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Numan M. Durakbasa
Kemal Güven Gülen *Editors*

Sustainable Green Conversion

Selected Papers from ISPR2024, October 10–12, 2024, Budva, Montenegro, Volume 2

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This book is dedicated to the memory of Prof. Dr. Güneş Gençyılmaz, with respect and gratitude…

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Contents

Trends and Research Progress in Sustainable and Green Energy Management: A Bibliometric Analysis

Mesut Ulu, Semra Birgün, and Aysel Çakır

Abstract This study presents a bibliometric analysis of research trends and advancements in the field of sustainable and green energy management. The depletion of fossil fuels and the threats posed by increasing carbon emissions to global energy security have made the need for sustainable energy solutions more urgent. The analysis, conducted on articles published between 2008 and 2024 in the Web of Science (WoS) database, reveals that energy efficiency, renewable energy, sustainability, and green energy are the most frequently researched topics in the literature. Key themes include green energy efficiency, renewable energy technologies, and energy performance evaluation, with increasing interest in the role of policy and technological innovations in sustainable energy in recent years. The findings of the study demonstrate a strong research network in the energy management literature, but also highlight that some niche topics remain underexplored. The thematic map analysis shows that energy management, machine learning, and green energy efficiency are central topics, while less-researched areas are limited in the literature. This indicates the need for further expansion of research in new areas within the field of sustainable energy management. This bibliometric study reveals current research trends in sustainable energy management and offers strategic insights for future studies, providing important recommendations for addressing gaps in the field.

Keywords Bibliometric analysis · Energy performance evaluation · Green energy efficiency · Green energy management · Sustainable energy management · Sustainable development goals

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1 Introduction

Today, the rapid increase in energy demand and the depletion of fossil fuel reserves have made sustainable and innovative solutions in energy management mandatory. By 2020, worldwide energy consumption has reached 580 exajoules, and 84% of this consumption is still met by fossil fuels. This intense use of fossil fuels accounts for a large share of global carbon dioxide emissions, making the threat of climate change more serious than ever. According to data from the International Energy Agency, the energy sector is responsible for 42% of global carbon dioxide emissions. These data clearly show that there is an urgent need for green energy management approaches, not only for environmental sustainability, but also for long-term energy security and economic development [1].

The devastating effects of carbon emissions on the environment have made sustainable and green energy management one of the most important research topics of today. While sustainable energy management means using energy resources in a way that can meet the needs of future generations, green energy management means using these resources without harming the environment, minimizing the carbon footprint, or damaging natural ecosystems. In line with sustainability principles, increasing the use of renewable energy resources (such as solar, wind, hydroelectricity, and biomass), ensuring energy efficiency, and developing environmentally friendly technologies are vital for both economic growth and environmental sustainability [2].

The necessity of green energy management is not limited to reducing environmental impacts; strategic goals such as ensuring energy security, reducing energy dependency, and supporting long-term economic development also form the basis of this approach. For example, the European Union's 2030 targets include increasing the share of renewable energy sources in total energy consumption to 32% and increasing energy efficiency by 32.5%. These targets reflect the increasing importance of sustainable and green energy management on a global scale.

The number of scientific studies in the field of sustainable and green energy management is rapidly increasing, and the knowledge in this field is gradually deepening. However, it is important to understand which research topics come to the fore within this expanding literature, which themes are most studied, and which scientists and institutions are most influential in this field. At this point, bibliometric analysis stands out as a powerful tool to answer such questions. Bibliometric analysis helps determine the current situation and future research directions in the field by examining trends, collaborations, and impact factors in a particular research field through numerical data of scientific publications.

The main purpose of the study is to deepen the existing knowledge in the field of sustainable and green energy management and to present a general framework of research in this field. In this context, by analyzing research trends and collaboration networks in this field, it has been revealed how sustainability and green energy approaches in energy management have evolved over time and which themes are effective in this evolution. The objectives of the study include determining the scope

of research in this field, making guiding suggestions for future research, and making a strategic contribution to the development of sustainable energy policies.

2 Bibliometric Analysis

Bibliometrics is a method used for the quantitative analysis of scientific studies, and its foundations were laid in the 1950s [3, 4]. Although this method is not very new, it has started to be widely used in the academic world, especially recently [4]. Bibliometrics is defined as the application of mathematical and statistical techniques to academic publications. The sources where these techniques are applied include not only articles but also different types of scientific documents such as books, reports, and conference proceedings [5]. By using the numerical data of such scientific studies, bibliometrics allows revealing various trends and relationships in the academic world. Researchers can analyze scientific developments and follow changes in the literature through these data [6]. Bibliometric analysis is an application derived from this general method and refers to the quantitative examination of elements such as the number of authors, journals in which they are published, subject headings of the study, publication information, and even the geographical region where the study is published [7].

Bibliometric analysis stands out as a very effective method in the analysis of large data sets today. This method provides great convenience, especially for researchers who want to map the literature on a specific research field and examine large-scale scientific data in an organized manner. Becoming increasingly popular in the academic world, bibliometrics is used for a wide variety of purposes, such as measuring article and journal performance, analyzing collaboration networks, and exploring the intellectual structure of a research field [8, 9]. Bibliometric analysis, which offers a systematic tool to examine the interconnections of research conducted in different disciplines and to measure scientific productivity, follows a more organized and sequential approach compared to other methods in this field. The most commonly used analysis techniques within the framework of this method include citation-based analysis, keyword co-occurrence analysis, and co-authorship analysis. Under citation-based analyses, there are more specific methods such as citation analysis, co-citation analysis, and bibliographic matching. These analyses provide important indicators to measure the impact of a study in the academic world [10, 11].

Bibliometrics is not only used as a retrospective analysis tool but also plays an active role in identifying new research areas and future scientific trends. Particularly for researchers who want to discover development trends and "hot spots" of a particular discipline, bibliometric analysis offers a method that is both quantitative and objective. These analyses are of great importance in understanding the development dynamics in the research field and determining which topics need further research. The results obtained from bibliometric analysis contribute to scientific progress in different aspects. These contributions include: (1) general evaluation of the progress made in a particular research field; (2) identification of the most reliable

and most referenced scientific sources in the field; (3) identification of prominent important authors and institutions; (4) new developments provide an academic basis; (5) identifying emerging research topics and areas of interest; and (6) predicting future scientific success [12–14].

At this point, bibliometric analysis emerges as a powerful tool that allows us to analyze not only the current state of academic literature but also future research potential. Thanks to the comprehensive analyses provided by bibliometrics, researchers can more effectively follow advances in their fields and guide future scientific studies.

2.1 Data Collection and Work Motivation

The main purpose of a literature review involves compiling existing information on a particular topic, understanding and analyzing this information in depth, and taking the necessary steps to create a solid foundation for future research. This process helps to understand the current status of a research area and determine the direction of further studies. When conducting a literature review, a systematic process is usually followed in line with the determined search criteria and keywords. This regular and sequential process ensures that the relevant literature is comprehensively scanned and evaluated. In this study, the Web of Science (WoS) database was used to comprehensively analyze the international academic literature. Web of Science is among the international citation indexes and is considered a "quality certificate" for scientific fields, research, and researchers. Therefore, examining WoS data is of great importance in order to evaluate the global impact of scientific studies and to monitor developments in academic fields. Analyzing records in Web of Science, one of the international databases, increases the accuracy and reliability of research findings.

The research theme of this study was determined as sustainable and green energy management and energy efficiency. While conducting the literature review, criteria such as database, publication date, language, and document type were used as criteria. Figure 1 shows the stages of the research process in detail. As a result of the keyword search conducted on 06.09.2024 in the Web of Science (WoS) database, a total of 228 publications were reached. Then, English was selected as the language criterion of the publications, the document type was determined as article, article early access, review, and the publication year was limited to between 2008 and September 2024. These criteria allowed for a more specific and qualified examination of the literature.

2.2 Results of Performance Analysis

In order to perform a detailed bibliometric analysis, the use of an accurate and effective statistical program is as important as the choice of database. In this context, it was concluded that the "bibliometrix" module in the R program is superior to the "BIBExcel" package in terms of comprehensiveness. The VOSviewer software

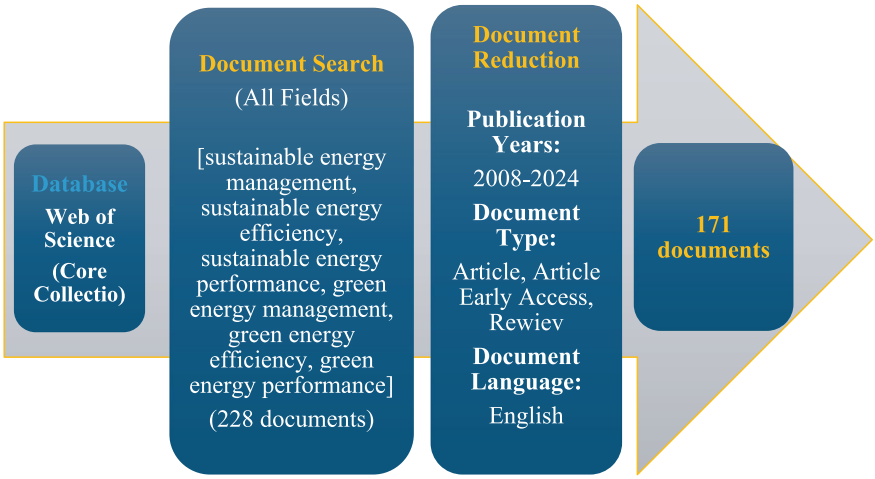

Fig. 1 Stages of research process

was developed specifically for visual network analysis and includes various visual elements such as word clouds, cluster analysis, and network maps. Thanks to its network analysis capacity [15], it can also perform many different types of analysis, such as citation analysis, author analysis, journal analysis, and institution analysis, and the "bibliometrix" module in the R program has emerged as the most suitable statistical package [7]. Therefore, the "bibliometrix" module was preferred in performing bibliometric analysis within the scope of this study.

Figure 2 provides detailed summary information on the articles examined within the scope of bibliometric analysis. As a result of the analysis conducted on the Web of Science (WoS) database, a total of 171 articles published in 105 different academic journals were examined. The first published study in this field dates back to 2007, and publications between 2008 and 2024 were selected for analysis. The annual growth rate of studies on sustainable and green energy management was 24%, indicating that the field has developed rapidly in recent years. The average age of the articles was calculated as 3.7 years, which reveals that the literature on this subject is relatively new and dynamic.

Of the 171 articles included in the study, 12 were published by a single author, while the remaining articles were the result of multi-author collaborations. When multi-author articles are examined, it is seen that there are an average of 4.64 co-authors for each article, indicating that research in this field has a largely collaborative nature. The total number of keywords used in these articles reached 807, which shows that the researchers cover various conceptual frameworks and subfields. In addition, a total of 9773 references were given in the 171 articles examined, with an average of 24 citations per article, which shows that the studies have a wide literature support and that the relevant topic has a wide echo in the scientific field.

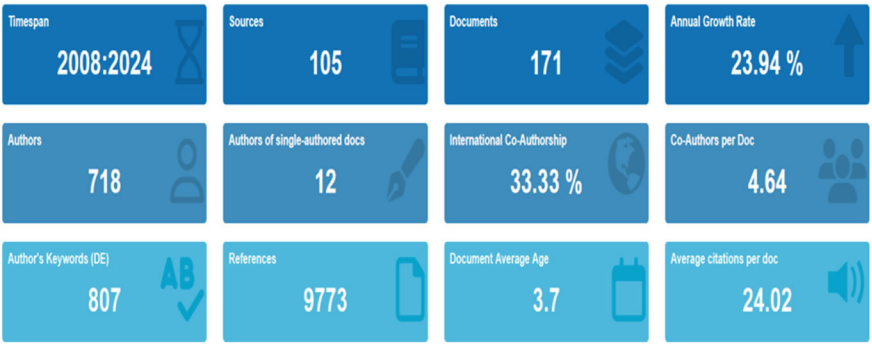

Fig. 2 Preliminary statistics

These data show that research on sustainable and green energy management is rapidly increasing and that scientific studies in this field are increasingly cited, and that there is a strong collaboration network among authors. The density of keywords and references indicates that the subject is based on a wide research area and literature base.

The data in Table 1 reveal some important trends in the field of sustainable and green energy management. First of all, it is seen that the journals "Sustainability," "Energies," and "Journal of Cleaner Production" are the most preferred and influential journals in this field. These journals stand out as the leading platforms where research on sustainable energy management is published. In addition, journals such as "Energy Policy," "Renewable and Sustainable Energy Reviews," and "Journal of Cleaner Production" are among the most referenced sources in terms of local citations and have an important place in the literature. Especially "Renewable Energy," "Renewable and Sustainable Energy Reviews," and "Energy and Buildings" journals have a strong local impact, and it is observed that the studies published in these journals contribute to important research in the field.

In terms of institutions, the most influential academic and research centers in the field of sustainable energy management are the "Italian National Agency for New Technologies Energy and Sustainable Economic Development" in Italy and the "Nanjing University of Posts and Telecommunications" and "Nankai University" in China. This shows that China and Italy are among the leading countries in this field. In parallel, these countries also stand out in terms of their scientific production capacity; China, Italy, and India are at the forefront in terms of author countries and scientific production. In addition, the fact that China is the most cited country in this field shows that the studies conducted in this country have a wide impact. In addition, Malaysia and the USA are also among the countries with significant citations. The most cited papers have made significant contributions to the sustainable energy management literature, and it has been observed that these studies have created a wide-ranging scientific impact. This table emphasizes that countries such as China, Italy, and India are leading countries in the field of sustainable energy

Table 1 The most influential journals, institutions and countries

Criteria/Rank order	First	Second	Third
Most relevant sources	Sustainability	Energies	Journal of cleaner production
Most local cited sources	Energy policy	Renewable and sustainable energy reviews	Journal of cleaner production
Sources' local impact	Renewable energy	Renewable and sustainable energy reviews	Energy and buildings
Most relevant affiliations	Italian national agency for new technologies, energy and sustainable economic development	Nanjing University of Posts and Telecommunications	Nankai University
Corresponding author's countries	China	Italy	India
Countries' scientific production	China	Italy	India
Most cited countries	China	Malaysia	USA
Most global cited documents	Liu et al., [16]	Ghaffarian Hoseini et al., [17]	Nazir et al., [18]
Most local cited documents	Meng ve Qu, [19]	Herce et al., [20]	De Corato et al., [21]

management, that certain journals and institutions are more prominent in this field, and that international collaborations are of great importance in this field.

The most cited papers globally [16–18] are fundamental in topics such as energy management, hydrogen energy, and energy efficiency technologies and have had a wide impact worldwide. The high citation counts indicate that these studies guide policymaking, technological developments, and future research in the field of renewable energy. The most cited papers at the local level [19–21] have had significant impacts on energy management and sustainability issues in local research communities or specific regions. Local citation analyses show that these studies have a strong impact on energy efficiency practices and sustainability policies in specific countries or regions. In particular, regional solutions and energy management strategies suitable for local conditions increase the importance of such studies.

Global and local citation trends reveal that research on sustainable energy management and efficiency attracts great interest both at the broad and local levels and that studies in this area play a critical role in policy making and technological innovation.

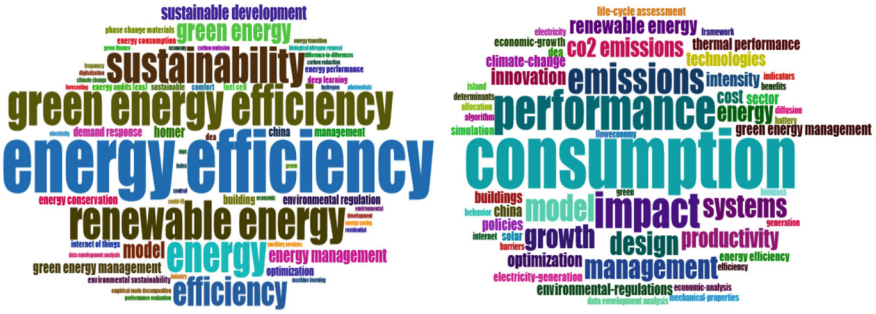

Fig. 3 Keyword clouds

2.3 Results of Science Mapping

The network analysis technique is widely used to determine the structural relationships among the factors according to their relative importance. The keyword most frequently used words and word cloud are given in Fig. 3.

Figure 3 presents the most frequently used keywords and the number of occurrences of these words in studies conducted in the field of sustainable energy management and energy efficiency in detail. The data provides important clues in determining the focus points and research trends of the literature in this field. Among the prominent keywords, "energy efficiency" and "green energy efficiency" have the highest number of repetitions, indicating that these concepts are at the center of sustainable energy management studies. This situation reveals that researchers aim to develop strategies for more efficient use of energy resources and to disseminate green energy applications.

In addition, it was observed that keywords such as "renewable energy" and "emissions" were frequently used. This shows that research on sustainable energy management is not limited to energy efficiency but also focuses on important issues such as the use of renewable energy resources and the reduction of environmental impacts. In this context, the development of renewable energy technologies and the reduction of carbon emissions stand out as key issues in sustainability studies.

Other important keywords include concepts such as "performance," "consumption," and "impact," indicating that researchers are focusing on measuring the performance of energy efficiency and renewable energy strategies, optimizing energy consumption, and assessing the environmental impacts of these strategies. When evaluated with the WordCloud approach, these keywords will stand out as the largest and most frequently used concepts. This shows that the main topics of sustainable energy management literature are energy efficiency, renewable energy sources, reducing environmental impacts, and optimizing energy performance.

Figure 4 presents a thematic map of the keywords used in the analyzed articles. The thematic map is a visual tool where topics are clearly evaluated on a graph and presented grouped in four different quadrants. This map is structured on centrality

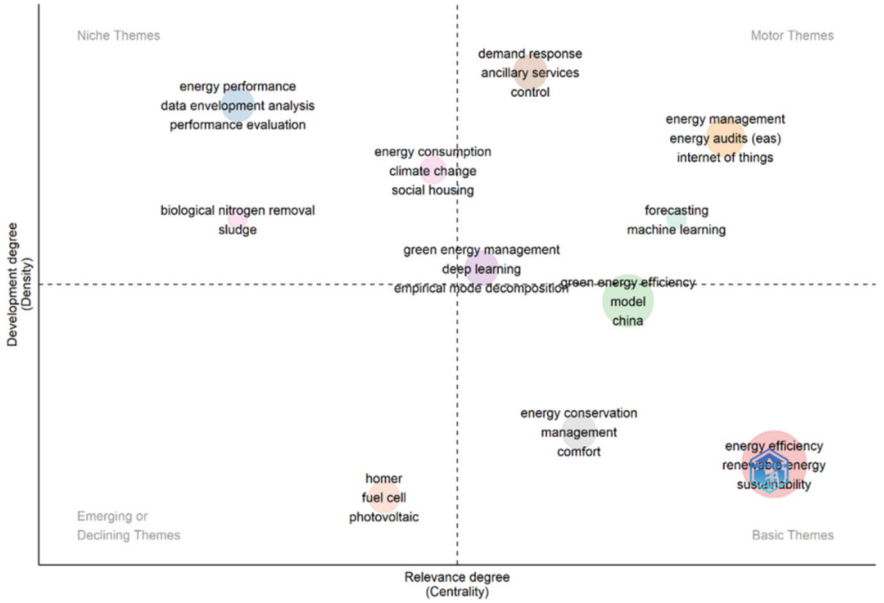

Fig. 4 Keyword thematic map

(x-axis) and density (y-axis). Density refers to the level of development of a particular theme, while centrality measures the importance of the theme in the general literature. A thematic map is a simplified diagram that helps readers group different themes into four different quadrants.

Themes in the lower left corner of the map are called rising or falling themes. Such themes represent topics that have either lost their importance in the literature or are newly developing, and these themes can either be removed from the study or brought to the attention of researchers for further development in the future. Themes in the lower right corner are the basic themes that have been studied extensively in the literature. These are frequently researched themes in the field of sustainable energy management and have an important place in the literature. The upper left corner represents niche themes that have been developed but remain relatively isolated. These themes, although studied in depth in specific research areas, are less relevant to the general literature. Themes in the upper right corner are developed themes and have both high centrality and density in the literature. The themes are analyzed in detail according to the quadrant they are located in.

Motor themes represent the research topics with the highest relevance and development, and represent the strongest impact in the literature. Themes such as "energy management," "energy audits," and "Internet of Things" are at the core of the energy management literature and illustrate how the field is being transformed by technological developments. Similarly, data-driven approaches such as "machine learning" and "forecasting" play an important role in studies on energy management.

Niche themes represent topics that are well developed but have a more limited central role in the literature. Themes such as "energy performance," "data envelopment analysis," and "performance evaluation" represent areas where studies focusing on performance and efficiency have been analyzed in depth, while more specific technical topics such as "biological nitrogen removal" and "sludge" are included in this category.

The main themes have high relevance and cover the most frequently discussed and researched topics in the field of sustainable energy management. Concepts such as "energy efficiency," "renewable energy," and "sustainability" have an important place in the energy management literature and form the basis of these studies. These themes stand out as the main elements shaping the general structure of the literature.

Finally, emerging or declining themes represent topics with low relevance and development in the literature. Technologies such as "fuel cell" and "photovoltaic" may be new areas of interest in sustainable energy management research, but in some cases they may be among the topics that have lost their importance. This thematic map provides important clues in terms of showing which topics are more prominent in the sustainable energy management literature and which areas need more research.

Multiple correspondence analysis (MCA) is considered a common method for dimensionality reduction in multivariate data sets. Figure 5 shows the conceptual structure map in terms of MCA.

This cluster map shows the classification of conceptual constructs used in studies in the field of sustainable energy management into groups. The map is framed by

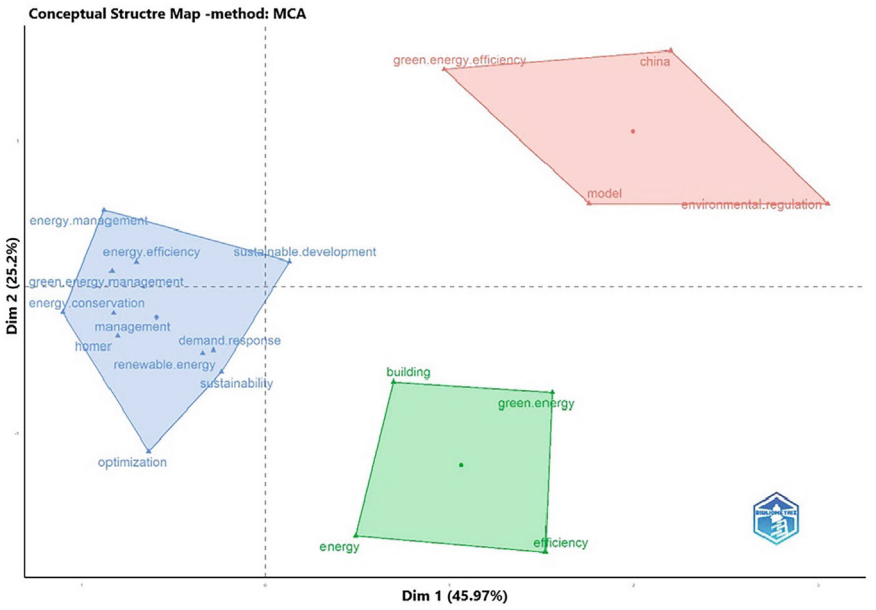

Fig. 5 Cluster map

axes “Dim 1” and “Dim 2” on a two-dimensional plane to determine the conceptual relationships between themes. These axes are used to examine the interconnections of specific concepts and their place in the general research literature.

The Blue Cluster (top left) includes important concepts such as “energy management,” “energy efficiency,” “green energy management,” and “renewable energy”. This cluster addresses themes such as sustainable development and energy conservation, which are concentrated in studies on energy management and efficiency. These concepts represent fundamental research topics related to the effective management of energy systems, the integration of renewable energy sources, and green energy applications.

The Red Cluster (top right) includes the concepts of “green energy efficiency,” “China,” “environmental regulation,” and “model.“ This cluster focuses specifically on the effects of environmental regulations and models on green energy efficiency. The prominence of China in this context indicates that sustainable energy policies and regulations in this country are frequently discussed and analyzed in the global literature.

The Green Cluster (bottom right) includes the concepts of “green energy,” “building,” “energy,” and “efficiency.“ This cluster represents a group where studies focusing on green energy applications and energy efficiency in buildings are concentrated. In particular, energy efficiency strategies and green energy applications in the building and construction sector constitute the main research themes in this cluster.

In general, this cluster map shows that topics such as energy management, renewable energy, and green energy efficiency are at the center of studies in the field of sustainable energy management. The map also reveals that studies on environmental regulations and energy efficiency models are concentrated in the context of certain countries, especially China. In this context, the concepts of energy management and sustainability appear to be key areas of research for future research.

Figure 6 shows trending topics. Concepts such as energy efficiency and green energy management have long held an important place in the literature, but interest in these topics has increased after 2015. This interest shows that green practices and efficient use of renewable energy resources are becoming increasingly important in energy management. The fact that these terms are studied more frequently after 2020 reveals that sustainable energy management approaches are increasingly emphasized.

Concepts such as “green energy efficiency,” “green energy management,” and “sustainability” are among the fundamental issues that have been frequently emphasized and studied in recent years. These concepts play a critical role in the efficient use of renewable energy sources and in achieving sustainable development goals. It is observed that these issues have intensified, especially since 2020, and that studies on sustainable energy solutions have increased. It is noteworthy that terms such as “energy performance,” “impact,” and “technologies” have also gained significant momentum in recent years. This shows that technological innovations related to energy efficiency and the effects of these innovations on energy performance are becoming increasingly important.

In general, it is observed that the terms have become more specific over time and the sustainable energy management literature has taken on a more focused structure

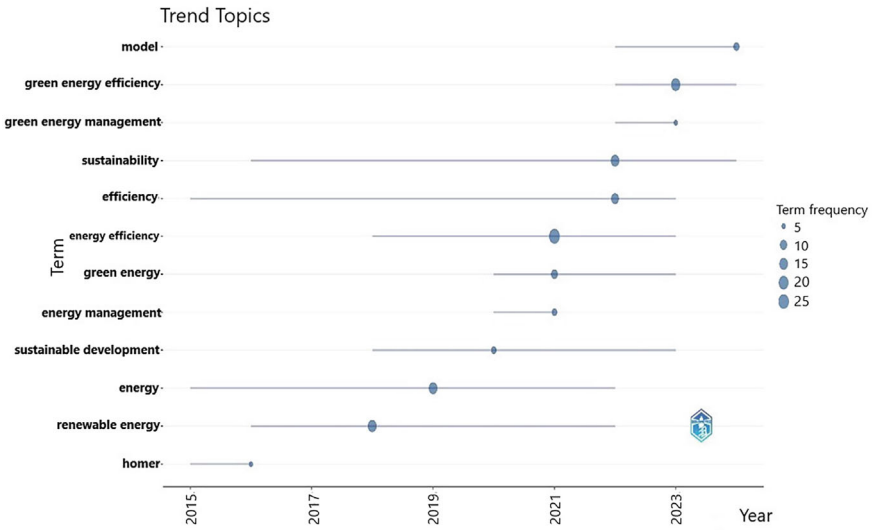

Fig. 6 Trend topics

in the 2020s. While more general terms were dominant in the 2010s, more focused and policy-related terms such as "green energy management," "CO_2 emissions," and "environmental regulations" have come to the fore in the 2020s. This change clearly reveals the reflection of scientific developments and global policies in sustainable energy management in the literature.

3 Conclusions

This bibliometric analysis offers a detailed evaluation of research trends and developments in the field of sustainable and green energy management. The findings reveal that key topics such as green energy efficiency and energy performance evaluation have gained significant attention, while the role of policy and technological innovations in advancing sustainable energy practices has become more prominent in recent years.

The thematic map analysis further underscores the importance of core themes like energy management, machine learning, and green energy efficiency, which are well-established and highly relevant in the literature. However, the map also identifies underexplored niche areas, particularly emerging technologies such as fuel cells and photovoltaic systems, which have potential but are not yet fully integrated into the mainstream research agenda. The presence of such themes in the lower quadrants of the thematic map suggests opportunities for expanding research into these areas to address the growing demand for innovative and sustainable energy solutions.

The cluster analysis reveals strong research collaborations, with China, Italy, and India emerging as leading contributors to the field. These countries not only produce a high volume of research but also form the backbone of global scientific networks. Nevertheless, the analysis also indicates that the field would benefit from broader international collaborations, particularly between developed and developing nations, to accelerate technological advancements and policy integration. From a science mapping perspective, the conceptual structure map shows a well-established relationship between energy management, sustainability, and performance optimization. However, the development of region-specific energy policies and the adoption of cutting-edge technologies, such as artificial intelligence and IoT in energy management, remain underexplored, offering valuable directions for future research.

In conclusion, this study provides a strategic roadmap for advancing research in sustainable and green energy management. While the field has seen rapid growth, there remain significant gaps, particularly in the exploration of emerging technologies and localized solutions. Future research should focus on expanding interdisciplinary approaches, deepening the integration of technological innovations, and fostering international collaborations to build a more resilient and sustainable global energy system. Addressing these gaps will be crucial for developing effective policies and practices that meet the challenges posed by climate change and energy security.

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