaluating the Global Research Landscape on Renewable Energies in the Context of Climate Change," used an in-depth methodology to examine scholarly discourse from 2013 to 2023. The study harnessed the Scopus database for its wide-ranging coverage, employing VOSviewer for visual data analysis and Microsoft Excel for detailed data examination. This approach yielded rich insights into publication trends, country contributions, key journals, and influential authors in the renewable energy sector.

The methodology centered on collecting data based on specific title keywords: "renewable energy consumption" and "Climate change," resulting in a dataset of 3,195 research documents. The use of VOSviewer facilitated the visualization of the complex relationships among keywords, authors, and countries, providing a deeper understanding of the dynamics within the field.

The analysis revealed a significant increase in publications on renewable energies, with a notable peak in 2020, reflecting growing academic attention amidst rising concerns over climate change. Despite a lower publication volume, a subsequent peak in citations in 2021 suggested the profound impact of the research produced around that time. The study identified China and the United States as key contributors in both publications and citations, with countries like India displaying a high citation count despite fewer publications, underscoring the global and diverse nature of renewable energy research. Journals such as "Renewable and Sustainable Energy Reviews" and "Science of the Total Environment" emerged as central to disseminating influential research, with variations in Citation per publication indicating different levels of impact. The network visualization highlighted "climate change" as a focal theme, with authors like Shahbaz M. and Ozturk I. recognized for their significant roles in shaping the research landscape.

Building upon the nuanced findings of this comprehensive bibliometric analysis, it is imperative to translate insights into actionable policy recommendations. The following specific policy recommendations are proposed to guide decision-makers in fostering a more sustainable and impactful global research landscape on renewable energies in the context of climate change:

Encourage the creation of international platforms that facilitate collaboration among researchers, institutions, and policymakers. These platforms should focus on sharing best practices, coordinating research efforts, and fostering interdisciplinary collaboration. Initiatives such as joint research grants, exchange programs, and collaborative workshops can strengthen the global network of researchers working on renewable energy solutions.

Promote interdisciplinary research initiatives that bridge the gap between traditional scientific disciplines. Policymakers should allocate funding and resources to support research projects that integrate expertise from diverse fields, including engineering, environmental science, economics, and social sciences. This approach will enhance the holistic understanding of renewable energy challenges and solutions.

Allocate research funding strategically, prioritizing high-impact areas with the potential to address critical challenges in renewable energy and climate change. Policymakers should collaborate with research institutions to identify key research priorities aligned with global sustainability goals. Targeted funding can drive innovation and accelerate the development of transformative technologies.

Implement initiatives to enhance research capacity in developing regions, recognizing the importance of diverse perspectives in addressing global challenges. Policymakers should support training programs, provide research grants, and establish partnerships to empower researchers in regions with limited resources. Building research capacity globally will contribute to a more inclusive and equitable research landscape.

Collaborate with international stakeholders to develop a standardized framework for assessing the impact of renewable energy research. Policymakers can work with research organizations and funding agencies to establish metrics that measure not only publication quantity but also the real-world impact of research outputs. This framework will guide resource allocation and ensure the effectiveness of research investments.

Finally, Facilitate collaboration between public institutions, private enterprises, and research organizations. Policymakers should create an enabling environment for public-private partnerships that drive research and development in renewable energy technologies. By leveraging the strengths of both sectors, innovative solutions can be brought to market more efficiently.

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