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Hybrid renewable energies for rural/urban electrification in emerging economies: A bibliometric review

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Abstract. Limited economic viability, energy scarcity, rising power costs, geographical limits, and infrastructural issues are the main challenges of regional electrical network growth. Though intermittent, renewable energy is clean, sustainable, and infinite. Off-grid or grid-connected hybrid renewable energy solutions solve these issues. This article provides a comprehensive analysis of the large integration of renewable energy systems in emerging regions using bibliometrics. It summarizes scientific advances and trends from 2014 to 2023 using statistical analysis and publication features. Scopus yielded 1222 bibliographic entries for this analysis. This review looks at the number of publications, the most prolific authors, citations, country productivity, country-author collaboration, and journals that publish hybrid renewable energy system articles in poor countries. The proposed bibliometric study will guide end-users in relation to system planning, sizing, and siting for the deployment of future renewable energy systems. The widespread use of keywords related to "renewable energy," "hybrid renewable energy system," "microgrids," and "rural electrification" in scientific journals highlights the significance of conducting collaborative studies in these topics.

Keywords: Bibliometrix analysis, Hybrid renewable energy systems, Developing area, Microgrids, Renewable energy, Homer.

1 Introduction

Global energy consumption rises annually with economic growth. Energy and economic development are linked by two factors. Economic progress depends on energy availability and accessibility. Second, economic development conditions determine energy use and efficiency [1, 2]. Some people still lack electricity. The seventh SDG goal – to provide everyone with modern, reliable, and affordable energy services – is failing. Around 675 million people lack power and 2.3 billion need green cooking in 2021. Global patterns suggest a similar path until 2030 [3]. Over 80% of energy comes from fossil fuels like coal, oil, and natural gas, which continues to be substantial and has been a major driving force behind the economy [4]. People who live in remote regions get their electricity from fossil fuels like diesel and kerosene.

This energy has many limitations, including high fuel costs, long transit distances, high maintenance and operational costs, and environmental damage [5]. Energy usage pollutes air, water, thermal, and solid waste, but climate change is the worst. The main source of urban air pollution is fossil fuels [6]. Nevertheless, global fossil fuel sources are rapidly decreasing. Long-term, intensive use of non-renewable energy sources leads to air pollution, climate change, and irreversible degradation of resources. Climate change threatens wellness, availability of food, ecosystems, revenue growth, and social equilibrium [7].

Increasing green energy consumption is crucial to fixing traditional energy sources. Wind, water, biofuel, geothermal, and tidal energy are renewable [8, 9]. Compared to fossil energy, renewable energy is abundant and distributed and does not emit greenhouse gases [10, 11]. Renewable energy diversifies energy sources and reduces fossil fuel use, improving energy security. Renewable energy should assist sustainable development by reducing energy constraints and improving public health [12, 13].

The renewable energy sources, as depicted in Figure 1, have various obstacles including fluctuations in availability, restricted storage capacity, and environmental impacts [14, 15]. Solar and wind energy are weather-dependent and

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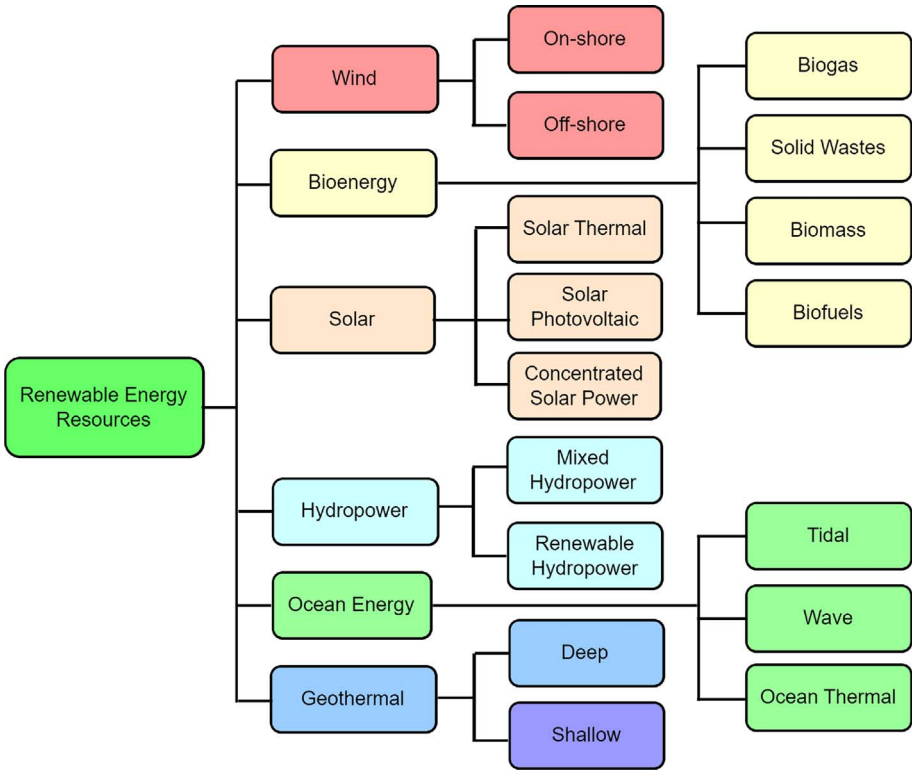

Figure 1. Types of renewable energy sources.

intermittent. Energy sources that require large areas or water supplies harm ecosystems and the environment. A hybrid renewable energy system can solve this by merging and complementing energy sources or technologies [16–18]. Its stability, low emissions, affordability, and ability to combine the virtues of multiple energy sources while minimizing their weaknesses make this system attractive. A hybrid renewable energy system integrates wind turbines, solar panels, water turbines, diesel generators, and batteries [19, 20]. Since expanding the central electricity grid to remote areas with low population density is financially and practically not feasible, hybrid energy generation systems are an attractive solution to facilitate the provision of power in geographically isolated regions [21].

Figure 2 depicts the energy system configuration including conventional, hydro, PV, battery banks, charge controllers, two-way converters, principal loads, and dummy loads. The primary power source is derived from hydro and PV using a bidirectional converter. The surplus power generated by the hydroelectric system or photovoltaic (PV) system, surpassing the load demands, is stored in the battery bank until the battery reaches its maximum charge capacity. If there is extra power after the batteries are fully charged, it will be used to power "dummy loads," like cooling and heating loads, water pumping, and emergency lights batteries. Once power needs exceed power produced, the battery compensates until the minimum limit is reached. Whenever battery storage runs out and HRES cannot meet load demands, a diesel generator is employed.

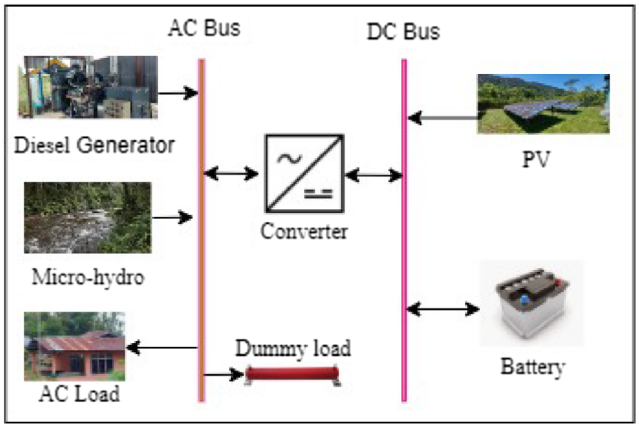

Figure 2. Schematic diagram of the hybrid energy system.

Energy sources can output AC or DC. Solar power plants produce DC output; thus, inverters convert it to AC or vice versa depending on the load. Many academics have undertaken research associated with hybrid systems of clean energy, such as the PV-Diesel hybrid system [22–24], PV-Diesel-Hydro [25, 26], PV-Hydro [27–29], PVWind-Diesel [30–32]. Renewable energy hybrid systems can power large industrial loads, remote communities, microgrids, and grid connectivity. The hybrid system is capable of operating in both off-grid [33–36] and on-grid

modes [37–39]. Researchers struggle to keep up with hybrid system research from many angles.

The purpose of this article is to assist researchers working on renewable energy hybrid systems, with a particular focus on rural and underdeveloped regions. Bibliometric analysis is a quantitative approach that employs statistical methods to investigate extensive compilations of scientific publications and their patterns of citation. This can aid scientists in comprehending the evolution, patterns, cooperation, framework, and influence of a specific domain of knowledge. To perform bibliometric analysis, researchers must employ software that can create and analyze bibliometric networks based on various interactions between publications, authors, journals, and institutions.

The key objectives of this study are summarized as follows (a) technical assessment of renewable energy hybrid systems, (b) identify field contributors such as original sources, authors, countries, and research institutions, (c) explores current trends within the field of renewable energy hybrid systems, (d) demonstrates the progress and development of study findings through time, and (e) investigate how renewable energy relates to using hybrid renewable energy systems in underdeveloped and remote places.

The rest of the paper is organized as follows: Section 2 introduces the methodology, including the data source, retrieval strategy, and bibliometrix methods. Section 3 presents the details of the results and analysis. Furthermore, Section 4 presents the conclusions.

2 Research method and data collection

2.1 Conceptual framework

In the field of bibliometrics, mathematical and statistical techniques are employed to measure and analyze the output, growth, maturation, and consumption of scientific publications. It is frequently employed to evaluate and study the efficiency of researchers in many research domains. Performance analysis and science mapping are bibliometric functions. Performance analysis uses bibliographic data to assess scholarly production's kind, language, journal, and country to identify trends or tipping points in a study field [40, 41]. Science mapping illustrates the scientific field structure. The analysis in this section mostly encompasses citation analysis, co-authorship analysis, burst detection analysis, and co-occurrence analysis [42].

2.2 Selection of database

SCOPUS-based bibliometric examination of hybrid renewable energy systems in developing/remote regions. Scopus was chosen because it is a major repository of published papers, including metadata from reputable journals, and facilitates bibliometric study [35, 36]. The inquiry was conducted between the years 2014 and 2023. The document search was conducted on December 6, 2023, using the keywords "hybrid," "renewable," "energy," "systems," "developing," and "areas." The search focused on relevant literature in the title, abstract, and keyword fields, utilizing the AND operator among other search techniques.

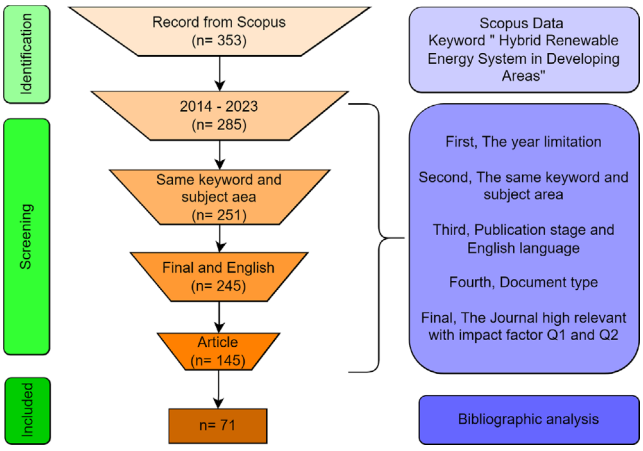

Figure 3. Schematic illustration of the accomplished literature surveying methodology.

In Figure 3, the research technique is diagrammed. The approach has various drawbacks. The authors chose papers using inclusion/exclusion criteria. The criteria are (1) English document type, (2) final publication stage, (3) English language, and (4) journal source type. Finally, even if the keywords are closely connected to the research topic, alternate keywords may indicate additional documents not included in this study. The author exclusively utilizes articles sourced from respected international publications, specifically those classified inside quartile 1 (Q1) and quartile 2 (Q2). Conference papers, reviews, book chapters, conference reviews, books, letters, editorials, data papers, errata, notes, and other publications are excluded. After the inclusion and exclusion criteria were applied, 71 documents were utilized for the research. Afterwards, the 71 documents' metadata was saved in CSV format. Step two involves researching hybrid renewable energy systems in underdeveloped and remote locations using bibliometric tools. This paper's bibliometric analysis was conducted using VOSviewer, and Rstudio Biblioshiny. The processes for employing both bibliometric methods are described in Figure 4.

2.3 VOS viewer

VOSviewer was originally introduced in a paper published in Scientometrics in 2010 [43]. The Vosviewer application can be downloaded on the following page https://www.vosviewer.com/download. VOSviewer is a specialized software that is specifically created to construct and display bibliometric networks. It aids in analyzing the scientific landscape, particularly in regard to publications, journals, and co-authorship connections.

A bibliometric network might demonstrate relationships between the most cited authors, collaboration among authors coordination between countries, organizations, keywords, and topic knowledge [44]. Additionally, VOSviewer provides text-mining capabilities that enable the construction and visualization of networks or flows of literacy mapping from various sources. Some uses of this application

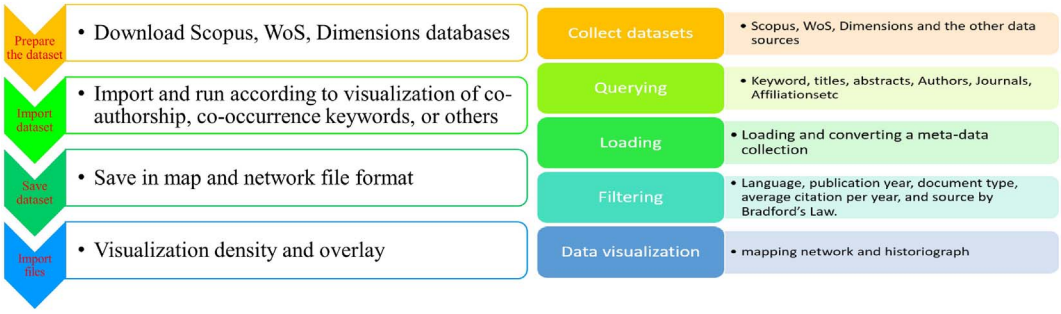

Figure 4. Steps to use VOSviewer and biblioshiny.

Table 1. Key data retrieved from the database.

Description	Results
Timespan	2014:2023
Sources (journals)	23
Documents	71
Annual growth rate %	9.43
Document average age	3.06
Average citations per doc	28.54
References	0
Keywords plus (ID)	749
Author's keywords (DE)	278
Authors	283
Authors of single-authored docs	1
Single-authored docs	1
Co-authors per Doc	4.15
International co-authorships %	47.89
Article	71

include platform research [45], Technological pedagogical content knowledge in Chemistry education [46] and sustainable energy research trends [47].

2.4 Biblioshiny (R-tool software)

Bibliometrix, an open-source tool for quantitative research in the fields of scientometrics and bibliometrics, has been developed by Massimo Aria and Corrado Cuccurullo. This tool encompasses a comprehensive range of bibliometric techniques for analysis. This application can be downloaded on the page https://www.bibliometrix.org/home/.

Biblioshiny is an open-source application capable of importing data from many sources like Scopus and Web of Science, and offering a range of bibliometric analysis options [48]. Bibliometrix is a R utility for performing extensive science mapping analysis. This application is intended to simplify the complicated science mapping process and give detailed analysis of research streams [48]. This application has been widely used in various fields of health research [49–51], social [52, 53], business and management [54].

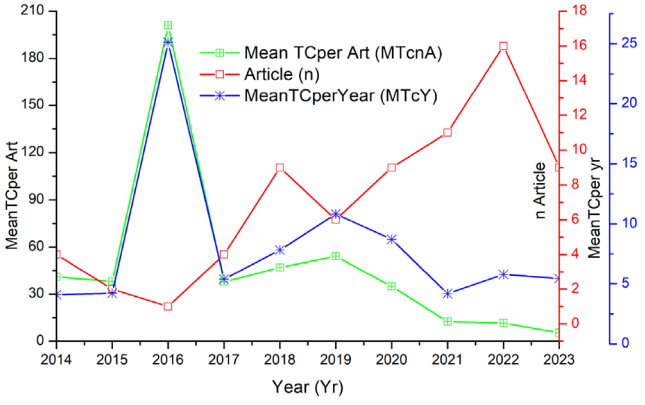

Figure 5. Article and citation growth from 2014 to 2023.

3 Result and analysis

3.1 Descriptive of publications

Table 1 shows that 71 articles have been released in 23 reputable international journals in quartile 1 and quartile 2. A total of 283 people has contributed to this work, with an average of 4.15 writers per document. Publications concerning renewable energy hybrid systems in developing regions encounter an annual growth rate of 9.43%. Table 2 lists the 71 most referenced Scopus publications on hybrid renewable energy systems in developing countries. Future researchers can gain insight from the retrieved data.

Figure 5 illustrates the significant quantity of papers generated annually from 2014 to 2023. The number of publications has consistently risen throughout the years, reaching its peak in 2022 with 16 pieces. As of December 8, 2023, there have been 9 articles published in 2023. This tendency is also observed in the number of citations received in each article and the number of citations received per year.

3.2 Keywords

Figure 6 shows a network visualization map with colored nodes for labels. Frequency of use affects node size. Product label size correlates with usage frequency. The size of segments and connecting lines indicates label co-occurrence frequency. Nodes of the same hue correlate more.

Table 2. The top 71 most cited article in field of hybrid renewable energy systems in developing areas.

Rank	Ref	Author/year/country	Journal	Publisher	Result outcome	Total citations	TC (year)
1	[55]	Shezan SA/2016/Malaysia	Journal of Cleaner Production	Elsevier	The paper illustrates how off-grid wind-PV-diesel-battery hybrid energy systems may supply reliable, sustainable, and cost-effective power for remote places, helping the world shift to cleaner, more efficient energy generation.	201	25.13
2	[56]	Bagheri M/2019/Canada	Applied energy	Elsevier	Research on the economic and carbon costs of urban electrification with renewables at neighborhood scales of a city's electric loads is crucial. It also stresses the necessity to assess how low-emission natural gas turbines could improve 100% renewable electric power systems' techno-economic performance under diverse load patterns.	103	20.60
3	[57]	Jahangir MH/2020/Iran	Sustainable Energy Technologies and assessments	Elsevier	Optimization of system configuration, economic feasibility, and environmental benefits are examined in this study of hybrid systems' sustainable energy solutions for rural areas.	88	22.00
4	[58]	Islam MS/2018/Bangladesh	Energy	Elsevier	This article is original in its comprehensive analysis of hybrid mini-grid systems, techno-economic evaluation using advanced software, emphasis on environmental sustainability, innovative business models, and policy recommendations for rural electrification through renewable energy solutions.	87	14.50
5	[59]	Suresh Kumar U/2014/India	Energy conversion and management	Elsevier	The research examines the renewable portion, carbon emissions, fuel consumption, and economic effects of hybrid power systems in different climates, revealing potential sustainability and efficiency.	81	8.10
6	[60]	Kumar A/2018/India	IEEE access	IEEE	This paper's multidisciplinary microgrid design emphasizes sustainability and community participation, making it unique. The designed microgrid systems are technically feasible, socially acceptable, financially profitable, and environmentally sustainable.	81	13.50
7	[61]	Armin R/2020/Iran	Energy sources part a recovery utilization and environmental effects	Taylor and Francis	The paper's overall approach to energy sustainability within the SDGs is innovative. The report tackles the particular problems and opportunities of emerging countries in attaining sustainable energy systems.	69	17.25
8	[62]	Adaramola MS/2017/Ghana	Sustainable energy technologies and assessments	Elsevier	These findings highlight the importance of renewable energy solutions in distant locations to address energy and water issues, with an emphasis on sustainability, cost-effectiveness, and social advantages.	63	9.00
9	[63]	Ayodele E/2019/Africa	Sustainable energy technologies and assessments	Elsevier	The research shows that a hybrid microgrid system for rural microfinance institutions is economically viable, environmentally friendly, reliable, and potentially applicable to other off-grid communities.	63	12.60

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Table 2. (Continued)

Rank	Ref	Author/year/ country	Journal	Publisher	Result outcome	Total citations	TC (year)
10	[64]	Chowdhury SA/ 2015/ Bangladesh	Journal of Cleaner Production	Elsevier	This study is innovative in its practical insights, extensive research, and realworld implementation of sustainable energy solutions through solar-diesel hybrid mini-grids in offgrid rural areas, particularly Bangladesh.	58	6.44
11	[65]	Kumar R/2022/ India	Journal of Cleaner Production	Elsevier	The study shows the PV-Biomass off-grid hybrid renewable energy system for rural electrification in Punjab, India, is feasible, economically viable, and environmentally friendly.	57	28.50
12	[66]	Razmjoo A/ 2019/Iran	Energy sources part a recovery utilization and environmental effects	Taylor and Francis	The research shows that freestanding hybrid solar-wind systems can provide electricity to small residential areas in regions with high sun radiation and moderate wind speeds. The study stresses the need to consider technical and economic variables in hybrid energy system design and deployment to ensure efficacy and sustainability.	53	10.60
13	[67]	Aaldering LJ/ 2019/Germany	Journal of Cleaner Production	Elsevier	The findings can help stakeholders, practitioners, and policymakers create alternative power-train systems and promote a low-carbon economy. The study sheds light on sustainable transportation by investigating the rivalry and collaboration dynamics of electric, hybrid, and fuel cell electric vehicles.	50	10.00
14	[68]	Kaur M/2020/ India	International Transactions On Electrical Energy Systems	Wiley	The findings demonstrate that photovoltaic and biomass-based systems can be used for sustainable rural electrification in developing regions, providing a cost-effective, job-creating, and environmentally friendly solution.	47	11.75
15	[69]	Shezan SKA/ 2018/Indonesia	Environmental Progress And Sustainable Energy	Wiley	The innovation is creating and simulating a PV-wind diesel-battery hybrid energy system for a small rural or off-grid settlement to reduce greenhouse gas emissions and improve environmental sustainability. This technology optimises renewable energy sources to overcome their constraints.	47	7.83
16	[70]	Balderrama S/ 2019/Bolivia	Energy	Elsevier	The paper considered renewable resource uncertainties and rural electricity consumption stochasticity, suggested the adaptability of the two-stage stochastic optimization framework for isolated microgrids in rural contexts, and provided relevant insights for rural electrification and energy system optimization practitioners.	46	9.20
17	[71]	López G A/ 2018/Venezuela	Energy	Elsevier	This paper's complete evaluation technique for 13 Venezuelan hybrid microgrids is innovative. The results reveal that rural electrification is technically, environmentally, socially, and economically viable.	45	7.50

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Table 2. (Continued)

Rank	Ref	Author/year/country	Journal	Publisher	Result outcome	Total citations	TC (year)
18	[72]	Lata Garcia J/2018/Spain	Energy	Elsevier	The results show that a hydrogen and battery hybrid system with a photovoltaic generator, river turbine, and energy storage subsystem can meet load power requirements with optimized hydropower and solar generation. A techno-economic study shows that the battery storage subsystem regulates loading to prevent severe discharges and ensure reliable power delivery.	45	7.50
19	[73]	Micangeli A/2017/Kenya	Energies	MDPI	These results show that optimizing energy output in off-grid power plants improves dependability, performance, and sustainability, especially in remote poor nations like Kenya. The evaluation of hybrid systems (solar, diesel generator, with and without batteries) focuses on electrification issues, optimization criteria and levels, and policy consequences.	44	6.29
20	[74]	Kirmani S/2018/India	IET Renew Power Generation	Wiley	This paper's comprehensive analysis of integrating renewable energy sources (solar and wind) with conventional power generation, economic feasibility assessment, solar radiation estimation model development, and carbon emission reduction in specific Indian locations is unique.	39	6.50
21	[75]	Edwin M/2014/India	Energy conversion and management	Elsevier	The results illustrate how hybrid energy systems can improve milk preservation in remote areas by using renewable energy sources while considering economic viability and sustainability.	36	3.60
22	[76]	Fioriti D/2018/Kenya	Electric Power System Research	Elsevier	Stochastic sizing for remote rural mini-grids is examined in this research, taking fuel procurement and operating strategy risks into account. Photovoltaic generators, batteries, and converters can be sized to maximize efficiency, dependability, and cost.	33	5.50
23	[77]	Li Y/2014/Southern Alaska	Applied Energy	Elsevier	This project uses offshore renewable energy holistically to reduce emissions and prices and enable sustainable energy solutions in remote places.	33	3.30
24	[78]	Arefin SS/2017/Malaysia	Technology And Economics Of Smart Grids And Sustainable Energy	Springer	The results highlight the design and simulation of wind-diesel hybrid energy systems in providing cost-effective and environmentally friendly electricity supplies to off-grid communities, contributing to energy resilience and sustainability in geographically remote areas.	29	4.14
25	[79]	Naeini MA/2020/Iran	Energy	Elsevier	This article highlights microalgae's potential as a sustainable biodiesel feedstock and provides a roadmap for policymakers, researchers, and industry players to build Iran's biodiesel sector. The interdisciplinary approach strengthens the research findings and provides a holistic understanding of microalgae-based biodiesel production's prospects and challenges.	29	7.25

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Table 2. (Continued)

Rank	Ref	Author/year/ country	Journal	Publisher	Result outcome	Total citations	TC (year)
26	[80]	Garćıa VERA YE/2020/ Colombia	Energy conversion and management	Elsevier	This research examines how realistic battery aging models, temperature, economics, and battery technology affect isolated hybrid microgrids with renewable energy. These discoveries help improve hybrid microgrid systems in remote or off-grid regions' efficiency, dependability, and cost.	27	6.75
27	[81]	Apichonnabutr/ 2018/Thailand	Applied Energy	Elsevier	This research shows just how challenging it is to balance economic and environmental concerns while adopting hybrid energy systems, especially in rural and environmentally sensitive places like Khun Pang village in Thailand.	26	4.33
28	[82]	Faessler B/ 2021/Europe	Energies	MDPI	This article discusses energy storage system reuse trends, difficulties, and opportunities. It also emphasizes the need to overcome economic, environmental, technological, and legal constraints to promote sustainable and environmentally friendly second-hand baenergienergy storage systems.	24	8.00
29	[83]	Shafiullah GM/ 2021/Zimbabwe	IEEE Access	IEEE	In Zimbabwe, integrating microhydro renewable energy sources, PV, with diesel generators increases energy access, reduces greenhouse gas emissions, and supports sustainable development goals. The report analyses the technical, economic, and environmental elements of rural system implementation.	23	7.67
30	[84]	Talaat M/2021/ Egypt	International Journal Of Electrical Power And Energy Systems	Elsevier	This paper integrates renewable energy sources with fuel cells in off-grid hybrid systems, developing novel experimental and control models for energy generation and system performance. This research examines efficiency, dependability, and system adaptability under varied settings.	23	7.67
31	[85]	Al G L/2020/ Jordan	Energy conversion and management	Elsevier	The study analyses a 100% renewable energy network for rural electrification from technical, economic, and environmental perspectives to deliver sustainable electricity in remote places.	20	5.00
32	[86]	Khan MA/ 2018/Tanzania	Energies	MDPI	This research offers options that can be easily implemented in similar climates, improving electrification and sustainable energy. A closed-loop cooled solar system (CLC-SS) extracts more power from solar modules to boost solar-wind hybrid system efficiency.	20	3.30
33	[87]	Edwin M/2015/ India	Energy	Elsevier	The article integrates renewable energy sources, optimizes energy combinations based on regional features, and emphasizes the economic and environmental benefits of sustainable milk cooling unit energy solutions in rural settlements.	18	2.00

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Table 2. (Continued)

Rank	Ref	Author/year/country	Journal	Publisher	Result outcome	Total citations	TC (year)
34	[88]	Goswami A/2020/India	Journal Of Solar Energy Engineering Transactions Of The ASME	ASME	This research demonstrates how a solar-wind hybrid system could help Sagar Island overcome its energy challenges, such as location and electricity supply, by maximizing energy generation and efficiency while reducing carbon emissions and fossil fuel dependence.	17	4.25
35	[89]	Vaziri RAD MA/2022/Iran	Energy conversion and management	Elsevier	A holistic approach to pandemic energy concerns in healthcare facilities, unique optimization methods, detailed sensitivity analysis, concentration on poor nations, and validation and generalization of results are presented in this work.	16	8.00
36	[90]	Islam MR/2022/Bangladesh	Energies	MDPI	This paper examines the effectiveness of optimal system design, the economic viability of hybrid energy solutions, the system's sensitivity to key parameters, the payback period, and the overall feasibility of sustainable rural electrification in developing countries, focusing on Bangladesh.	16	8.00
37	[91]	Belboul Z/2022/Algeria	Energies	MDPI	In optimizing a PV/Wind/Battery/Diesel Hybrid Power Plant System in Djelfa, Algeria, this paper applies the MOSSA algorithm, multiobjective optimization, a rule-based EMS, real data analysis, and a comparative analysis of optimization algorithms.	15	7.50
38	[92]	Tang S/2021/China	Journal of Cleaner Production	Elsevier	This research establishes that the hybrid CS-PS algorithm optimizes solar-powered microgrid resource scheduling efficiently, effectively, and robustly. This study shows that this technique can overcome renewable energy integration and microgrid operational cost difficulties.	15	5.00
39	[93]	Shahverdian MH/2022/Tehran	Energy conversion and management	Elsevier	This research employs multi-objective optimization, water footprint functions, detailed economic analysis, and comprehensive parameter analysis to evaluate the hybrid PV-PEMFC system performance, sustainability, and economic feasibility.	15	7.50
40	[94]	Tiwari P/2017/South Asian	Technology And Economics of Smart Grids And Sustainable Energy	Springer	This paper covers the latest microgrid technological breakthroughs in Hybrid Renewable Energy Systems. Microgrid modelling, control, dependability, and energy management with HRES are covered. The authors emphasise rural electrification and the possibility of renewable energy microgrids to address remote electricity needs. (b) Comparison of renewable energy sources in different areas to demonstrate hybrid energy system feasibility and efficacy.	15	2.14

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Table 2. (Continued)

Rank	Ref	Author/year/ country	Journal	Publisher	Result outcome	Total citations	TC (year)
41	[95]	Tarife R/2022/ Philippines	Energies	MDPI	This research employs MOPSO algorithm modeling to design an off-grid hybrid renewable energy microgrid. This study shows that renewable energy solutions can solve rural farming communities' electrical electricity problems in the Southern Philippines.	14	7.00
42	[96]	Klintenberg P/ 2014/Africa	Applied Energy	Elsevier	This study emphasizes community participation, capacity building, and sustainable financing models for renewable energy technology transfer in poor nations, particularly rural Sub-Saharan Africa.	14	1.40
43	[97]	Buenfil R V/ 2022/Mexico	Applied Energy	Elsevier	A cost study found that a hybrid energy system with a photovoltaic system, diesel generator, and energy storage is best for a distant rural town near Yucatan, Mexico. This article discusses fuel usage, system dependability, and project costs.	12	6.00
44	[98]	Demirci A/ 2023/Turkey	Energy	Elsevier	The design and setup of a PV-DG-ESS-WT hybrid renewable energy system for rural electrification are optimized. This study assesses the economic and technical viability of hybrid configurations, taking into account climate zones, economic and technical integration, and rural electrification project decision-making frameworks.	12	12.00
45	[99]	Mishra S/2023/ India	Renewable Energy Focus	Elsevier	This study emphasizes the necessity of integrating renewable energy sources with battery storage in grid-connected systems to alleviate rural areas' lack of sustainable grid electricity supply by selling or buying grid power. DHS optimizes a biomass, solar PV, converters, and battery bank hybrid system.	12	12.00
46	[100]	Garćıa V YE/ 2020/Colombia	Energy Conversion and Management	Elsevier	This article discusses site-specific optimization, demand-side management, and the potential benefits of integrating renewable energy sources and advanced control strategies in isolated microgrid systems to improve sustainability and coste-ffectiveness in remote energy supply solutions.	11	2.75
47	[101]	Calise F/2021/ Italy	Energies	MDPI	Dynamic simulation, SOFC technology integration, hydrogen storage to reduce power grid dependence, significant energy savings, and optimized operation of renewable hybrid systems demonstrate their effectiveness in balancing energy supply and demand while ensuring economic viability.	10	3.33
48	[102]	Bilal M/2023/ India	Energy Conversion and Managementf	Elsevier	Optimizing system layout and overcoming hurdles for sustainable deployment are crucial to the technical and economic feasibility of using renewable energy sources such as PV, WT, and EV charging for electric vehicle charging stations in India.	10	10.00

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Table 2. (Continued)

Rank	Ref	Author/year/country	Journal	Publisher	Result outcome	Total citations	TC (year)
49	[103]	Anand P/2019/India	International Journal Of Energy Technology and Policy	Inderscience Enterprises	This paper proposes a particle swarm optimization (PSO)-optimized biomass-biogas-solar power generation hybrid model based on available resources and total annual costs (TAC).	10	2.00
50	[104]	Safiullah S/2022/New England	Energy Reports	Elsevier	An innovative control strategy for voltage-frequency stabilization in multi-area power networks using advanced AI algorithms, electric vehicles, and renewable energy sources is presented in this study.	9	4.50
51	[105]	Fathollahzadeh MH/2021/United States	Sustainable Cities And Society	Elsevier	To model renewable energy systems, this paper uses indigenous communities, the LK script language script technique, and open-source System Advisor Model software components. This strategy emphasizes sustainability and resilience in energy planning to help indigenous communities comprehend and implement renewable energy systems.	9	3.00
52	[106]	M gamil M/2021/Egypt	Aims Energy	AIMS	The economic feasibility of PV with BESS is examined using uncertainty, bio-gasification generation, thorough case studies, and optimization algorithm comparisons.	9	3.00
53	[107]	Salem AA/2021/Egypt	IEEE Access	IEEE	This article applies stability analysis to real-world grid codes, focuses on a single wind turbine, and validates it with simulations and practical data.	8	2.67
54	[108]	Kheir ABADI M/2023/Iran	Energy Conversion and Management	Elsevier	This article generates heating and power for absorption and compression chillers using evacuated tube collectors (ETC) and photovoltaic (PV) panels, addressing energy efficiency, economic feasibility, and renewable resource utilization.	6	6.00
55	[109]	Mohd SAFARI MA/2020/Malaysia	Energies	MDPI	This article analyses rural populations' adoption of wind and solar energy technology, makes policy recommendations, and emphasizes renewable energy education.	6	1.50
56	[110]	Shen Y/2022/Hongkong	Journal of Cleaner Production	Elsevier	This research combines selected air recirculation tactics with solar power to reduce emissions, enhance air quality, and increase energy efficiency in an indoor CO2 collection system.	6	3.00
57	[111]	Konneh KV/2022/Africa	Energy	Elsevier	This study analyses hybrid and independent system configurations for environmental sustainability, cost effectiveness, sensitivity to key variables, and potential use in Sierra Leone and other electrification projects.	6	3.00
58	[112]	Tahir MUR/2021/Pakistan	Aims Energy	AIMS	This research indicates that hybrid energy generation systems optimized with HOMER software may deliver sustainable electricity to rural areas, boosting society's progress and well-being.	6	2.00

(Continued on next page)

Table 2. (Continued)

Rank	Ref	Author/year/country	Journal	Publisher	Result outcome	Total citations	TC (year)
59	[113]	Sanjel N/2021/Nepal	Clean Energy	Oxford University	Analytical methodologies and electrification choices are used to optimize renewable energy systems and power grid expansion. The evaluation is based on LCC and economic distance limits. Compare each energy system under different load conditions to find the best one. This study aims to create a reliable and affordable electrification framework.	6	2.00
60	[114]	Baldinelli A/2021/Africa	Journal of Cleaner Production	Elsevier	This paper evaluates innovative technologies, sector integration strategies, techno-economic optimization, and geographic relevance for improving energy access, water desalination, and economic competitiveness in remote and rural developing countries, particularly Sub-Saharan Africa.	5	1.67
61	[115]	Osman AM/2022/Sudan	Energy Reports	Elsevier	This research uses unique control methodologies, system design considerations, and performance evaluation to demonstrate the technical and economic feasibility of a grid-connected PV-Bayu hybrid system in Dongola.	5	2.50
62	[116]	Beitelmal WH/2022/Libya	MRS Energy and Sustainability	Cambridge university press	This research employs renewable energy to overcome inconsistent electricity supply to distant villages during the COVID-19 pandemic at three health centers. This article helps stakeholders and designers optimize remote community hybrid energy systems.	5	2.50
63	[117]	El HASSANI S/2023/Morocco	Solar Energy	Elsevier	This research applies civil engineering and energy systems engineering to design near-zero energy buildings (nZEB) using locally produced environmentally friendly building materials and customized renewable energy systems to reduce environmental impact and energy costs.	5	5.00
64	[118]	Jacob E/2022/Japan	Energy Conversion and Management	Elsevier	This study shows that a self-sustaining hybrid microgrid system for off-grid energy applications in three Japanese regions is technically feasible and promising.	3	1.50
65	[119]	Rangel N/2023/Africa	Applied Energy	Elsevier	This study considers pollutant emissions costs, provides a cost-benefit analysis, and offers practical system selection and diesel generator performance suggestions to optimize hybrid microgrid systems.	3	3.00
66	[120]	Lopez P JL/2022/Colombia	IEEE Access	Elsevier	This computing-based study investigates how microgrids impact the reliability of rural distribution systems. Consideration of distributed generation penetration and energy storage capacity improves system resilience with microgrid integration.	6	1.50

(Continued on next page)

Table 2. (Continued)

Rank	Ref	Author/year/country	Journal	Publisher	Result outcome	Total citations	TC (year)
67	[121]	Roshanzadeh B/2022/USA	Energies	MDPI	The study discusses an evaporated solar hybrid photovoltaic-thermal collector that produces energy and domestic hot water while emitting less carbon. This study examined ways to improve thermal efficiency with vacuum glass tube encapsulation.	3	1.50
68	[122]	Huang Y/2023/China	Energy Conversion and Management	Elsevier	This study suggests that the suggested framework optimizes biomass power trading in hybrid renewable energy systems to improve reliability, profitability, and sustainability. Established a two-level multiobjective dynamic optimization model to simulate stakeholder interactions in a 100% renewable energy hybrid to balance system dependability, environmental benefit profit requirements, and social value.	1	1.00
69	[123]	Olatomiwa L/2023/Nigeria	Energies	MDPI	This research utilizes geographic diversity, novel data sources, technoeconomic analysis, simulations, and environmental impact assessments to address energy challenges in rural Nigerian healthcare facilities and recommend a feasible hybrid renewable energy system.	0	0.00
70	[124]	Iweh CD/2023/Cameroon	Energy Reports	Elsevier	This study demonstrates how PSO and DE algorithms can optimize solar-hydro PV hybrid power systems by taking into account operational constraints and uncertainties in renewable energy generation, improving the economic and technical feasibility of off-grid renewable energy applications.	0	0.00
71	[125]	Ali A/2022/Pakistan	Energies	MDPI	This study offers a nano grid technology to power disadvantaged rural Pakistani areas using renewable hybrid energy. This article calculates society's payback time using mathematical modeling, artificial neural network-based forecasting, and social analysis.	0	0.00

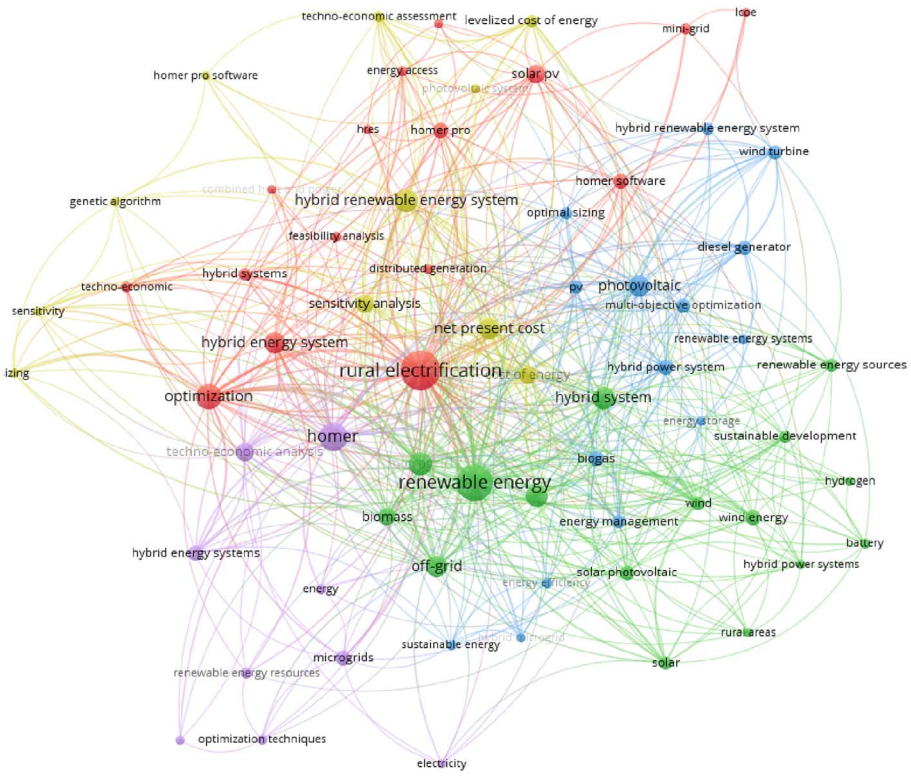

Figure 6. Keyword co-occurrence network map.

Co-occurrence of keywords Network analysis is an effective way to visualize and comprehend scientific trends and problems over time. This map of patterns is concise and easy to read. Co-occurrence analysis shows a framework's conceptual organization or condenses it into a bibliography. Utilizing co-occurrence networks to visualize and cluster keyword phrases does this.

The keyboard is partitioned into five distinct clusters, as illustrated in Figure 6. Each cluster is designated by aunique color. A total of 1222 keywords were examined to generate a co-occurrence network. Keywords that appear no less than five times in the publication under consideration. Clusters are established on the basis of thematic coherence, which is determined by the total number of connections that exist between specific keywords.

The categorization of terms is displayed in Table 3, based on clusters, occurrences, overall link strength, average annual publication, and average normal citations. Table 3 shows the publication year and average normalized citation value to assess if research is trending or falling. Cluster 1 is the largest, with the keyword that appears most frequently being rural electrification followed by optimization. In clusters 2, 3, 4, and 5, renewable energy (68), hybrid renewable energy system (28), net present cost (24), and homer (42).

Scientific mapping uses themed maps to show a study domain's conceptual structure (Fig. 7). The horizontal (centrality) and vertical (density) axes split the thematic map into four quadrants: quadrant 1 (basic themes), quadrant II (Motor Themes), quadrant III (Niche Themes), and

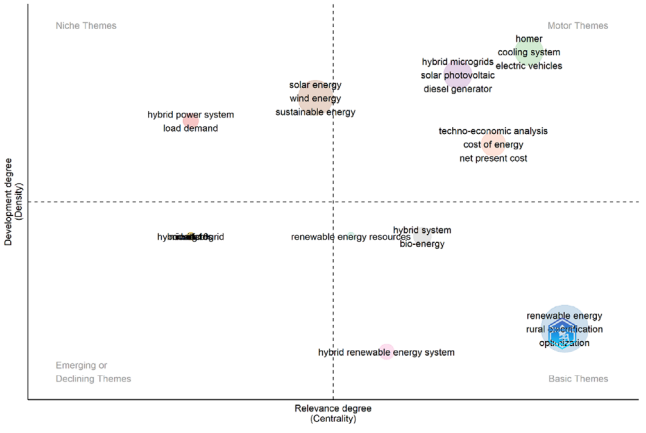

Figure 7. Thematic map.

quadrant IV (Emerging or Declining Themes). Quadrant I has strong centrality and low intensity, addressing the field's key issues and intersecting with allied disciplines. Quadrant II has lesser centrality and intensity, indicating underdeveloped or irrelevant issues. Quadrant III has higher centrality and density values, indicating a well-developed motor theme relevant to domain conceptual frameworks. Quadrant IV is a specific area since the issue is well-developed but outside the scope. Motor themes are extensively researched and developed subjects. Themes that are highly developed and isolated occupy a moderate level

Table 3. The most popular keywords in HRES in developing areas.

Keyword	Cluster	Occurrences	Total link strength	Avg. Pub. year	Avg. Norm citations
Rural electrification	1	81	155	2021.22	1.46
Optimization	1	34	87	2021.79	1.13
Hybrid system	1	27	54	2021.19	0.75
Hybrid energy system	1	24	44	2021.17	1.49
Solar pv	1	17	32	2020.88	1.32
Homer pro	1	12	26	2021.92	0.79
Homer software	1	12	24	2021.25	0.84
Techno-economic	1	7	16	2021.29	1.16
Energy access	1	6	14	2021.50	1.29
Feasibility analysis	1	6	11	2020.17	0.93
Distributed generation	1	6	10	2020.83	0.44
Mini-grid	1	7	9	2020.14	0.96
Combined heat and power	1	5	7	2022.20	1.08
HRES	1	5	7	2021.80	0.54
Rural area	1	5	6	2022.60	0.66
LCOE	1	5	5	2022.40	0.33
Renewable energy	2	68	141	2021.19	1.09
Microgrid	2	29	77	2021.38	1.37
Off-grid	2	23	55	2021.30	1.25
Solar energy	2	26	46	2020.81	0.90
Biomass	2	16	39	2021.31	2.05
Wind	2	10	37	2020.90	2.37
Hybrid power systems	2	12	31	2020.00	0.49
Solar photovoltaic	2	11	29	2021.82	0.88
Solar	2	9	27	2020.78	0.73
Wind energy	2	12	24	2020.33	1.27
Sustainable development	2	8	19	2021.35	0.92
Renewable energy sources	2	9	18	2022.29	0.73
Hybrid systems	2	8	16	2021.25	1.80
Battery	2	6	13	2020.83	1.15
Rural areas	2	5	11	2021.00	1.13
Hydrogen	2	5	8	2020.20	1.39
Hybrid renewable energy systems	3	28	53	2021.25	2.42
Photovoltaic	3	25	50	2020.88	0.99
Biogas	3	13	31	2020.92	1.51
Diesel generator	3	11	31	2021.36	0.86
Wind turbine	3	11	27	2021.45	0.85
Energy management	3	9	22	2021.67	1.60
Optimal sizing	3	8	21	2021.88	1.60
Multi-objective optimization	3	11	18	2020.91	1.38
pv	3	9	18	2021.11	1.85
Energy storage	3	5	14	2021.40	0.30
Hybrid microgrid	3	5	13	2021.60	0.68
Sustainable energy	3	6	12	2020.67	0.87
Energy efficiency	3	6	11	2021.17	1.14
Renewable energy systems	3	6	10	2021.50	0.97
Hybrid power system	3	12	31	2021.50	1.39

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Table 3. (Continued)

Keyword	Cluster	Occurrences	Total link strength	Avg. Pub. year	Avg. Norm citations
Net present cost	4	24	71	2021.25	1.26
Cost of energy	4	18	55	2021.72	1.68
Levelized cost of energy	4	8	22	2021.62	1.73
Techno-economic assessment	4	7	20	2021.86	2.29
Sizing	4	5	17	2021.00	0.89
Genetic algorithm	4	5	10	2021.20	1.64
Photovoltaic system	4	5	10	2021.60	2.01
Homer pro software	4	5	8	2020.40	2.53
Sensitivity	4	5	21	2022.40	2.70
Hybrid renewable energy system (hres)	4	5	6	2021.40	1.64
Homer	5	42	82	2021.17	1.24
Techno-economic analysis	5	17	40	2021.29	1.28
Micorgrids	5	12	16	2020.50	0.64
energy	5	6	12	2021.50	0.52
Hybrid renewable energy sistems	5	8	11	2021.12	0.74
Electricity	5	5	9	2021.80	0.63
Optimization techniques	5	6	9	2022.00	1.43
Hybrid energy systems	5	13	25	2021.38	1.57
Renewable energy resources	5	7	9	2022.29	0.37

Table 4. Top ten articles based on highest citation in 2019–2023.

Rank	Ref	Keywords	Article DOI	Total citations	TC per year
1	[56]	Urban electrification; Hybrid renewable power system; Load patterns; Neighborhood scales; City of Victoria	10.1016/j.apenergy.2019.02.031	103	20.60
2	[57]	Hybrid renewable energy system; Rural settlement; Environmental assessment; Optimal system configuration; HOMER Pro software	10.1016/j.seta.2020.100895	88	22.00
3	[61]	Energy sustainability; indicators; hybrid system; renewable energy; electrical production	10.1080/15567036.2019.1602215	69	17.25
4	[63]	Renewable energy; Sustainable energy; Hybrid microgrid; Energy efficiency	10.1016/j.seta.2019.06.009	63	12.60
5	[65]	Sustainable energy generation; PV system; Biomass system; hybrid renewable energy system; design and optimization; TOPSIS	10.1016/j.jclepro.2022.131347	57	28.50
6	[66]	Sustainable energy; hybrid systems; wind energy; solar energy	10.1080/15567036.2018.1544996	53	10.60
7	[67]	Electric vehicles; Electric mobility; Link prediction; Patent analysis; Social network analysis; ecosystem	10.1016/j.jclepro.2018.12.047	50	10.00
8	[68]	Biomass; hybrid energy system; microgrid; optimization; pollutant emission; renewable energy integration	10.1002/2050-7038.12347	47	11.75
9	[70]	Microgrids; Rural electrification; Isolated energy systems; energy; Open energy modeling	10.1016/j.energy.2019.116073	46	9.20
10	[79]	Microalgae; SWOT analysis; Fuzzy cognitive map; Step-wise weight assessment ratio analysis; Weighted aggregated sum product assessment	10.1016/j.energy.2020.116895	29	7.25

Table 5. Top15 journals, the number of documents, published articles, citations, and impact factor.

No.	Journal source	Country	Quartile	H_index	TC	NP	PY_start
1	Energies	Switzerland	Q1	10	210	14	2017
2	Energy	United Kingdom	Q1	7	294	9	2015
3	Journal of Cleaner Production	United Kingdom	Q1	6	393	8	2015
4	AppliedEnergy	United Kingdom	Q1	5	191	6	2014
5	Energy conversion and management	United Kingdom	Q1	4	145	5	2014
6	Sustainable energy technologies and assessments	United Kingdom	Q1	4	230	4	2017
7	IEEE access	United Kingdom	Q1	3	115	4	2018
8	AIMS energy	United Kingdom	Q2	2	15	2	2021
9	Energy reports	United Kingdom	Q2	2	14	3	2022
10	Energy sources, part A: recovery, utilization and environmental effects	United Kingdom	Q2	2	122	2	2019
11	Technology and economics of smart grids and sustainable energy	Singapore	Q2	2	44	2	2017
12	Clean energy	United Kingdom	Q2	1	6	1	2021
13	Electric power systems research	Netherlands	Q1	1	33	1	2018
14	Environmental progress and sustainable energy	United Kingdom	Q2	1	47	1	2018
15	IET renewable power generation	United Kingdom	Q2	1	39	1	2018

Table 6. Top 10 prolific writers with 2+ articles.

Rank	Author name	Current institution	Country	No. of article	No. of citation	H-index	Position on the authors' list
1	Senjyu T	University of the Ryukyus	Japan	3	25374	72	fourth ($n = 4$), fourth ($n = 4$), sixth ($n = 6$)
2	Bernal-Agustin JL	University of Zaragoza	Spain	2	9178	39	Third ($n = 3$), Third ($n = 3$)
3	Davarpanah A	Islamic Azad University	Iran	2	3147	34	Third ($n = 3$), Second ($n = 2$)
4	Del Citto R	University of Rome La Sapienza	Italy	2	77	3	Sixth author ($n = 8$), Second author ($n = 9$)
5	Dufo-Lopez R	University of Zaragoza	Spain	2	10455	41	Second author ($n = 3$), Second author ($n = 3$)
6	Edwin M	Anna University	India	2	448	12	First ($n = 2$), First ($n = 2$)
7	Fioriti D	University of Pisa	Italy	2	778	16	First author ($n = 8$), eighth ($n = 9$)
8	Garcia-Vera YA	San Buenaventura University	Colombia	2	353	5	First author ($n = 3$), First author ($n = 3$)
9	Micangeli A	University of Rome La Sapienza	Italy	2	640	16	First author ($n = 9$), Sixth ($n = 8$)
10	Poli D	University of Pisa	Italy	2	2520	24	Third ($n = 8$), ninth ($n = 9$)

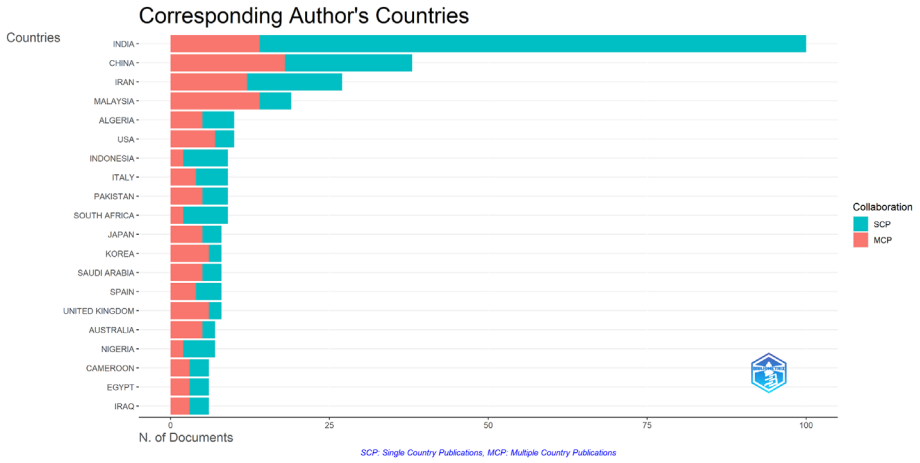

Figure 8. Publications per country using SCP and MCP parameters.

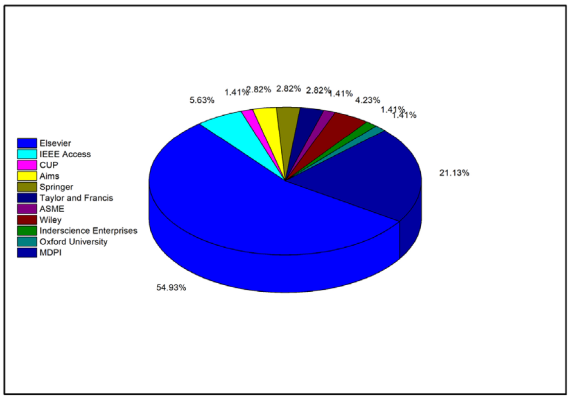

Figure 9. Number of articles according to publisher.

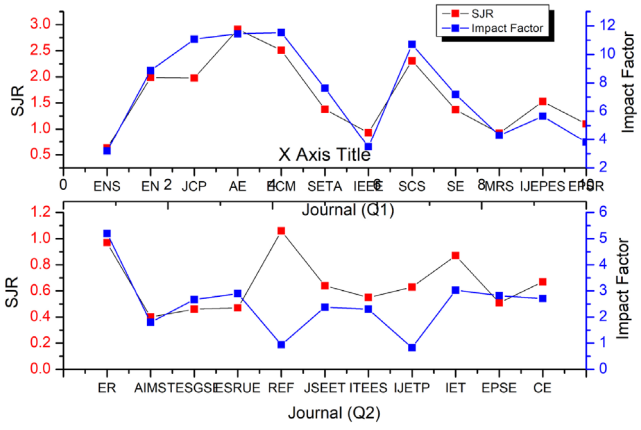

Figure 10. SJR and Impact Factor of article.

of density, yet they lack centrality and are regarded as peripheral. The concepts of emergence and decline are underdeveloped and marginal. Simultaneously, fundamental and transverse concerns arise due to inadequate density. Most scientific studies and citations on "hybrid microgrids, solar PV, and diesel generator" belong to keywords in the motor theme group. High centrality and low density characterize hybrid power systems and load demand, two advanced but specialist subjects. The keywords in this group have been more productive in the past, but their relevance has declined. Renewable energy, rural electrification, and optimization are basic themes with a great deal of density but weak centrality. Keywords in the following category have a low inherent connectivity.

3.3 The most influential publications

Table 4 exhibits the ten articles that received the most citations in the past five years, along with the overall number of citations per year. The first article by Bagheri M, followed by Jahangir MH, with numbers of citations 103 and 88, respectively. Annual citation counts alter due to research focus and renewable energy technology advances.

According to the values of h-index, TC, NP, and PYstart in Table 5, the journal Energies is the top publisher in the field of renewable energy hybrid systems. During the period from 2014 to 2023, the Applied Energy and Energy Conversion and Management journals were the pioneers in publishing publications on hybrid renewable energy. These articles were selected from a pool of 15 prestigious journals. Journals ranked in positions 1–7 are classified as Q1 journals, indicating that they have a higher quality compared to journals in other quartiles when considering the h-index.

3.4 Authors and co-authorship

Table 6 presents the most prolific authors with two or more articles, country of origin, current institution, number of articles, the current number of citations, h-index, and the position of the author's list. Senjyu T holds the record for the most citations among authors, with 3 works affiliated with the University of the Ryukyus in Japan. Italy has the most authors, with a total of 4, who have contributed

Table 7. The top 10 Countries with the most articles and citations.

No.	Country	Article	Total citation	Average article citation
1	India	12	351	29.20
2	Iran	7	276	39.40
3	Malaysia	3	254	84.70
4	China	4	130	32.50
5	Spain	4	128	32.00
6	Canada	1	103	103.00
7	Sweden	2	101	50.50
8	Italy	4	92	23.00
9	Norway	2	87	43.50
10	United Kingdom	3	87	29.00

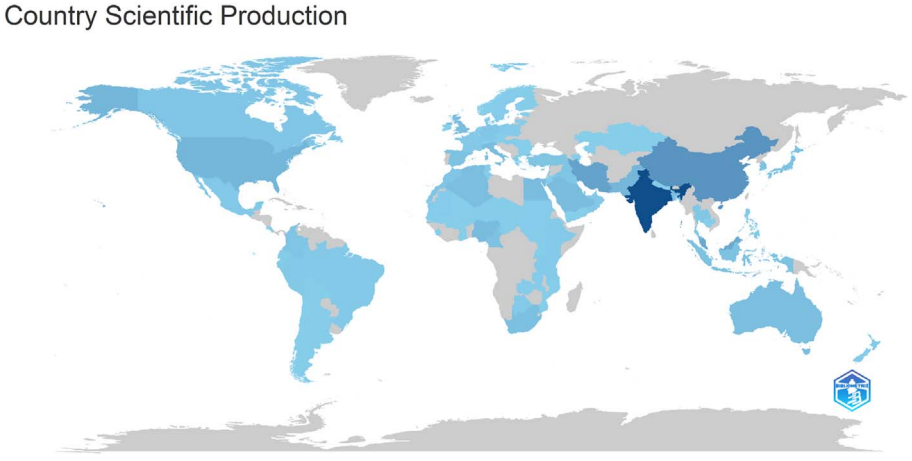

Figure 11. Density map of publications in different countries.

8 pieces. Spain follows closely behind with 2 authors who have written 4 articles.

Using the SCP (single country publications) and MCP (multiple country publications) criteria, Figure 8 presents the collaboration map for research papers on topics related to hybrid renewable energy systems in developing areas. Though China has more MCP articles, India has more SCP articles. From what we can tell, Chinese authors collaborate more than any other country.

3.5 Highly productive publisher

Figure 9 presents a comprehensive visual representation of the highly referenced papers chosen from the Scopus database, which were published by various publishers. Elsevier was the most prolific publisher, responsible for 54.93% of the total 71 papers. Following closely behind was MDPI, with a contribution of 21.13%. Figure 10 illustrates the frequency of articles published in various journals categorized as quartile 1 and quartile 2, together with their corresponding impact factor and scimago journal rank (SJR) values.

3.6 Countries and collaboration

Based on Table 7, India has the most documents (12) with 351 citations. The United States, China, and Iran consistently have the highest number of publications in energy and engineering bibliometric research; therefore, this is significant. Iran follows with 7 articles (276 citations), China, Spain, and Italy with 4 articles and 130, 128, 92 citations, respectively.

Countries' research production is directly related to publication numbers. Figure 11 depicts the geographic trend of highly productive countries using publication density maps. The survey included 89 countries, with blue tints representing publication numbers. Darker blue-green indicates more publications in the country. According to the figures presented in Figure 11, India exhibits the highest level of productivity, with a total of 122 publications, whilst China ranks second with 46 publications. Iran, Malaysia, and the USA have 41, 33, and 25 publications, respectively. Typically, scholarly publications tend to be concentrated in the regions of Asia and America.

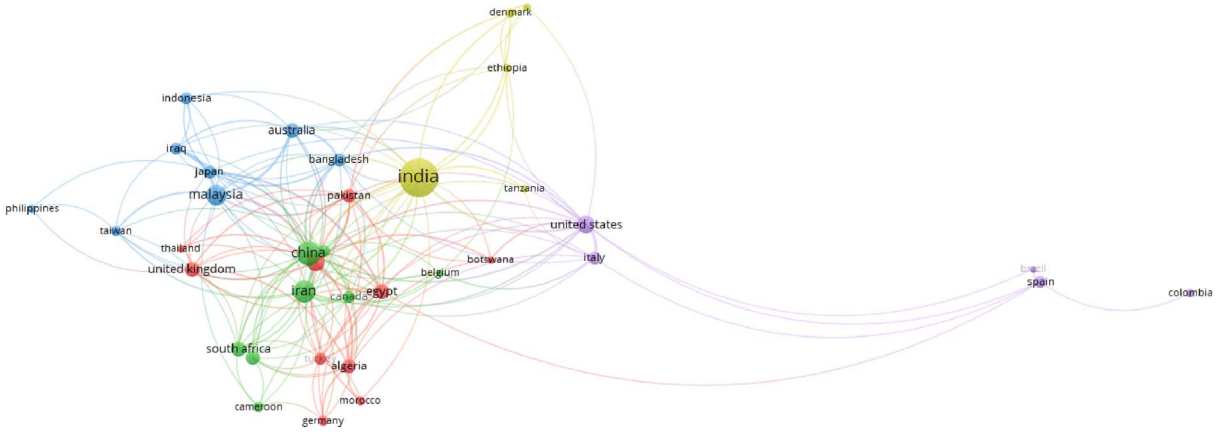

Figure 12. The collaboration network of authors with 35 countries.

Table 8. Top 15 productive institutions in HYRES research.

No.	Affiliation	Articles	Country
1	University of the Ryukyus	11	Japan
2	University of Malaya	9	Malaysia
3	University of Tehran	9	Iran
4	Pusan National University	7	Korea
5	Federal University of Technology	6	Nigeria
6	Mirpur University of Science And Technology	6	Pakistan
7	University of Pisa	6	Italy
8	Islamic Azad University	5	Iran
9	Universidad Autónoma de Yucatán	5	Mexico
10	University Kebangsaan Malaysia	5	Malaysia
11	University of Naples Federico II	5	Italy
12	Colorado School of Mines	4	United States
13	Dhofar University	4	Oman
14	Oujda	4	Morocco
15	University of Rome La Sapienza	4	Italy

A global collaboration network is illustrated in Figure 12. Countries are represented by nodes, and the presence of a link between two nodes signifies that the two nations have collaborated on publications. A greater number of pertinent research papers are published in the correspondence between two nations, as the node size increases. Furthermore, centrality increases with circle size. Five nations with the greatest level of centrality are India, China, Iran, Malaysia, and the United States, as demonstrated. This shows that substantial interaction and collaboration have occurred between these nations.

3.7 Most productive institutions

Table 8 displays the top 15 institutions that have produced the most number of articles on hybrid renewable energy systems in developing regions. These institutions have accounted for 90 publications, which represent 60.81% of the total. Among these institutions, there were three representatives from Italy and two representatives from Malaysia and Iran. Based on total article production, Italy has 15 articles, Malaysia and Iran have 14 articles each, followed by Japan with 11 articles, Korea with 7 articles, and Pakistan with 6 articles. Meanwhile, countries like Mexico, United States, Oman and Morocco each have 4 articles.

4 Conclusion

Renewable energy sources like fuel cells, wind, solar, biomass, hydro, and others can meet future energy needs. Renewable energy can be hybridized. In developing countries, renewable energy hybrid systems are used when power grid expansion is unaffordable. Hybrid renewable energy systems are reliable and environmentally friendly, especially when fossil fuel sources decline. Recently, hybrid renewable energy systems have emerged as a new concept that needs

further study. The fast advancement of renewable energy technology, the opening of new energy markets, and financial strategies and rules all help create clean, long-lasting mixed renewable energy systems. Their number has climbed to several dozen per year. This report examines growing region hybrid renewable energy hybrid system research from 2014 to 2023. VOSviewer, Rstudio Biblioshiny, and Excel will help with bibliometric analysis. The analysis focuses on publication numbers, authors with the highest productivity, citation counts, productivity by country, collaboration between countries and authors, hybrid renewable energy systems (HRES) journals, and HRES thematic evolution. Following Scopus statistics, 353 entries were found on this topic. Keyword screening, subject area relevance, publishing stage, English language, and high-impact journals (Q1 and Q2) yielded 71 papers for study. Both total and average article citations rise annually. Japanese University of the Ryukyus professor Senjyu T writes prolifically. They have the most articles and citations among 283 authors. Elsevier published 54.93% of the 71 papers, followed by MDPI with 21.13%. Applied Energy and Energy Conversion and Management pioneered hybrid renewable energy papers in 15 key journals from 2014 to 2023. India has the most documents, 12, with 351 citations. Second with 7 documents is Iran, followed by China, Spain, and Italy with 4. Italy produces the most articles (15). Malaysia has 14, Iran 14, and Japan 11. Pakistan has 6 articles, and Korea has 7. This bibliometric study found relationships between author keywords, showing the growth of hybrid renewable energy system subtopics in developing regions. There are several trending keywords that can give empirical researchers an overview of topics, including "rural electrification, optimization, renewable energy, microgrid, solar energy, hybrid renewable energy system, techno-economic analysis, sensitivity analysis, cost of energy, and Homer". The study proposed in this paper guides researchers to identify hybrid renewable energy system patterns with a source of information tailored to their interests.

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Conflicts of interest

The authors declare no conflict of interest.

Data availability statement

Data will be made available on request.

Author contribution statement

Conceptualizations, EKB.; methodology, EKB. and FDW.; software, EKB and FDW.; validation, EKB., FDW., HRA. and JCV.; formal analysis, EKB., FDW. and HRA.; investigation, EKB. and FDW.; data curation, EKB. and FDW.; writing, EKB., FDW. and HRA.; original draft preparation, EKB., and HRA.; writing-review and editing, EKB., FDW., HRA., JCV.; visualization, supervision, FDW.;. All authors have read and agreed to the published version of the manuscript.

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