Educational Administration: Theory and Practice
2024, 30(3), 2966-2976
ISSN: 2148-2403
https://kuey.net/

Research Article

The Future of Indian Renewable Energy Research: Insights from a Bibliometric Analysis

Rajeev Kumar Attri[1*] and Dr. Ashok Kumar Upadhyay[2]

[1*,2] Department of Library and Information Science Mangalayatan University, Aligarh, Uttar Pradesh, India 202146, rkattri.amity@gmail.com ashok.upadhyay@mangalayatan.edu.in

Citation: Rajeev Kumar Attri, et.al (2024), The Future of Indian Renewable Energy Research: Insights from a Bibliometric Analysis, *Educational Administration: Theory and Practice*, 30(3) 2966-2976
Doi: 10.53555/kuey.v30i3.8840

ARTICLE INFO

ABSTRACT

India's renewable energy research progress from 2019 to 2024 was examined using Scopus-indexed papers to identify significant priority areas, growth trajectories, and collaborative activities. Due to climate change and India's urgent need for sustainable energy solutions, renewable energy has become a vital area, increasing scholarly publications. Bibliometric tools are used to assess renewable energy research trends in India and identify the top contributors and collaboration networks. This baseline bibliometric analysis is the first to provide a foundational view of India's renewable energy research and offers stakeholders key insights to strengthen India's clean, resilient energy future's innovation and policies.

Keywords: Renewable energy; solar energy; sustainable energy; green energy; Scopus; India

Introduction:

India is moving rapidly towards a sustainable energy future, nationally and abroad. As part of the world's largest and fastest growing economy, India's rising energy demand has historically been met with fossil fuels like coal, oil and natural gas. With all this came an increased reliance on carbon emissions, pollution, and depletion of resources. Yet, given the environmental impacts of traditional energy sources and the economic cost, the push for renewable energy alternatives has increased. By positioning itself as one of the lead countries in renewable energy development in globally, India's ambitious climate goals under the Paris Agreement, including the reduction of carbon emissions intensity by 33-35 per cent by 2030, along with ensuring that 40 per cent of electricity is generated from non-fossil fuel sources, make it a lighthouse in global ambitious climate efforts.

In recent years, the renewable energy sector in India has witnessed strong growth, backed by well-supported government policies and programs. National Solar Mission, National Wind Mission and Green Energy Corridor have set an atmosphere for growing renewable energy capacities. India has taken advantage of its plentiful sunlight and fast-expanded solar power, which is a big reason India has become one of the top solar energy producers in the world. They have also expanded the country's wind and bioenergy sectors with policies that promote investment, subsidies and financial incentives that attract private sector participation. These factors helped drive huge investments in renewable energy infrastructure based on academic and industrial research to enhance renewable technologies' efficiency, scalability, and viability. This is because research plays a critical role in driving the renewable energy transition, and a bibliometric analysis enables us to understand the extent of research in the Indian renewable energy sector. By applying bibliometric analysis, outputs from research, the thematic areas covered, and the networks of collaboration at a given time can be assessed systematically, generating insight into the path and impact of research in a given field.

India has enacted many laws and initiatives to surmount these obstacles and foster the development of the renewable energy sector. The Energy Conservation Act of 2001, revised in 2022, instituted regulations for energy consumption and sought to advance renewable energy initiatives. The amendment aims to implement the "Panchamrit", which includes India's five commitments to combat climate change, specifically the target of increasing non-fossil energy capacity to 500 GW by 2030 (Naik & Bhakare, 2023). This dedication highlights the Administration's significant emphasis on renewable energy as a critical foundation for sustainable development. Highlighting its commitment towards clean energy transition, the nation has set a target of achieving 175 GW of renewable energy capacity (Kumar et al., 2024). The Indian government has implemented laws such as net metering to promote solar energy adoption by enabling households to sell surplus solar energy

to the grid. Financial incentives such as subsidies and tax benefits have been provided to encourage investment in solar energy projects. The establishment of solar parks such as Bhadla Solar Park near Jodhpur has facilitated the growth of large-scale solar power installations, attracting significant investment (Kumar et al., 2024).

This paper identifies important influential authors and key issues of renewable energy research in India by providing a comprehensive overview of the research dynamics of the field. This paper's analysis of Scopus-indexed literature from 2019 to 2024 results in this conclusion. Solar, wind and bioenergy; and emerging technologies like hybrid systems, energy storage and grid integration are all important as India transitions to clean energy. To fulfil these goals, this paper addresses the areas of research most pertinent to India's renewable energy aims. It reveals gaps and opportunities to improve the intellectual contribution to the growth of this sector. Such a bibliometric analysis also conveys implications to stakeholders, policymakers, industry leaders and researchers. The study identifies key trends and thematic areas, and data-based insights are offered to support policy decisions and provide direction in research funding priorities. First part of the papers is organized to present an overview of publication trends and thematic areas of concentration in the renewable energy sector. The next sections discuss prominent authors and collaborative networks that have propelled renewable energy research and how research trends converge with India's policy-based goals.

Literature review

Renewable energy is becoming increasingly vital globally due to apprehensions regarding fossil fuel exhaustion, energy security, and environmental sustainability (Kannan & Vakeesan, 2016; Hajimineh & Rezaei Rad, 2024). The country of India possesses a wealth of renewable energy resources and has made tremendous progress in harnessing these resources. The country has also established lofty objectives for the deployment of renewable energy (Naik & Bhakare, 2023; Kumar et al., 2024). The objective of this literature review is to provide an overview of the status of research in the subject of renewable energy, with a specific focus on solar energy technology and laws in India. Specifically, the review will focus on India.

Innovation in technology, falling costs, and supportive government policies bode well for the future of renewable energy, especially solar energy, in India. Renewable and environmentally friendly, it has the potential to reduce dependence on fossil fuels and mitigate the effects of climate change. Since no greenhouse gases are released during its operation, the solar power system is environmentally friendly (Verma & Goswami, 2024; Lin et al., 2025 & International Energy Institute (IEI), 2023).

To make solar energy more accessible and affordable, researchers are working to improve existing solar technology. Solar energy, when combined with other renewable energies such as wind and biomass, can create a more stable and long-term power system. Intermittency problems associated with individual renewable energy sources can be mitigated by hybrid systems that combine different technologies, guaranteeing a consistent power supply (Østergaard & et. al., 2024). Moreover, the adoption of solar energy might result in substantial savings on electricity expenses (Lin et al., 2025; International Energy Institute (IEI), 2023 & IEA, IRENA, UNSD, World Bank, 2024). This is particularly pertinent in nations such as India, where electricity demand is swiftly escalating due to factors including population expansion, urbanization, and industrialization (Naik & Bhakare, 2023; Kumar et al., 2024).

Despite the benefits, there are numerous practical and legal barriers to widespread adoption of solar energy in India. Current renewable energy laws and regulations are not being adequately enforced. Investors and developers may feel uneasy due to lack of consistent and defined legal framework (Naik & Bhakare, 2023). The sporadic nature of solar energy is a considerable problem, necessitating the creation of effective energy storage technologies or the integration with alternative energy sources to guarantee a stable power supply (Kannan & Vakeesan, 2016). It is challenge to set-up large solar energy facilities especially in densely populated areas of the country like India. The process of getting approval from multiple governments makes it a lengthy and complex process. Lack of awareness among the Indian community on solar energy adoption is the biggest hindrance in achieving the country's renewable energy goals (Kumar et al., 2024).

To fully realize the potential of renewable energy in India, continued support from government including removal of all barriers will be required. To foster stockholder confidence and accelerate the implementation of projects on renewable energy, we need to enhance the legal and regulatory environment, streamline processes, and encourage public awareness (Naik & Bhakare, 2023). The advancement of efficient and economical energy storage technology is essential to address intermittency issues and maintain grid stability. This will facilitate the extensive incorporation of renewable energy into the current energy infrastructure (Kannan & Vakeesan, 2016). Global collaboration and knowledge exchange will be essential in promoting the transfer of technology and best practices within the renewable energy sector. Through the cultivation of ties with other nations and organizations, India can harness global experience to expedite its transition to a sustainable energy future (IEA, IRENA, UNSD, World Bank, 2024).

All the same, the sources stress how research on renewable energy and Sustainable development has changed over the last one decade. Researchers can discover patterns, identify key contributors, and outline the intellectual framework of a research subject through bibliometric analysis, which employs quantitative approaches to research substantial literature (Dinçer et al., 2024; Xu et al., 2024). The sources demonstrate several applications of this method, emphasizing its ability to recognize research hotspots, track the

development of certain study fields, and uncover potential gaps for further study (Zaidi, 2024; Ziegler, 2009 & de Oliveira Costa Souza Rosa et al., 2022).
A study analysed publishing trends in artificial intelligence applications in sustainable smart cities (AISC) research from 2011 to 2022, indicating a extraordinary rise in publications and identifying principal research flash point (Zaidi et al., 2023). A further study examined the application of machine learning in solar energy systems and development (MLPVSE) from 2014 to 2022, highlighting the increasing significance of this research domain and underscoring the necessity of international collaboration (Zaidi, 2024). Additionally, the sources reference bibliometric analyses examining research trends in energy storage solutions, solar cooling technologies, and energy efficiency in manufacturing sectors, providing significant visions into advancements and hindrances in these essential domains (Tripathy et al., 2024; Abdullah et al., 2023; Musango, 2024; Saikia et al., 2020 & Prisca, 2024). The authors recognize the constraints of bibliometric analysis, including the risk of bias from dependence on certain databases and the possible omission of pertinent research published in languages other than English (Xu et al., 2024 & Elie et al., 2021). Furthermore, they suggest that subsequent research should investigate the utilization of bibliometric analysis in nascent fields such as the cybersecurity of renewable energy systems, especially considering the rising incidence of assaults on energy infrastructure (Zaidi, 2024). Renewable energy is becoming more important for long-term sustainability. Sustainable and efficient energy systems that use renewable energy sources including solar, biomass, wind, and wave power are the focus of ongoing research into these technologies and their many aspects. Clean, sustainable energy will power our future, and while there are still challenges to solve, ongoing research and policy efforts are laying the groundwork.

Objectives

The study has the following goals:
a) In 2019–2023, what are renewable energy research article and citation trends?
b) Who is the most prolific author?
c) Energy research's most significant publications?
d) Find the author's most important keyword patterns.
e) To discover influential journals and collect title data.
f) highlight author keyword mapping and worldwide collaboration mapping.

Methodology

To this study, the research data was gathered from the Scopus database, which is a repository for abstracts and citations. The purpose of this acquisition was to extract information on the prominent energy sector in India from January 1, 2019, to December 31, 2023. During the investigation, which spans a period of five years, from 2019 to 2023, a total of 18,459 papers were discovered. When doing the literature search, which took place on September 25, 2024, the advanced document search option was utilized in conjunction with a query to locate relevant material that had been published within the specified timeframe.
For this bibliometric investigation, the search query that was utilized was: (TITLE-ABS-KEY (Solar Energy OR “Renewable Energy” OR “Green Energy” OR “Sustainable Energy” AND PubYear > 2019 AND PubYear < 2023 AND Limit-To AffilCountry, "India" AND Limit-To SubjArea, "engi" OR Limit-To SubjArea, "ener" OR Limit-To SubjArea, "mate" AND Limit-To DocType, "ar". This query was used to look up relevant material on renewable energy and other connected topics. The search was conducted by making use of the fields for the title, abstract, and keywords.

Data extractions

For this investigation, the necessary data was extracted from SCOPUS database on 29 Sep 2024, with special emphasis on research articles published during the years 2019 and 2024. Search keywords were used as "renewable energy", "solar energy", "sustainable energy", and "green energy" The search returned a total of 870177 documents. To reduce the large dataset, the search was limited to areas such as “engineering,” “energy,” and “materials science”, and the document was limited to published articles, with a focus on research publications from India. To achieve these goals the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach was employed, as shown in Figure 1. This method is often used to find, select, and evaluate published papers on a range of literary topics (Zaidi, 2024). The result was a total of 18,459 articles (as shown in figure 1). For conducting additional research, the bibliographic data was exported in the SCOPUS (.CSV) file format. Following that, the Bibliometric package, version (4.2.3), was utilized within the R-Studio environment, version (4.4.0), with the Biblioshiny program being utilized for the purpose of doing extensive analysis (Aria & Cuccurullo, 2017). To perform scientific mapping and generate a variety of analyses and visualizations, Biblioshiny was used, which is famous for its user-friendly interface and vast functionality. Furthermore, VOSviewer program was used for the purpose of data visualization, resulting in greater insight on publication patterns, prolific authors, and leading journals in the field of bibliographic research in India.

Data analysis and result

The Primary Information

A total of 1,485 academic articles covering topics related to renewable energy is shown in Table 1. Between the years 2019 and 2023, 42066 authors from 1460 different sources contributed to the publication of the papers published. A total of 333 of the papers were produced by a single author. The findings indicated a yearly growth rate of 18.32% and a mean of 16.41 citations per document. The overall count of keywords (ID) was 58470, whereas the number of author keywords (DE) was 39335. Various sources, including journals, books, conference papers, and reviews, presented analyses of the 18459 articles.

Publications and citation trends

A representation of the research productivity of the literature on "renewable energy", "solar energy", "sustainable energy", "green energy" is shown in Figure 2, which covers the years 2019 to 2023. In figure 2, there is a consistent increase in the number of publications. In terms of total publications, 2023 topped the list with 5224 (28.10%), followed by 2022 with 4533 (24.56%), and 2021 with 3267 (17.70%). The most citations were received in 2020 with TC-73519, then in 2021 with TC-67310 and in 2022 with TC-62986.

Figure 1. *Diagram showing four data removal and separation procedures*

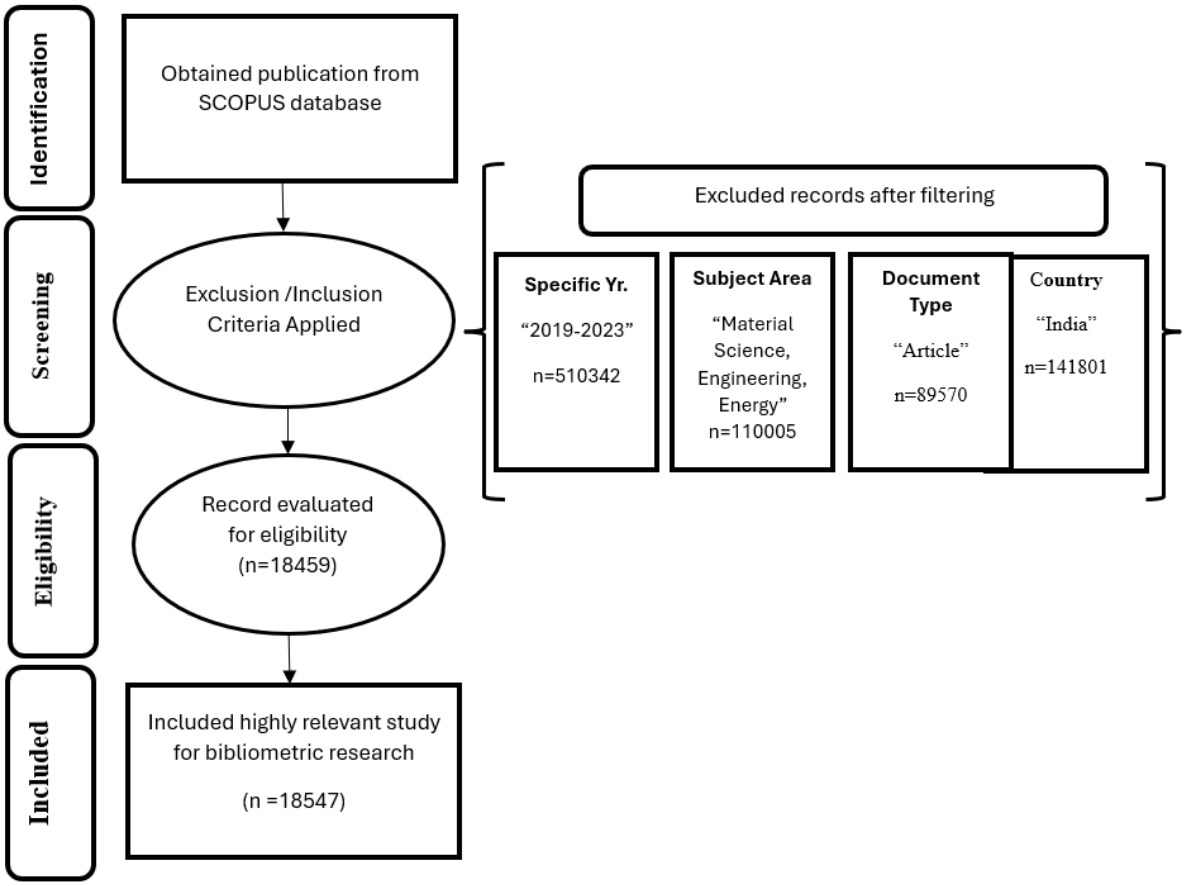


Table 1. *The Primary information about the data*

Descriptions		Results
1.	Timespan	2019:2023
2.	Sources (Journals, Books, etc)	1460
3.	Documents	18459
4.	Annual Growth Rate %	18.32
5.	Average citations per doc	16.41
Document Contents		
6.	Keywords Plus (ID)	58470
7.	Author's Keywords (DE)	39335
Authors		
8.	Authors	42066

9.	Authors of single-authored docs	333
Document Types		
10.	Article	18459

Figure 2. *Publication and average citation trends.*

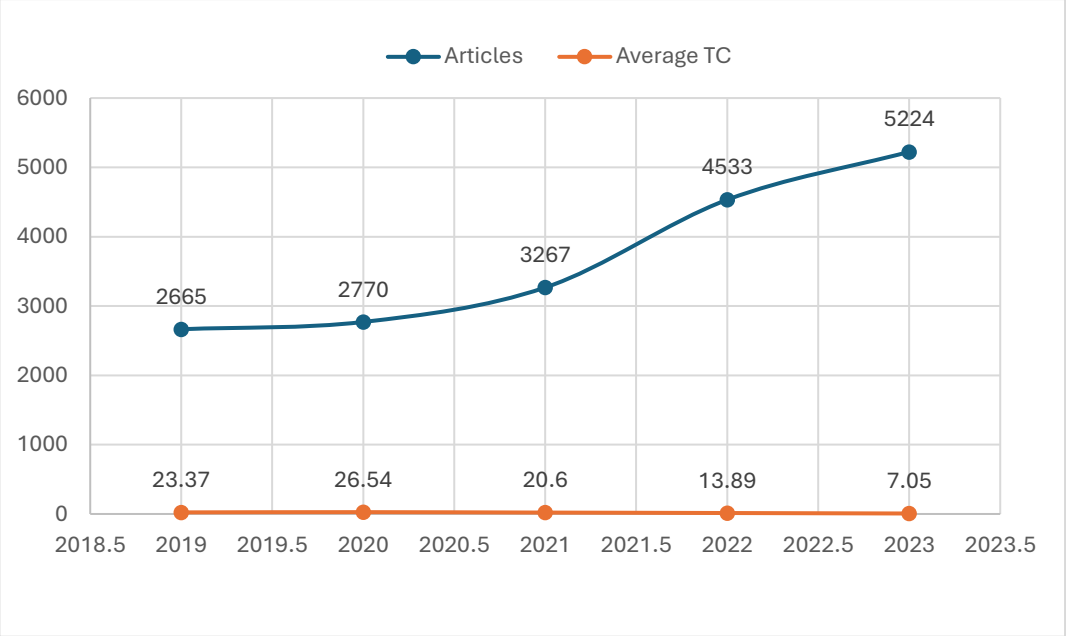


Table 2: *Most popular author keywords*

Keywords	TP	TC	ACPP	NCP	CP	Start Year	End Year
Solar energy	2460	41806	16.99	142	2318	2019	2023
Solar power generation	1959	32241	16.46	121	1838	2019	2023
Energy gap	1766	27771	15.73	68	1698	2019	2023
Energy efficiency	1585	33664	21.24	67	1518	2019	2023
Renewable energy resources	1684	31730	18.84	110	1574	2019	2023
Scanning electron microscopy	1245	22782	18.3	58	1187	2019	2023
Sustainable development	1112	28896	25.99	57	1055	2019	2023
Fourier transform infrared spectroscopy	906	18383	20.29	44	862	2019	2023
Energy utilization	938	23459	25.01	60	878	2019	2023
Renewable energies	1125	23002	20.45	69	1056	2019	2023

NOTE: "The table lists top keywords, TP=Total publications; TC=Total Citation, ACPP=Average Citation per publication; NCP=Not Cited Papers; and CP=Cited Papers are included.(Hussain & Ahmad, 2024)"

Ranked list of author keywords

Table 2 details the author keywords that were used most often in this study. The data presented indicates that out of all the terms, "solar energy" had the most citations (41806), followed by "energy efficiency" with 33664 citations, and "solar power generation" with 32241. "Sustainable development" had the greatest average number of citations per publication at 25.99%, followed by "energy utilization" at 25.01% and "energy efficiency" at 21.24%. Of the papers that were not cited, the most numerous were those dealing with "solar energy" (142 citations), "solar power generation" (121) and "renewable energy resources" (110 citations). The most cited work was CP-2318, which dealt with "solar energy", while the least cited was CP-44, which dealt with "fourier transform infrared spectroscopy".

Table 3: *Patterns of Authorship*

Authorship	TP	TC	ACPP	NCP	CP	Percent
1	397	4358	10.98	77	320	2.15
2	4243	52477	12.37	566	3677	22.99
3	4195	59202	14.11	452	3743	22.73
4	3112	51142	16.43	285	2827	16.86
5	2263	45709	17.8	157	2106	12.26
6	1616	32644	20.2	92	1524	8.75
7	1045	21501	20.58	38	1007	5.66
8	677	14378	21.24	24	653	3.67
9	396	8020	20.25	20	376	2.15
10	250	5835	23.34	2	248	1.35

Note: "The table lists authorship patterns, TP=Total publications; TC=Total Citation, ACPP=Average Citation per publication; NCP=Not Cited Papers; and CP=Cited Papers are included.(Hussain & Ahmad, 2024)"

Patterns of Authorship

Table 3 presents the authorship trends for literature published between 2019 and 2023. According to the data, these publications had anywhere from one to ten authors. The two-author pattern emerged as the most prevalent, comprising 4,243 publications and a total publication rate of 22.99. This was succeeded by the three-author pattern with 4,195 publications, and the four-author trends with 3,112 publications, spanning the years 2019 to 2023. Publications with author patterns of two to four authors constituted 74.83% of the total. The three-author pattern garnered the highest citation count, totalling 59,202 citations. The single author trends ranked eighth in citation frequency, accumulating a total of 4,358 citations for its publications.

Most leading journals

Table 4 presents an analysis of leading journals on the specified theme from 2019 to 2023, encompassing a total of 1460 relevant journals. The journal "Solar Energy" published the highest number of papers, a total of 389 publications. Of those, only two were uncited, while 387 had citations. The journal Sustainable Energy Technologies and Assessments published 313 papers, of which 309 were cited and 4 were not cited. Of the 18459 papers, 16742 were cited and 1717 were not, with a mean citation per paper of 16.41. With a total of 13,828 mentions, the Journal of Cleaner Production got the most attention. The journal of Renewable Energy garnered 11,137 citations, whereas the journal of Solar Energy accumulated 10,111 citations, ranking it third in total citations.

Table 4: *The top-rated Source*

Source	TP	TC	ACPP	NCP	CP	Start Year	End Year	CiteScore 2023
Solar Energy	389	10111	25.99	2	387	2019	2023	13.9
Sustainable Energy Technologies and Assessments	313	7489	23.93	4	309	2019	2023	12.7
Journal of Energy Storage	308	7884	25.6	6	302	2019	2023	11.8
Journal of Materials Science: Materials in Electronics	296	3014	10.18	20	276	2019	2023	5.0
Energies	292	5353	18.33	5	287	2019	2023	6.2
Renewable Energy	291	11137	38.27	1	290	2019	2023	18.4
Journal of Cleaner Production	283	13828	48.86	1	282	2019	2023	20.4
Materials Today: Proceedings	277	1988	7.18	44	233	2020	2023	4.9
Energy Sources, Part A: Recovery, Utilization and Environmental Effects	264	2701	10.23	20	244	2019	2023	4.4
Sustainability (Switzerland)	251	4018	16.01	9	242	2019	2023	6.8

Note: "TP=Total publications; TC=Total Citation, ACPP=Average Citation per publication; NCP=Not Cited Papers; and CP=Cited Papers are included (Hussain & Ahmad, 2024)"

Among the recorded publication, the "*Journal of Cleaner Production"* sets out with the maximum CiteScore of 20.4, reflecting a notable impact in the industry. "*Renewable Energy"*, with the second highest CiteScore of 18.4, closely follows it. Another publication, "*Solar Energy",* demonstrates a relatively high CiteScore, with the third highest of 13.9. These numbers highlight, these journals significant contribution and influence within their respective domains.

Top ten prolific authors

Table 5 lists the 10 most prolific authors in the field of renewable energy. From the point of view of affiliation, the 42066 authors. Bhim singh is the leader and most productive author published 148 publications from Indian Institute of Technology Delhi, which represents 0.80% of the total publications followed by Ganesh D. Sharma published 71 publications representing The LNM Institute of Information Technology, Jaipur representing 0.38% and V.V. Tyagi published 60 publications from Shri Mata Vaishno Devi University, Katra. Observing the highest citations Singh, B. had 2512 citations, Sathyamurthy, R. had 2155 citations and Tyagi, V.V. had 2064 citations. Sathyamurthy, R. had the highest average citation per paper at 38.48%, followed by Padmanaban, S.K. at 37.04% and Pandey, A.K. at 34.89%. Based on the findings, it can be concluded that these ten authors made major contributions to the field of renewable energy. Their highly cited research and publications have advanced the field and impacted the Renewable Energy industry.

Table 5: *Leading Author*

Source	Affiliations and Countries	TP	TC	ACPP	NCP	CP	Start Year	End Year	h-index 2024
Singh, B.	Indian Institute of Technology Delhi, New Delhi, India	148	2512	16.97	4	144	2019	2023	88
Sharma, G.D.	The LNM Institute of Information Technology, Jaipur, India	71	679	9.56	1	70	2019	2023	38
Tyagi, V.V.	Shri Mata Vaishno Devi University, Katra, India	60	2064	34.4	1	59	2019	2023	58
Sathyamurthy, R.	King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia	56	2155	38.48	0	56	2019	2023	60
Pandey, A.K.	Sunway University, Bandar Sunway, Malaysia	54	1884	34.89	2	52	2019	2023	47
Padmanaban, S.K.	University of South-Eastern Norway, Kongsberg, Norway	50	1852	37.04	1	49	2019	2023	57
Shkir, M.	King Khalid University, Abha, Saudi Arabia	49	777	15.86	0	49	2019	2023	55
Khan, B.	Hawassa University, Awassa, Ethiopia	48	1017	21.19	5	43	2020	2023	33
Panchal, H.	Government Engineering College Patan, Gujarat, India	44	1155	26.25	0	43	2019	2023	59
Sudhakar, K.	Universiti Malaysia Pahang Al-Sultan Abdullah, Pekan, Malaysia	43	1452	33.77	0	43	2019	2023	50

Note: "TP=Total publications; TC=Total Citation, ACPP=Average Citation per publication; NCP=Not Cited Papers; and CP=Cited Papers are included (Hussain & Ahmad, 2024)"

Top ten documents

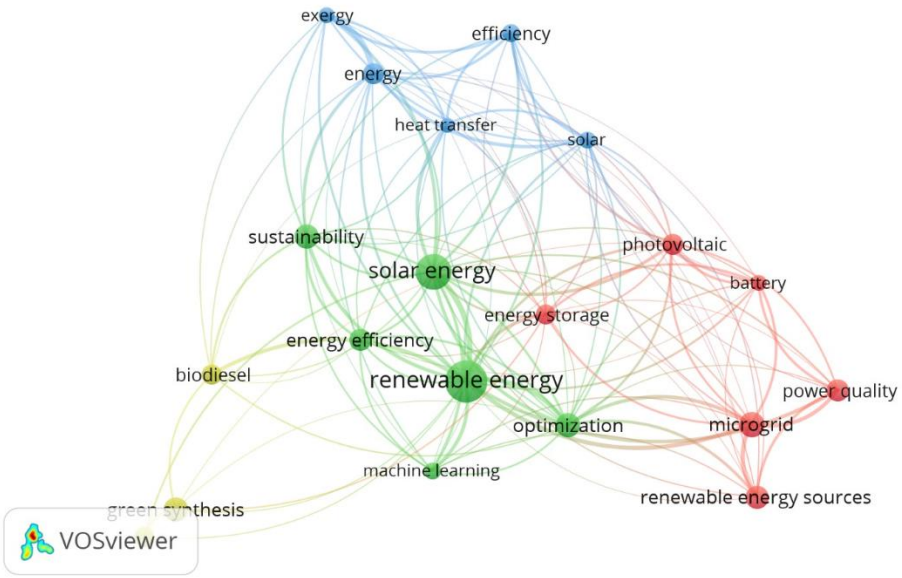
Table 6 displays the top ten documents information on renewable energy published from 2019 to 2023. "Renewable, non-renewable energy consumption, economic growth, trade openness and ecological footprint: Evidence from organisation for economic Co-operation and development countries" received the highest number of citation (752) by Destek MA, found in "Journal of Cleaner Production", followed by "Revisiting the role of renewable and non-renewable energy consumption on Turkey's ecological footprint: Evidence from Quantile ARDL approach" with 614 citation by Sharif A found in "Sustainable Cities and Society" and "Understanding the role of digital technologies in education: A review" with 531 citations by Haleem A found in "Sustainable Operations and Computers.

Table 6: *Most leading Publications*

Total Citations	Document title	First Author Institution / Country	Author, Year, Source
752	"Renewable, non-renewable energy consumption, economic growth, trade openness and ecological footprint: Evidence from organisation for economic Co-operation and development countries"	Gaziantep University, Turkey	Destek MA, 2020, Journal of Cleaner Production
614	"Revisiting the role of renewable and non-renewable energy consumption on Turkey's ecological footprint: Evidence from Quantile ARDL approach"	Sunway University, Malaysia	Sharif A, 2020, Sustainable Cities and Society
531	"Understanding the role of digital technologies in education: A review"	Jamia Millia Islamia, India	Haleem A, 2022, Sustainable Operations and Computers
455	"Foreign direct Investment–CO 2 emissions nexus in Middle East and North African countries: Importance of biomass energy consumption"	Beijing Institute of Technology, China	Shahbaz M, 2019, Journal of Cleaner Production
442	"Self – cleaning superhydrophobic coatings: Potential industrial applications"	Vivekanand College, Kolhapur, India	Latthe SS, 2019, Progress in Organic Coatings
411	"From non-renewable to renewable energy and its impact on economic growth: The role of research & development expenditures in Asia-Pacific Economic Cooperation countries"	Riphah International University, Pakistan	Zafar MW, 2019, Journal of Cleaner Production
349	"The effect of renewable energy consumption on economic growth: Evidence from the renewable energy country attractive index"	Beijing Institute of Technology, China	Shahbaz M, 2020, Energy
329	"Interplay between technological innovation and environmental quality: Formulating the SDG policies for next 11 economies"	Management Development Institute, Gurgaon, India	Sinha A, 2020, Journal of Cleaner Production
326	"Energy efficiency and sustainable development goals (SDGs)"	University of Wollongong, Australia	Zakari A, 2022, Energy
325	"Impacts of COVID-19 pandemic on the global energy system and the shift progress to renewable energy: Opportunities, challenges, and policy implications"	Royal Institute of Technology, Sweden	Hoang AT, 2021, Energy Policy

Note: "The table lists top articles. Total Citation (TC)".

Figure 3. *Author keyword co-occurrence mapping*

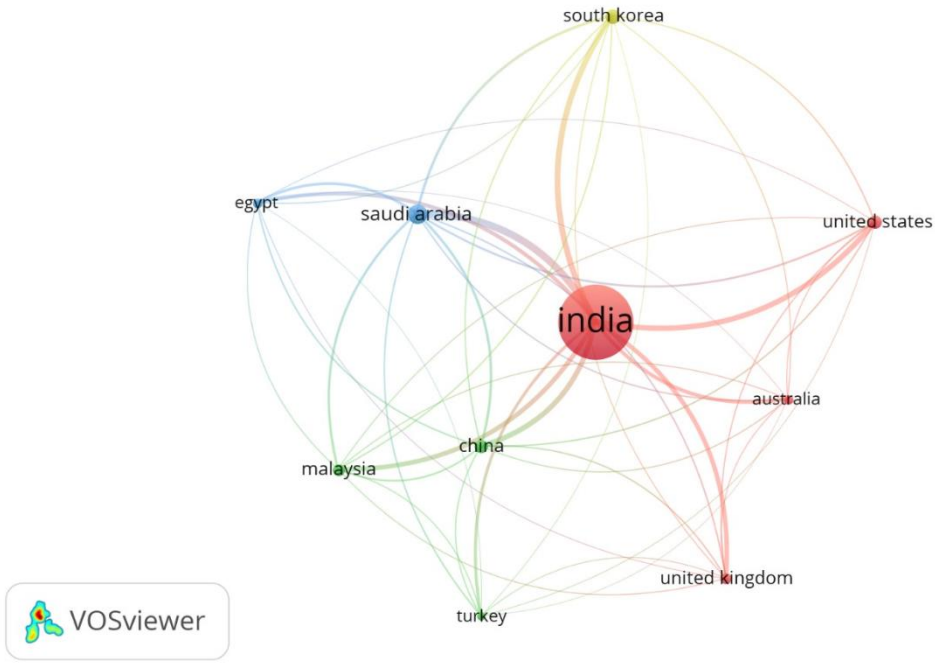


Author keyword co-occurrence mapping

Renewable, solar, green, and sustainable energy are some of the most popular search terms among academics, as seen in Figure 3. For this purpose, we visualized the keywords using the VOS viewer. The full counting method was implemented to ensure that each keyword was encountered at least ten times. There were only 1061 keywords out of 39384 that met the criteria for analysis. Different colors were used to display the top twenty keywords, which were selected based on the total link strength of each keyword. The growing size of the cluster led to an increase in the frequency with which keywords were utilized. A direct correlation exists between the amount of research articles that contain the keywords that have been provided and the degree of

collaboration that exists between the nodes. Based on the findings of the analysis, it was found that researchers commonly used keywords including “renewable energy,” “solar energy,” “optimization,” “energy,” “microgrid,” “solar,” and “sustainability.” Figure 3 illustrates four distinct clusters of keywords, each corresponding to a unique research domain.

Figure 4: *Mapping co-authorship countries.*



Top ten co-authorship influential countries

Figure 4 displays visualization of the most influential countries in co-authorship for research on renewable energy. based on a bibliometric analysis using Scopus data. We utilized the VOS viewer tool to visualize the nations that had significant co-authorship. We employed a full counting approach and limited each document to 25 countries. Each country was considered based on at least 5 documents and 1 citation. Out of 195 countries, 95 fulfil the threshold for analysis. Based on their total link strength, the top 20 keywords were chosen and shown by a cluster of four different colors. The countries are represented by text labels with their relative influence indicated by colour intensity and positioning on the map. India stands out as the most dominant contributor positioned at the centre of the map with the brightest orange coloration, signifying its central role in collaborative research in this topic. Countries like Saudi Arabia, China, South Korea and Malaysia indicates they may be emerging as important hubs for collaboration among Asian countries and suggested opportunities for increased international partnership in future research on renewable energy.

Discussions

In the period between 2019 and 2023, there were a total of 302929 citations for 18547 research publications on renewable energy that were indexed in SCOPUS. This information was gleaned from the examination of this study. With a total of 36829 citations and 5224 (28.30%) articles, the year 2023 was the year with the highest number of publications. In the year 2020, there was a significant increase in the number of citations, with 73519 citations arising from only 2770 (15%) articles. Solar energy, solar power generation, energy gap, and energy efficiency were the keywords that were most frequently used by the top author. On the other hand, the publication pattern with the second-highest number of citations was three authors (4195, with 59202 citations out of 18459 articles). The most prevalent authorship pattern consisted of dual authors (4243, 22.99%). Between the years 2019 and 2023, the journal titled "Solar Energy" produced the greatest number of articles (389, 2.11%), with 10111 papers that were cited. During the period of 2019 to 2023, Singh, B., who was affiliated with the Indian Institute of Technology Delhi (with 148 publications), was a highly contributing author. Among the countries that collaborated with India on research, Saudi Arabia and China were the most significant.

Conclusion

To mapping the existing body of published material on renewable energy in India and the influence of its citations between the years 2019 and 2023, this article made use of bibliometric methodology. The VOSviewer

software was utilized to carry out a network evaluation on the mapping of the co-occurrence of the author's keywords. It was discovered in the study that throughout the course of the past five years, energy research in India has experienced enormous growth. The significance of the expansion of the energy sector in India is demonstrated by the fact that Scopus has indexed 18459 publications, 1460 sources, and 302929 citations. This research offers important new perspectives on the field of energy research. According to the findings, there is a substantial amount of opportunity for scholars and academic institutions to conduct additional research on the subject in the future. The literature that is indexed in Scopus was used for this study. There is a possibility that it will incorporate findings from other bibliographic databases, such as Google Scholar, IEEE, PubMed, and Web of Science.

Acknowledgments

The authors thank the anonymous reviewers for their insightful remarks, which considerably improved the manuscript.

Disclosure statement

No potential conflict of interest was reported by the author(s).

References

1. Abdullah, A. G., Hakim, D. L., Sugito, N. T., & Zakaria, D. (2023). Investigating Evolutionary Trends of Hybrid Renewable Energy Systems: A Bibliometric Analysis from 2004 to 2021. *International Journal of Renewable Energy Research*, *13*(1), 376–391. https://doi.org/10.20508/ijrer.v13i1.13766.g8690
2. Aria, M., & Cuccurullo, C. (2017). bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of Informetrics*, *11*(4), 959–975. https://doi.org/http://dx.doi.org/10.1016/j.joi.2017.08.007
3. de Oliveira Costa Souza Rosa, C., dos Santos, L., Costa, K. A., & da Silva Christo, E. (2022). Research trends in renewable energy complementarity: a bibliometric analysis. In *Complementarity of Variable Renewable Energy Sources* (First Edit). Elsevier Ltd. https://doi.org/10.1016/B978-0-323-85527-3.00013-3
4. Dinçer, F. C. Y., Yirmibeşoğlu, G., Bilişli, Y., Arık, E., & Akgün, H. (2024). Trends and emerging research directions of sustainable aviation: A bibliometric analysis. *Heliyon*, *10*(11). https://doi.org/10.1016/j.heliyon.2024.e32306
5. Elie, L., Granier, C., & Rigot, S. (2021). The different types of renewable energy finance: A Bibliometric analysis. *Energy Economics*, *93*, 104997. https://doi.org/10.1016/j.eneco.2020.104997
6. Hajimineh, R., & Rezaei Rad, E. (2024). The future of renewable energy in Iran's energy policy. *Future Energy*, *3*(3), 1–13. https://doi.org/10.55670/fpll.fuen.3.3.1
7. Hussain, A., & Ahmad, S. (2024). Mapping the Literature on Artificial Intelligence in Academic Libraries: A Bibliometrics Approach. *Science and Technology Libraries*, *43*(2), 131–146. https://doi.org/10.1080/0194262X.2023.2238198
8. IEA, IRENA, UNSD, World Bank, W. (2024). Tracking SDG 7: The Energy Progress Report 2024. In *International Bank for Reconstruction and Development*. https://trackingsdg7.esmap.org/
9. International Energy Institute (IEI). (2023). Statistical Review of World Energy 2023. *BP Energy Outlook 2023*, *70*, 8–20.
10. Kannan, N., & Vakeesan, D. (2016). Solar energy for future world: - A review. *Renewable and Sustainable Energy Reviews*, *62*, 1092–1105. https://doi.org/10.1016/j.rser.2016.05.022
11. Kumar, S. M., Kumari, P., Lad, Y. A., & Maria, S. (2024). Scenario of solar energy and policies in India. *Clean Energy*, *8*(5), 117–128. https://doi.org/10.1093/ce/zkae057
12. Lin, L. Y., Jing, K. T., Qing, C. T., & Yee, H. C. (2025). Sustainable Development in Renewable Energy: Solar Energy Application in Malaysia. *Journal of Advanced Research in Applied Sciences and Engineering Technology*, *43*(1), 1–16. https://doi.org/10.37934/araset.43.1.116
13. Musango, J. K. (2024). Energy technology assessment in managing sustainable energy transitions: A Bibliometric analysis. *Sustainable Energy Technologies and Assessments*, *72*(104021). https://doi.org/https://doi.org/10.1016/j.seta.2024.104021
14. Naik, A. A., & Bhakare, J. (2023). Renewable Energy Sector in India: Legal Perspectives, Issues and Challenges. *NIU International Journal of Human Rights*, *10*(VI), 923–938.
15. Østergaard, P. A., & et. al. (2024). Sustainable development using integrated energy systems and solar, biomass, wind, and wave technology. *Renewable Energy*, *235*(121359). https://doi.org/https://10.1016/j.renene.2024.121359
16. Prisca, N. (2024). Renewable Energy Storage Solutions: Innovations and Challenges. *Research Output Journal of Engineering and Scientific Research*, *3*(2), 45–48. https://rojournals.org/roj-engineering-and-scientific-research/
17. Saikia, K., Vallès, M., Fabregat, A., Saez, R., & Boer, D. (2020). A bibliometric analysis of trends in solar cooling technology. *Solar Energy*, *199*(January), 100–114. https://doi.org/10.1016/j.solener.2020.02.013
18. Tripathy, P., Jena, P. K., & Mishra, B. R. (2024). Systematic literature review and bibliometric analysis of energy efficiency. *Renewable and Sustainable Energy Reviews*, *200*(April), 114583.

https://doi.org/10.1016/j.rser.2024.114583
19. Verma, A., & Goswami, D. P. (2024). Integration of Solar Energy in Agriculture Leads to Green Energy and Golden Crop Production. *Educational Administration: Theory and Practice*, *July*. https://doi.org/10.53555/kuey.v30i7.6626
20. Xu, J., Liu, Q., Wider, W., Zhang, S., Fauzi, M. A., Jiang, L., Udang, L. N., & An, Z. (2024). Research landscape of energy transition and green finance: A bibliometric analysis. *Heliyon*, *10*(3), e24783. https://doi.org/10.1016/j.heliyon.2024.e24783
21. Zaidi, A. (2024). A bibliometric analysis of machine learning techniques in photovoltaic cells and solar energy (2014–2022). *Energy Reports*, *11*(February), 2768–2779. https://doi.org/10.1016/j.egyr.2024.02.036
22. Zaidi, A., Ajibade, S. S. M., Musa, M., & Bekun, F. V. (2023). New Insights into the Research Landscape on the Application of Artificial Intelligence in Sustainable Smart Cities: A Bibliometric Mapping and Network Analysis Approach. *International Journal of Energy Economics and Policy*, *13*(4), 287–299. https://doi.org/10.32479/ijeep.14683
23. Ziegler, B. E. (2009). *Methods for bibliometric analysis of research: renewable energy case study* (Issue September). http://dspace.mit.edu/handle/1721.1/61289

ORCID

Author a, https://orcid.org/0000-0001-9497-3361
Author b, https://orcid.org/0000-0002-1859-675X