

Towards a Greener Future: Analyzing the Trends and Influences in Sustainable Energy Literature

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Received: August 02, 2023 Revised: October 19, 2023 Accepted: January 26, 2024 * Corresponding author

ABSTRACT

The growth in sustainable energy relies significantly on the utilization of clean energy sources, attracting increasing attention in the literature with substantial growth in research outputs. This study employs bibliometric analysis via Scopus to depict the current cleaner energy research landscape and future directions. It amalgamates trends and influential research at the sustainability–renewable energy intersection. By mapping notable authors, institutions, and research clusters, it highlights interdisciplinary aspects across engineering, environmental science, economics, and policy studies. The journal *Renewable and Sustainable Energy Reviews* is pivotal in publishing articles on sustainable development and renewable energy. China leads in related research, with North China Electric Power University as a major contributor. The most cited article in *Nature* (2012) underscores the importance of sustainable energy for global prosperity, exploring solar, water-based, and biofuel energy, and outlining pathways for a sustainable future. This research not only reviews the current state-of-the-art literature but also informs researchers regarding the critical pathways and emerging trends in the sustainable development goals.

Keywords: Sustainable development ▪ Renewable energy ▪ Bibliometric analysis ▪ Alternate energy

1. INTRODUCTION

The global demand for electricity is on a continuous rise, surpassing the overall growth rate of energy consumption. The challenge is to meet this increasing demand amidst depleting fossil fuel resources and soaring fuel prices. Over the past decade, the world's primary energy demand has surged by approximately 26%, and the demand for electricity alone is expected to skyrocket by 81%, reaching 40,000 TWh by 2040, with 70% of this growth originating from countries like India and China. Relying solely on conventional sources is impractical due to rapidly depleting coal and natural gas reserves, posing environmental risks. Nuclear power, contributing 11% to global electricity, is considered low-cost but raises concerns about radioactive exposure and waste

disposal. Oil, though finite, faces escalating prices and geographical concentration. The need for sustainable and secure global energy solutions is crucial, as highlighted by the challenges in meeting growing energy demands while minimizing environmental impact.

Countries are striving for energy independence and environmental sustainability. Traditional centralized electricity generation faces challenges such as pollution and energy loss, prompting a shift towards renewable sources like hydro, solar, biomass and wind power. To incentivize the adoption of renewable energy, nations are implementing rules and offering financial incentives. India, for instance, is actively embracing renewable sources to reduce reliance on fossil fuel imports. While each renewable source has distinct advantages, their intermittent nature and geographic limitations

hinder widespread integration into the electrical grid. Hybrid renewable energy systems (HRES) emerge as a promising solution, combining multiple sources and incorporating energy storage to enhance overall performance, reliability, and efficiency, addressing the complexities associated with individual renewable sources [1, 2, 3, 4, 5, 8].

These studies address various aspects, including wind energy variability [1], cost frameworks [2, 3], economic viability [4], optimal coordination strategies [5], comparative economics and voltage security analysis [6], as well as economic emissions-discharge trade-offs in integrated wind-solar-thermal systems [8, 9]. Designing hybrid power systems is pivotal for cost-effective and reliable supply of power. Therefore, employing an optimization model with a robust method is crucial.

Zarnikau [10] defines green energy as electricity generated from renewable sources like PV solar panels, geothermal, biomass and wind, emphasizing its potential to minimize pollutants and be directly utilized in various sectors. This definition aligns with the global push for increased adoption of clean and renewable energy sources to address climate change, as evidenced by many countries setting targets for net-zero CO₂ emissions by 2050 [11, 12]. In response, nations worldwide are intensifying efforts to accelerate the transition to green energy and reduce carbon emissions from traditional energy sources [13].

Over the past two decades, research has yielded significant insights into the utilization of renewable energy sources. Bibliometrics, tracing its origins to the early twentieth century [14], offers a robust quantitative method for evaluating the influence of scholarly accomplishments within the discipline [15, 16, 17]. Widely recognized for uncovering knowledge structures and intellectual connections within disciplines [18, 19], bibliometrics stands as a valuable tool for understanding trends and advancements in green energy adoption.

The main objective of this paper is to utilize a bibliometric approach for describing the progression and current status of research in sustainable energy. This method allows for a more relevant and dependable statistical analysis. It aims to identify trends, influential research works, and emerging areas of interest in the field while highlighting the contributions of various authors, institutions, and regions in advancing the analysis within this domain.

2. METHODOLOGY

To achieve the above objectives, a bibliometric review is undertaken, encompassing evaluation of performance and visualization of scientific connections. The methodology used in this research is illustrated in Figure 1. For literature data collection, a search approach is applied to the Scopus database's Core Collection, using keywords such as "sustainable development," "alternate energy," and "renewable energy." This database is known for its comprehensive multidisciplinary citation data and is increasingly becoming a primary source for bibliometric analysis. In this study, three bibliometric analysis tools—VOSviewer, R Studio and Excel—are utilized. R Studio is mainly employed for gathering bibliographic data. VOSviewer serves for both network and content analysis,

enabling the creation and visualization of bibliometric networks. Microsoft Excel is utilized alongside R Studio due to the ease of editing graphs, which was not as convenient with those generated by R Studio. The total number of articles successfully analyzed is 17,000, spanning the years 1991 to 2024.

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Figure 1. Research methodology of this work.

This bibliometric analysis addresses the following research questions:

- RQ1: How many research articles are there on sustainable development, alternative energy, and renewable energy?
- RQ2: Which authors, journals, countries and articles exert the most noteworthy impact within this field?
- RQ3: What evolving research trends appear over distinct time periods in the chosen research topic?
- RQ4: What areas could future research in renewable energy explore?

The study aimed to answer RQ1 by investigating the research output in the domain. This involved looking at key contributors in the research area, using metrics such as publication counts to demonstrate efficiency, citations to assess influence over time, author participation, influential publication sources, and highly effective articles. Moreover, scientific mapping analysis was conducted to examine co-citations, scrutinizing extensively referenced publications to comprehend the primary themes in the research domain (RQ2). Additionally, keyword co-occurrence analysis was performed to investigate patterns in the research area (RQ3), while bibliographic coupling analysis was undertaken to grasp research discrepancies and potential opportunities (RQ4).

3. RESULTS AND DISCUSSIONS

Research output in the field of sustainable development and renewable energies experienced a significant surge starting in 2008. This is demonstrated by a remarkable 1353.03% rise in the number of articles published between 2008 and 2023, surging from 198 to 2679 (Figure 2).

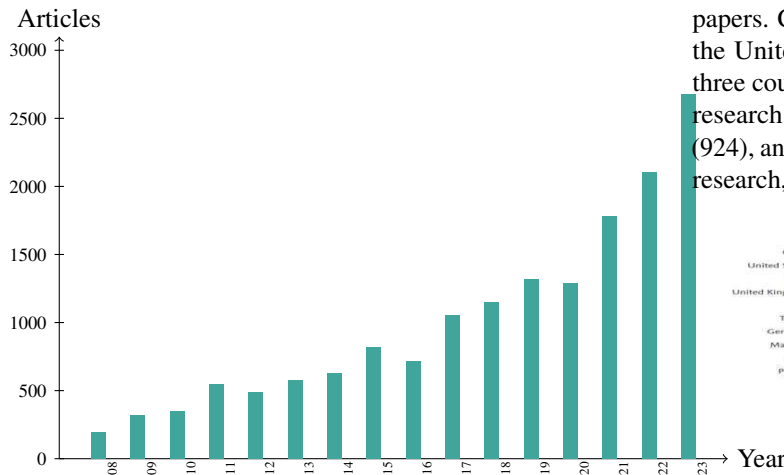


Figure 2. Research trend from the year of 2008–2023.

3.1 The Journals' Performance

All 17,000 articles about sustainable development and alternate energy were published in a total of 138 sources. *Renewable and Sustainable Energy Reviews* published the largest number of articles (772), followed by *Energies* (611), *Energy Procedia* (594), *Journal of Cleaner Production* (523), and *Renewable Energy* (492), as shown in Figure 3.

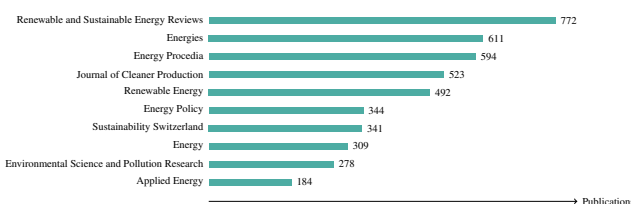


Figure 3. Top 10 journals with the most publications.

3.2 The Authors' and Countries' Performance

The growth in any research field depends upon the endeavor of the scholars working in the area. According to the bibliometric analysis, 1,159 authors out of 17,000 documents are recognized contributors to this field. Figure 4 presents data on ten pertinent authors from the Scopus database. The most prominent author, concerning the quantity of contributions, is Abdeen Mustafa Omer, with 60 publications. The second most productive author is Tomiwa Sunday Adebayo from Cyprus International University of Turkey with 52 articles, whose research interests mainly cover economic development and renewable energy [20, 21].

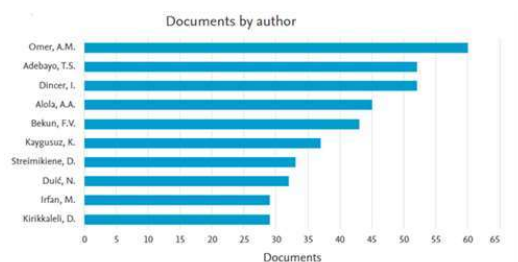


Figure 4. Top ten authors with the most publications.

Looking at where the analyzed scientific research comes from, Figure 5 reveals that China has the highest number of

papers. China has a total of 3,063 publications, followed by the United States with 1,957 and India with 1,564. These three countries together make up 38.23% of all the scientific research on this topic. The United Kingdom (1,237), Italy (924), and Turkey (816) also play significant roles in scientific research, ranking fourth, fifth, and sixth, respectively.

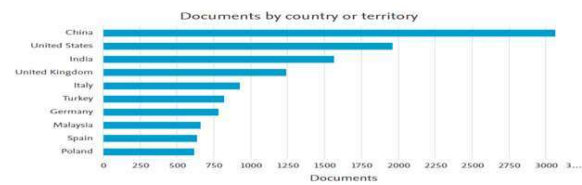
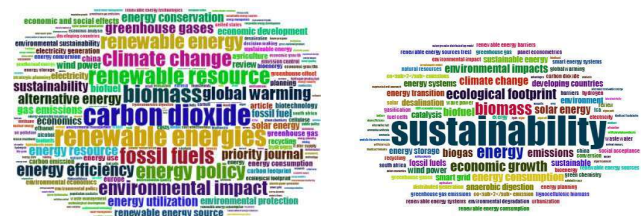


Figure 5. Number of publications by countries.

3.3 Prominent Research Topics

A word cloud is used to find the most commonly used terms in a particular field, utilizing Scopus for two types of keywords: author keywords and keywords plus. Author keywords show what authors like and summarize the main topics in articles. Keywords plus, generated by a computer program, come from a thorough analysis of words or phrases in publication titles and references. Keywords plus are effective for analyzing research and grasping the scientific concept of an article. Figure 6 shows the word cloud of the top 50 words for both author keywords and keywords plus. In Figure 6a, important terms like “renewable energies,” “carbon dioxide,” and “environmental impact” are prominent, while Figure 6b emphasizes “sustainability” as the most significant, with “energy” and “ecological footprint” closely following. Keywords plus cover a broader range compared to author keywords.



(a) Keyword plus.

(b) Authors keyword.

Figure 6. Word cloud of keywords.

3.4 Citation Analysis of Top Most Articles

Monitoring the annual fluctuations in citations can serve as a means to gauge the influence of publications. While occasional miscounting of citations may happen, the fundamental trends and identification of research trends persist in the data. Table 2 illustrates the ten topmost cited articles in the field of renewable energy from the Scopus database and analyzed to present further information for future researchers.

4. CONCLUSION

The objective of this work is to evaluate the global efforts contributed in the field of renewable energy and sustainable development. Using various knowledge mapping tools, including VOSviewer and Bibliometrix, this study presents the results of a thorough bibliometric analysis of 17,000 documents on renewable energy from the Scopus Core Collection database. Since 2008, there has been a noticeable rise in research interest in renewable energy sources, likely driven by

Table 1. Research trend from the year of 2008–2023

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
No.	198	316	346	547	485	574	631	820	718	1053	1146	1321	1290	1780	2108	2679

Table 2. Top ten most cited articles among the scientific contributions on renewable energy

No.	Authors	Title	Journal	Cites	Year
1	Chu S.; Majumdar A.	Opportunities and challenges for a sustainable energy future	Nature	7929	2012
2	Ragauskas A.J. et al.	The path forward for biofuels and biomaterials	Science	4915	2006
3	Panwar N.L.; Kaushik S.C.; Kothari S.	Role of renewable energy sources in environmental protection: A review	Renewable and Sustainable Energy Reviews	2531	2011
4	Gielen D. et al.	The role of renewable energy in the global energy transformation	Energy Strategy Reviews	2224	2019
5	Weiland P.	Biogas production: Current state and perspectives	Applied Microbiology and Biotechnology	2048	2010
6	Dincer I.	Renewable energy and sustainable development: A crucial review	Renewable and Sustainable Energy Reviews	1626	2000
7	Lund H. et al.	4th Generation District Heating (4GDH): Integrating smart thermal grids into future sustainable energy systems	Energy	1618	2014
8	Song C.	Global challenges and strategies for control, conversion and utilization of CO ₂ for sustainable development involving energy, catalysis, adsorption and chemical processing	Catalysis Today	1537	2006
9	Pant D.; Van Bogaert G.; Diels L.; Vanbroekhoven K.	A review of the substrates used in microbial fuel cells (MFCs) for sustainable energy production	Bioresource Technology	1481	2010
10	Logan B.E.; Rabaey K.	Conversion of wastes into bioelectricity and chemicals by using microbial electrochemical technologies	Science	1465	2012

concerns about climate change and environmental pollution from energy consumption. Lexical analysis was employed to identify the main themes in research papers by highlighting significant and recurring terms found in titles, abstracts, and keywords.

However, the study has limitations, such as relying exclusively on the Scopus database and excluding certain documents due to insufficient information. It is important to note the inherent constraint of bibliometric reviews, which focus on quantitative analysis rather than a detailed examination of article content. To address these limitations, future research could explore a systematic review of the literature. The approach may delve deeper into the objectives, methodologies, and conclusions of the analyzed scientific output contributed in this study.

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