

Energy Literacy Research: A Bibliometric and Science Mapping Analysis of Global Trends, Educational Innovations, and Emerging Themes (2000–2025)

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Abstract

Energy literacy has emerged as a critical area of research for addressing contemporary energy, environmental, and sustainability challenges. Despite the growing volume of literature, a comprehensive understanding of the intellectual structure, conceptual development, and emerging trends within the field remains limited. This study examines the evolution of Energy Literacy Research from 2000 to 2025 through a bibliometric and science mapping analysis of 697 Scopus-indexed articles. Data were collected from the Scopus database and analyzed using VOSviewer through bibliographic coupling and co-word analysis. The bibliographic coupling analysis identified five major intellectual clusters: (1) psychological and behavioral determinants of energy conservation, (2) sustainable energy transition and renewable energy development, (3) residential energy consumption and energy policy decision-making, (4) energy literacy and education for sustainable behavior, and (5) energy efficiency and energy management systems. Co-word analysis revealed that energy conservation, energy efficiency, energy utilization, energy use, energy policy, and household energy were the most influential and interconnected concepts in the field. The findings further indicate a growing integration of behavioral science, sustainability education, renewable energy studies, climate change education, and energy management technologies within contemporary energy literacy scholarship. Emerging research trends highlight increasing attention to behavioral interventions, sustainable energy transitions, low-carbon development, and interdisciplinary approaches to energy education and decision-making. Overall, this study provides a comprehensive overview of the intellectual and conceptual landscape of Energy Literacy Research and offers valuable directions for future research, educational innovation, policy development, and sustainability-oriented energy practices.

1. INTRODUCTION

The global energy landscape is undergoing profound transformations driven by climate change mitigation efforts, energy security concerns, rapid technological advancements, and the transition toward sustainable and low-carbon energy systems (Intergovernmental Panel on Climate Change [IPCC], 2023; International Energy Agency [IEA], 2023). As societies increasingly rely on renewable energy technologies and energy-efficient practices, the role of citizens in making informed energy-related decisions has become more critical than ever. Addressing contemporary energy challenges requires not only technological innovations and policy interventions but also a population that possesses adequate knowledge, attitudes, and behaviors regarding energy use and sustainability (United Nations Educational, Scientific, and Cultural Organization [UNESCO], 2020). Consequently, the concept of energy literacy has emerged as an important area of research and practice in education, environmental studies, and energy policy.

Energy literacy generally refers to an individual's understanding of energy concepts, awareness of the environmental and social implications of energy production and consumption, and the ability to make informed and responsible energy-related decisions. It encompasses cognitive, affective, and behavioral dimensions that collectively influence how individuals perceive, use, and conserve energy. Scholars have

argued that energy-literate citizens are better equipped to participate in public discourse, support sustainable energy transitions, adopt energy-efficient behaviors, and contribute to broader sustainability goals (IPCC, 2023; UNESCO, 2020). As nations pursue decarbonization strategies and renewable energy adoption, energy literacy has become increasingly recognized as a foundational competency for sustainable development.

Over the past two decades, energy literacy research has expanded considerably across diverse educational and societal contexts. Studies have examined energy literacy among elementary and secondary students, university learners, teachers, households, and the general public. Researchers have investigated various dimensions of energy literacy, including knowledge acquisition, behavioral intentions, energy conservation practices, decision-making processes, and public engagement with energy issues. Furthermore, educational innovations such as digital learning platforms, simulation-based instruction, project-based learning, gamification, and sustainability-oriented curricula have been increasingly employed to enhance energy literacy outcomes (Dichev & Dicheva, 2017; UNESCO, 2020). These developments reflect the growing interdisciplinary nature of the field, which integrates perspectives from education, environmental science, psychology, engineering, sustainability studies, and public policy.

Recent scholarship has highlighted the increasing attention devoted to energy literacy and its significance in supporting energy transitions and sustainable development. Existing reviews have primarily focused on conceptual definitions, dimensions of energy literacy, educational interventions, measurement instruments, and determinants of energy-related behaviors. While these studies provide valuable insights into the evolution of the field, they generally employ narrative or systematic review approaches and often focus on specific educational settings or thematic areas. Moreover, previous reviews have noted the diversity of conceptualizations and methodological approaches in energy literacy research, underscoring the need for a broader examination of the field's intellectual structure and developmental trajectory (UNESCO, 2020).

Despite the growing body of literature, comprehensive bibliometric and science mapping investigations of global energy literacy research remain limited. Existing studies have not fully explored the knowledge structure, collaboration networks, influential authors, leading institutions, emerging thematic clusters, and evolving research fronts that characterize the field. As energy literacy continues to intersect with sustainability education, climate change education, renewable energy adoption, digital learning technologies, and energy citizenship, there is a need to systematically map the intellectual landscape of the research domain. Bibliometric and science mapping techniques provide powerful tools for identifying publication trends, citation patterns, collaboration networks, thematic evolution, and emerging areas of inquiry, thereby offering a comprehensive understanding of how the field has developed over time (Aria & Cuccurullo, 2017; Donthu et al., 2021; Zupic & Čater, 2015).

Given the increasing importance of energy literacy in addressing global energy and sustainability challenges, a systematic examination of the scholarly literature is both timely and necessary.

Understanding the evolution of research themes, educational innovations, and knowledge networks can help researchers, educators, policymakers, and practitioners identify current strengths, research gaps, and future directions for advancing energy literacy worldwide.

Therefore, this study aims to analyze the global research landscape of Energy Literacy Research from 2000 to 2025 using bibliometric and science mapping techniques. Specifically, the study employs bibliographic coupling and co-word analysis using data from the Scopus database and visualizes the results in VOS viewer. Through these approaches, the study seeks to identify major publication trends, thematic clusters, conceptual structures, and emerging research directions shaping contemporary energy literacy scholarship.

Specifically, this study seeks to answer the following research questions:

1. What are the publication trends in Energy Literacy Research from 2000 to 2025?
2. What thematic clusters emerge from bibliographic coupling analysis in Energy Literacy Research?
3. What conceptual structures and dominant themes emerge from co-word analysis?
4. What emerging trends characterize contemporary Energy Literacy Research?

By systematically mapping the intellectual and conceptual landscape of energy literacy research, this study provides a comprehensive understanding of the field's evolution, knowledge structure, and emerging research trajectories. It highlights key thematic developments, influential areas of scholarship, and evolving educational innovations that have shaped the discourse over time. Furthermore, the findings offer valuable insights for researchers, educators, curriculum developers, and policymakers by identifying promising directions for future inquiry and informing evidence-based strategies that support energy education, sustainability learning, and the broader transition toward sustainable and resilient energy systems.

2. METHODOLOGY

2.1 Bibliometric approach

This study employed a bibliometric and science mapping approach to systematically examine the global development of energy literacy research from 2000 to 2026. Bibliometric analysis is a quantitative research method used to evaluate and map scientific literature by examining publication patterns, citation structures, authorship networks, and thematic relationships within a field. It enables researchers to identify influential publications, leading contributors, collaboration patterns, and emerging research themes, while offering a comprehensive view of a discipline's intellectual structure (Donthu et al., 2021; Zupic & Čater, 2015). In addition, science mapping provides a visual and analytical representation of the conceptual and intellectual organization of a research domain, enabling the tracing of how knowledge clusters, themes, and scholarly connections evolve over time (Aria & Cuccurullo, 2017; Van Eck & Waltman, 2010).

The analysis combined performance analysis and science mapping techniques. Performance analysis was used to assess publication productivity, citation impact, and influential authors, institutions, countries, and journals, whereas science mapping was applied to explore the field's conceptual and intellectual structure through bibliographic coupling and keyword co-occurrence analyses. This combined approach is widely recognized for revealing research trends, knowledge domains, and thematic evolution within a scientific field and is particularly effective for identifying both established and emerging areas of inquiry (Donthu et al., 2021; Zupic & Čater, 2015).

1. Bibliographic coupling analysis was used to examine the intellectual structure and thematic organization of energy literacy research by identifying publications that share common references, which indicates conceptual relatedness and helps reveal contemporary research fronts and thematic clusters (Boyack & Klavans, 2010; Donthu et al., 2021; Zupic & Čater, 2015). This technique is especially useful for mapping current scholarly connections and emerging topics because it highlights how recent studies are linked through shared theoretical, empirical, or methodological foundations (Cobo et al., 2011). In this study, bibliographic coupling was performed in VOSviewer to identify clusters of related publications and to illustrate the major research streams, intellectual linkages, and thematic foundations that have shaped energy literacy research from 2000 to 2025
2. Co-word analysis was employed to uncover the conceptual architecture and thematic evolution of energy literacy research by examining the frequency and co-occurrence of keywords across scientific publications. As a content-based bibliometric technique, it assumes that keywords that appear together in the same documents reflect shared intellectual meaning and collectively represent the core themes of a research field (Callon et al., 1983; Donthu et al., 2021). This approach is especially powerful for science mapping because it reveals dominant topics, thematic clusters, and emerging trends through the visualization of keyword relationships, thereby exposing how research agendas develop and shift over time (Cobo et al., 2011). In this study, co-word analysis was conducted using author keywords and indexed keywords retrieved from Scopus and mapped in VOSviewer to generate keyword co-occurrence networks and thematic clusters, with clustering algorithms applied to identify the principal conceptual dimensions of energy literacy research. The resulting maps provide a clear and compelling picture of dominant themes, emerging issues, and evolving research priorities that have shaped the field from 2000 to 2026 (Aria & Cuccurullo, 2017).

2.2 Research design and data collection procedure

The bibliographic data for this study were retrieved from the Scopus database, which is widely used in bibliometric research because of its broad coverage of peer-reviewed literature and reliable citation information (Donthu et al., 2021; Martín-Martín et al., 2018).

Data collection was carried out on June 25, 2026, using the Scopus Advanced Search function. A search string was developed with relevant keywords and Boolean operators and applied to the Title, Abstract, and Keywords fields (TITLE-ABS-KEY) to retrieve publications on energy literacy. The search was limited to documents published between 2000 and 2026. Only English-language journal articles and review

papers were included, while conference papers, book chapters, editorials, notes, errata, and non-English documents were excluded. Duplicate and incomplete records were also removed during screening.

The final dataset was exported as a CSV and checked for inconsistencies in author names, affiliations, and keywords. The cleaned data were then imported into VOSviewer (Version 1.6.20) for bibliometric analysis. The software was used to conduct bibliographic coupling and co-word analysis, allowing the identification of intellectual linkages, thematic clusters, and emerging research trends in energy literacy research from 2000 to 2025

Table 1
Search String in the Scopus Database

Keywords	Justification
("energy literacy" OR "energy literate" OR "energy education" OR "energy awareness" OR "energy knowledge" OR "energy understanding" OR "energy behavior" OR "energy behaviour" OR "energy conservation behavior" OR "energy conservation behaviour" OR "energy-saving behavior" OR "energy-saving behaviour")	Captures the broad dimensions of energy literacy, including knowledge, awareness, understanding, education, and energy-related behaviors, ensuring comprehensive coverage of relevant literature while minimizing the exclusion of related studies.

The initial search conducted in the Scopus database yielded 6,251 documents related to energy literacy and its associated concepts. To ensure relevance and quality, the results were limited to Environmental Science, journal articles, and English-language publications. After applying these criteria, the dataset was reduced to 697 documents and served as the final corpus for the bibliometric and science mapping analyses.

For the bibliographic coupling analysis, all 696 articles were considered, and a minimum threshold of 110 citations per document was applied in VOSviewer. As a result, 60 documents met the threshold and were included in the network visualization and cluster analysis, representing the most influential and intellectually connected studies in the field.

For the co-word analysis, 5,229 keywords were extracted from the dataset. To focus on the most significant concepts, a minimum occurrence threshold of 20 was applied in VOSviewer. Following this filtering process, 62 keywords met the threshold and were included in the final co-occurrence network, capturing the dominant themes and emerging research areas in energy literacy research.

The application of these thresholds reduced network complexity and improved visualization clarity, enabling a more effective examination of the intellectual and conceptual structure of energy literacy

research.

3. FINDINGS AND DISCUSSION

Figure 1 presents the annual distribution of publications on energy literacy research indexed in Scopus from 2000 to 2025. The results reveal a generally increasing trend in scholarly output over the 25-year period, indicating growing academic interest in energy literacy and its role in sustainability, environmental awareness, and energy-related decision-making.

During the early years (2000–2009), publication activity was relatively limited, with only a few studies published annually. This suggests that energy literacy was still an emerging research area and had not yet gained significant attention within the academic community. From 2010 to 2012, publication output gradually increased, reflecting growing recognition of the importance of energy education and public understanding of energy issues.

A notable rise in publication productivity occurred from 2013 onward, with annual outputs consistently exceeding those of previous years. Between 2013 and 2019, the number of publications steadily increased, indicating the expansion of research on energy awareness, energy conservation, sustainability education, and renewable energy transitions. This period reflects the growing integration of energy literacy into environmental and sustainability research agendas.

The most substantial growth was observed between 2020 and 2025. Publication output increased sharply, peaking in 2022, followed by consistently high publication counts in subsequent years. Although minor fluctuations were observed after 2022, the overall trend remained positive, culminating in another high publication output in 2025. This sustained growth highlights the growing importance of energy literacy as a research topic, particularly in response to global concerns about climate change, sustainable development, energy security, and the transition to low-carbon energy systems.

Overall, the publication trend demonstrates that energy literacy research has evolved from a relatively niche topic into a well-established and rapidly expanding field of study. The steady increase in publications reflects the growing recognition of energy literacy as a critical component of environmental sustainability, energy conservation, and informed public participation in energy-related decision-making.

(2000–2025) *Source: Scopus database*

3.1 Bibliographic Coupling

Bibliographic coupling analysis was conducted using documents as the unit of analysis to identify the intellectual structure and thematic organization of energy literacy research. The analysis was performed in VOSviewer version 1.6.20 using the full-counting method and association-strength normalization. A minimum citation threshold of 110 citations per document was applied to capture highly influential and conceptually connected publications while maintaining network clarity.

From the 696 articles in the dataset, 60 met the threshold and were included in the final network. The results showed strong connections among studies on energy-saving behavior, environmental attitudes, pro-environmental behavior, household energy conservation, workplace energy efficiency, and behavioral theories of energy use, highlighting the field's multidisciplinary nature.

Table 2 presents the top 10 most influential documents based on citation count and Total Link Strength (TLS). Citation count reflects scholarly influence, while TLS indicates how strongly a document is connected to others in the network. Higher TLS values suggest a more central position in the intellectual structure of energy literacy research. The most influential publications were Gao et al. (2017), Gadenne et al. (2011), and Delmas et al. (2013), which focused on energy-saving behavior, environmental beliefs, and intervention strategies for energy conservation. Stephenson et al. (2010) and Barr et al. (2005) also made important contributions by examining the social, cultural, and behavioral dimensions of energy use.

Overall, the dominance of publications from Energy Policy, Resources, Conservation and Recycling, and Applied Energy shows that energy literacy research is strongly shaped by sustainability, environmental management, and energy policy perspectives.

Table 2
Top 10 Most-Cited Documents in the Bibliographic Coupling Analysis

No.	Author	Journal	Scope	Citations	TLS
1	Gao et al. (2017)	<i>Resources, Conservation and Recycling</i>	Application of the Extended Theory of Planned Behavior to workplace energy-saving behavior	549	78
2	Gadenne et al. (2011)	<i>Energy Policy</i>	Influence of environmental beliefs and attitudes on energy-saving behaviours	544	73
3	Delmas et al. (2013)	<i>Energy Policy</i>	Meta-analysis of information strategies and energy conservation behavior	543	58
4	Stephenson et al. (2010)	<i>Energy Policy</i>	Energy cultures framework for understanding energy behaviours	456	19
5	Barr et al. (2005)	<i>Energy Policy</i>	Household energy gap and conservation behaviours	395	34
6	Pothitou et al. (2016)	<i>Applied Energy</i>	Environmental knowledge, pro-environmental behaviour, and household energy savings	343	73
7	Zhang et al. (2013)	<i>Energy Policy</i>	Employee electricity-saving behavior based on the Norm Activation Model	337	66
8	Trotta (2018)	<i>Energy Policy</i>	Factors affecting energy-saving behaviours and energy efficiency investments in British households	313	120
9	Lindén et al. (2006)	<i>Energy Policy</i>	Residential energy behaviour and policy instruments for change	291	6
10	Ru et al. (2018)	<i>Resources, Conservation and Recycling</i>	Effects of normative factors and perceived behavioral control on energy-saving intentions	286	84
Source: Researchers' findings					

Figure 2 presents the bibliographic coupling network of energy literacy research generated using VOSviewer. The network includes 60 highly cited documents selected from the 697 articles in the dataset after applying a minimum citation threshold of 110 citations per document. In the visualization, each node represents a publication, node size reflects its relative influence, and links indicate shared references between documents. Stronger links denote greater conceptual relatedness among studies. The network shows a clear degree of intellectual cohesion, with several publications occupying central positions. Studies such as Gao (2017), Gadenne (2011), Stephenson (2010), Pothitou (2016), and Zhang (2013) serve as key foundations of the field, reflecting their strong influence on later research on energy-saving behavior, environmental attitudes, energy conservation practices, and pro-environmental decision-

making. Some publications, including Tagliabue (2021) and Rossi (2014), are positioned toward the periphery of the network, suggesting more specialized or emerging research directions with fewer direct connections to the core literature. Overall, the bibliographic coupling network indicates that energy literacy research is primarily grounded in behavioral, environmental, and sustainability-oriented perspectives, with the core literature

centered on energy-saving behavior, environmental knowledge, and energy conservation.

Figure 2: Network visualization of bibliographic coupling

Source: VOSviewer

3.1.1. Behavioral and Socio-Cultural Determinants of Household Energy Conservation

The first cluster (red), comprising 14 publications, represents a foundational research stream focused on household energy conservation and the behavioral factors that influence energy use. The studies collectively examine how environmental beliefs, attitudes, social norms, cultural practices, and policy interventions shape individuals' energy-saving behaviors and decision-making processes (Gadenne et al., 2011; Barr et al., 2005; Lindén et al., 2006).

A dominant theme within this cluster is the role of behavioral and informational factors in promoting energy conservation. Several studies demonstrate that environmental awareness, feedback systems, and information-based interventions can significantly influence household energy consumption and encourage more sustainable practices (Ueno et al., 2006; Delmas et al., 2013; Hori et al., 2013). The cluster also highlights the importance of social learning and cultural contexts in shaping energy-related behaviors, as reflected in the Energy Cultures Framework proposed by Stephenson et al. (2010).

Overall, this cluster reflects the behavioral and socio-cultural foundations of energy literacy research, emphasizing that sustainable energy transitions depend not only on technological solutions but also on changes in individual behaviors, social practices, and environmental awareness.

3.1.2 Behavioral Intentions, Energy Literacy, and Technology-Enabled Energy Management

The second cluster (green), comprising 14 publications, focuses on the psychological, organizational, and technological factors that influence energy-saving intentions and sustainable energy practices. A dominant theme within this cluster is the application of behavioral theories, particularly the Theory of Planned Behavior (TPB) and the Norm Activation Model (NAM), to explain how attitudes, perceived behavioral control, social norms, and personal values shape energy conservation behaviors in households and workplaces (Gao et al., 2017; Ru et al., 2018; Wang et al., 2018; Zhang et al., 2013).

These studies collectively emphasize that energy literacy extends beyond knowledge acquisition and is strongly associated with behavioral intentions and decision-making processes.

Another important theme is the role of psychological and social influences in promoting sustainable energy actions. Research in this cluster highlights how personality traits, climate-change risk perceptions, value orientations, and organizational climates affect individuals' willingness to conserve energy and support sustainable energy initiatives (Lacroix & Gifford, 2018; Liu et al., 2020, 2021; Ho et al., 2019). These findings suggest that effective energy literacy programs must address both cognitive and affective dimensions of energy-related decision-making.

The cluster also reflects the growing integration of digital technologies into energy management and sustainability practices. Studies on smart buildings, Building Information Modeling (BIM), digital twins, and automated energy monitoring systems demonstrate how technological innovations can support energy efficiency, sustainability assessment, and informed energy-use behaviors (Capozzoli et al., 2018; Montiel-Santiago et al., 2020; Tagliabue et al., 2021). Overall, this cluster represents a contemporary research stream that integrates behavioral science, energy literacy, and technological innovation to promote sustainable energy consumption and management.

3.1.3 Energy Management, Sustainable Built Environments, and Organizational Energy Efficiency

The third cluster (blue), comprising 12 publications, represents a research stream focused on energy management, sustainable built environments, and organizational approaches to energy efficiency. The studies collectively examine how technological innovation, building design, management practices, and institutional support contribute to reducing energy consumption and improving sustainability outcomes across residential, commercial, and industrial settings (Fernando & Hor, 2017; Vikhorev et al., 2013).

A dominant theme within this cluster is the development and implementation of energy-efficient technologies and management systems. Several studies investigate energy management frameworks, smart building technologies, building information modeling (BIM), energy-aware scheduling systems, and architectural solutions designed to improve energy performance and reduce carbon emissions (Baldinelli, 2009; Capozzoli et al., 2018; Schulz et al., 2019). These studies highlight the growing role of technological innovation in supporting sustainable energy transitions.

Another important theme concerns organizational and institutional drivers of energy efficiency. Research by Fernando and Hor (2017), Henriques and Catarino (2016), and Zhang et al. (2018) demonstrates how management commitment, institutional pressures, and organizational support influence the adoption of energy-saving practices in firms and industrial sectors. Likewise, Heydarian et al. (2020) and Sweeney et al. (2013) emphasize the interaction among building occupants, organizational contexts, and energy-use practices in achieving energy-efficiency goals.

Overall, this cluster reflects the increasing integration of sustainability, technological innovation, and organizational management within energy literacy research. The findings suggest that effective energy conservation requires not only individual awareness and behavior change but also supportive technologies, efficient building systems, and institutional strategies that foster sustainable energy use.

3.1.4 Energy Literacy, Environmental Education, and Public Engagement for Sustainable Energy Transitions

The fourth cluster (yellow), comprising eight publications, represents a research stream focused on energy literacy, environmental education, public awareness, and policy-oriented approaches to sustainable energy transitions. The studies collectively examine how knowledge, attitudes, values, and educational interventions influence energy-related behaviors and public engagement with energy and climate issues (DeWaters & Powers, 2011; Jorgenson et al., 2019; Zografakis et al., 2008).

A dominant theme within this cluster is the development and assessment of energy literacy. The works of DeWaters and Powers (2011, 2013) established foundational frameworks for measuring energy literacy through cognitive, affective, and behavioral dimensions, highlighting the importance of educational assessment in understanding energy-related competencies. Similarly, Jorgenson et al. (2019) emphasized the growing role of climate change and energy education in preparing citizens to participate in sustainable energy transitions.

Another important theme concerns the influence of public attitudes, socioeconomic factors, and policy contexts on energy-related decision-making. Studies by Von Borgstede et al. (2013), Cayla et al. (2011), and Oikonomou et al. (2009) demonstrate that energy behaviors are shaped not only by knowledge but also by perceptions of climate change, income levels, and policy frameworks. Collectively, these findings underscore the importance of integrating education, public engagement, and policy support to foster energy-conscious behaviors and informed participation in sustainability initiatives.

Overall, this cluster reflects the educational and societal foundations of energy literacy research, emphasizing the role of learning, awareness, and public understanding in promoting sustainable energy practices and supporting long-term environmental goals.

3.1.5 Household Energy Conservation, Environmental Knowledge, and Energy-Saving Behavior

The fifth cluster (purple), comprising seven publications, represents a research stream focused on household energy conservation, pro-environmental behavior, and the factors influencing energy-saving practices among residential consumers. The studies collectively examine how environmental knowledge, psychological characteristics, socio-demographic factors, and household circumstances shape energy-related decision-making and conservation behaviors (Pothitou et al., 2016; Trotta, 2018; Yue et al., 2013).

A dominant theme within this cluster is the relationship between environmental awareness and energy-saving behavior. Several studies demonstrate that individuals with higher levels of environmental

knowledge and stronger pro-environmental values are more likely to adopt energy-conserving practices and invest in energy-efficient technologies (Pothitou et al., 2016; Sütterlin et al., 2011). The cluster also highlights the importance of psychological and socio-demographic influences, including attitudes, motivations, income, education, and household characteristics, in shaping conservation behaviors (Yang et al., 2016; Zhang et al., 2018).

Another significant theme concerns the broader environmental implications of household energy use. Research by Fan et al. (2013) and Trotta (2018) links residential energy consumption patterns to carbon emissions and energy efficiency outcomes, emphasizing the critical role of households in achieving sustainability goals. Overall, this cluster reflects the behavioral and environmental dimensions of energy literacy, demonstrating how knowledge, attitudes, and personal characteristics influence energy-saving actions and contribute to sustainable energy consumption.

Table 3
Summary of bibliographic coupling analysis

Cluster	Cluster Theme	Number of Publications	Representative Publications
Cluster 1 (Red)	Behavioral and Socio-Cultural Determinants of Household Energy Conservation	14	Gadenne et al. (2011); Delmas et al. (2013); Stephenson et al. (2010); Barr et al. (2005); Lindén et al. (2006)
Cluster 2 (Green)	Behavioral Intentions, Energy Literacy, and Technology-Enabled Energy Management	14	Gao et al. (2017); Zhang et al. (2013); Ru et al. (2018); Wang et al. (2018); Liu et al. (2021)
Cluster 3 (Blue)	Energy Management, Sustainable Built Environments, and Organizational Energy Efficiency	13	Fernando and Hor (2017); Vikhorev et al. (2013); Henriques and Catarino (2016); Heydarian et al. (2020); Zhang et al. (2018a)
Cluster 4 (Yellow)	Energy Literacy, Environmental Education, and Public Engagement for Sustainable Energy Transitions	10	DeWaters and Powers (2011); DeWaters and Powers (2013); Jorgenson et al. (2019); Zografakis et al. (2008); Oikonomou et al. (2009)
Cluster 5 (Purple)	Household Energy Conservation, Environmental Knowledge, and Energy-Saving Behavior	9	Pothitou et al. (2016); Trotta (2018); Sütterlin et al. (2011); Yang et al. (2016); Zhang et al. (2018b)

3.2-Co-word analysis

The co-word analysis revealed that energy conservation was the most prominent keyword, with 1,199 occurrences and the highest Total Link Strength (TLS) of 243, indicating its central position within the conceptual structure of energy literacy research. Similarly, energy efficiency recorded 986 occurrences and a TLS of 212, highlighting its strong association with numerous research themes. The dominance of

these two keywords suggests that the field is primarily concerned with promoting sustainable energy use through conservation practices and efficiency improvements.

Other highly occurring keywords included energy utilization (789 occurrences; TLS = 138), energy use (740 occurrences; TLS = 135), and household energy (532 occurrences; TLS = 91). Their substantial occurrence frequencies and strong link strengths indicate sustained scholarly attention toward understanding energy consumption patterns, particularly in residential contexts where behavioral changes can significantly influence overall energy demand.

The presence of energy policy (602 occurrences; TLS = 100) demonstrates the importance of governance and regulatory frameworks in shaping energy-related behaviors and sustainability outcomes. Likewise, sustainability (270 occurrences; TLS = 76), sustainable development (328 occurrences; TLS = 65), and climate change (305 occurrences; TLS = 66) reflect the growing integration of environmental concerns within energy literacy research. These keywords suggest that energy literacy is increasingly viewed as a critical component of broader efforts to address climate challenges and support sustainable development goals.

Keywords associated with technological and educational dimensions also emerged prominently. Alternative energy (287 occurrences; TLS = 60) highlights increasing interest in renewable energy systems and energy transitions, while education (231 occurrences; TLS = 52) underscores the importance of developing knowledge, awareness, and competencies related to energy issues. The keyword building (210 occurrences; TLS = 52) further indicates growing attention to energy-efficient infrastructure and sustainable built environments.

Finally, the high frequency of China (375 occurrences; TLS = 62) reflects the country's significant contribution to research on energy literacy and energy behavior. Overall, the combination of high-occurrence and high-TLS keywords demonstrates that energy literacy research is a multidisciplinary field that integrates energy conservation, efficiency, policy, sustainability, education, and technological innovation to support sustainable energy transitions.

Table 4

Top 15 keywords n the Co-Word Analysis of Energy Literacy Research (2000–2026)

Figure 3 illustrates the co-word network of energy literacy research based on 67 keywords that met the minimum occurrence threshold of 20. The network demonstrates a high degree of connectivity among keywords, indicating that the field is characterized by strong conceptual relationships rather than isolated research topics.

At the center of the network, energy conservation and energy efficiency emerge as the most interconnected keywords, serving as the primary hubs that link numerous research themes. Their central positions and extensive connections with terms such as energy use, energy utilization, household energy,

energy policy, and sustainability suggest that these concepts form the core foundation of energy literacy research.

The dense linkages among keywords also reveal the interdisciplinary nature of the field. Concepts related to energy behavior, household consumption, education, climate change, renewable energy, sustainable development, and energy policy are closely connected, indicating that researchers frequently examine these topics together. This interconnectedness suggests that energy literacy is not studied solely as a knowledge-based construct but is closely associated with behavioral change, environmental awareness, policy development, and sustainable energy practices.

Furthermore, the strong connections between educational terms such as energy literacy, energy education, knowledge, and student and broader sustainability-related concepts indicate that education is viewed as a key mechanism for promoting responsible energy behaviors and supporting sustainable energy transitions. Similarly, the links between energy policy, renewable energy, and climate change demonstrate the growing integration of energy literacy research with global environmental and policy challenges.

Overall, the network's high level of connectivity suggests that energy literacy research has developed into a cohesive and multidisciplinary field in which behavioral, educational, technological, environmental, and policy dimensions are strongly interconnected. This pattern reflects the increasing recognition that addressing energy challenges requires integrated approaches that combine knowledge, awareness, behavior change, and sustainable energy management.

Source: Vosviewer

1. Psychological and Behavioral Determinants of Household Energy Conservation

The red cluster focuses on the human dimensions of energy conservation, emphasizing how psychological factors, behavioral intentions, and household decision-making influence energy-saving practices. The prominence of keywords such as energy conservation, energy-saving behavior, energy conservation behaviors, behavior, psychology, and theory of planned behavior indicates a strong research interest in understanding the factors that motivate individuals to adopt energy-saving actions. Studies within this research stream demonstrate that attitudes, social norms, environmental concern, and perceived behavioral control significantly influence energy conservation intentions and behaviors (Frederiks et al., 2015; Wang et al., 2018).

The prevalence of household surveys and behavioral research further suggests that empirical studies often examine residential energy users to identify determinants of conservation behavior. Research has shown that energy-saving practices are shaped not only by economic considerations but also by environmental values, personal beliefs, social influences, and lifestyle characteristics (Abrahamse et al., 2005; Ru et al., 2018). Moreover, the occurrence of China highlights the substantial contribution of

Chinese studies to this research stream, particularly in exploring household energy consumption patterns and behavioral interventions designed to promote energy efficiency (Zhang et al., 2018).

Overall, the red cluster represents a major research theme centered on the psychological and behavioral foundations of energy conservation. The strong interconnectedness among the keywords suggests that understanding human behavior remains essential for designing effective energy policies, educational programs, and interventions that support long-term energy conservation and sustainable energy transitions (Frederiks et al., 2015; Wang et al., 2018).

3.2.2 Sustainable Energy Transition, Renewable Energy Development, and Low-Carbon Innovation

The green cluster represents a research stream focused on sustainable energy systems, renewable energy adoption, and carbon reduction strategies. The prominence of keywords such as *sustainable development*, *alternative energy*, *renewable energy*, *carbon emissions*, *emissions control*, and *energy resources* indicates a strong emphasis on addressing environmental challenges through cleaner and more efficient energy solutions. Research within this theme highlights the importance of renewable energy technologies in reducing greenhouse gas emissions and supporting sustainable economic development (Zhang et al., 2017).

The inclusion of *innovation* and *investments* suggests that technological advancement and financial support are critical drivers of energy transitions. Studies have demonstrated that investments in renewable energy infrastructure and innovative energy technologies accelerate the shift toward low-carbon energy systems while enhancing energy security and sustainability outcomes (Zhang et al., 2017). Furthermore, the presence of *energy behavior* and *energy behaviors* indicates that successful energy transitions depend not only on technological improvements but also on behavioral changes that encourage energy conservation and the adoption of sustainable energy practices (Sovacool, 2014).

Overall, this cluster reflects the interconnected nature of renewable energy development, sustainability, innovation, investment, and behavioral change. The strong linkages among these keywords demonstrate the multidisciplinary efforts required to achieve long-term sustainable energy transitions and carbon mitigation goals.

3.2.3 Residential Energy Consumption, Electricity Use, and Energy Policy Decision-Making

The blue cluster focuses on the interaction between household energy consumption, electricity systems, and policy-driven decision-making. The presence of keywords such as *household energy*, *housing*, *residential energy*, *electricity*, *electricity supply*, *electricity generation*, and *electric power utilization* indicate a strong emphasis on understanding how energy is consumed within residential settings and how electricity infrastructure supports societal energy demands. Research within this theme frequently

examines patterns of household energy use, residential energy efficiency, and the factors influencing electricity consumption behaviors (Cayla et al., 2011; Trotta, 2018).

The inclusion of *energy policy*, *energy planning*, and *decision-making* highlights the role of governance and strategic planning in promoting sustainable energy consumption and ensuring a reliable electricity supply. Studies in this area explore how policy interventions, economic incentives, and planning frameworks influence household energy choices and contribute to broader energy sustainability goals (Oikonomou et al., 2009). Furthermore, the keywords *regression analysis* and *environmental impact* suggest a strong methodological orientation toward quantitatively assessing energy consumption patterns and their environmental consequences, particularly regarding carbon emissions and resource utilization.

Overall, this cluster represents a significant research stream that links residential energy behavior, electricity management, policy formulation, and environmental sustainability. The strong connectivity among these keywords demonstrates the importance of integrating household energy practices with evidence-based policy and planning strategies to support efficient and sustainable energy systems.

3.2.4 Energy Literacy, Education, and Public Awareness for Sustainable Behavior

The yellow cluster represents the educational and cognitive dimension of energy literacy research, emphasizing how knowledge, awareness, and perceptions influence sustainable energy behaviors. The presence of keywords such as *energy literacy*, *energy education*, *education*, *knowledge*, *student*, *public attitude*, *perception*, and *questionnaire survey* indicates a strong focus on understanding and measuring individuals' energy-related knowledge, attitudes, and behavioral intentions. Studies within this cluster examine how educational interventions and literacy programs can enhance public understanding of energy issues and promote responsible energy consumption (DeWaters & Powers, 2011; DeWaters & Powers, 2013).

The inclusion of *sustainability*, *climate change*, *energy saving*, and *consumption behavior* further highlights the role of education in fostering environmentally responsible decision-making. Research suggests that greater energy literacy is associated with increased awareness of climate-related challenges and a stronger willingness to adopt energy-saving practices (Jorgenson et al., 2019). Moreover, the frequent use of *questionnaire surveys* reflects the widespread application of assessment instruments to evaluate energy knowledge, attitudes, and behaviors among students and the general public (DeWaters & Powers, 2013).

Overall, this cluster underscores the importance of education and energy literacy as foundational mechanisms for promoting sustainable behavior, strengthening public engagement with energy issues, and supporting long-term climate and sustainability goals.

3.2.5 Energy Efficiency, Building Performance, and Energy Management Systems

The purple cluster represents a research stream focused on improving energy efficiency through building performance optimization, energy management practices, and technological assessment. The prominence of keywords such as *energy efficiency*, *energy utilization*, *energy use*, *energy consumption*, and *energy management* indicates a strong emphasis on reducing energy demand while maintaining operational effectiveness. Studies within this cluster examine strategies for enhancing energy performance in residential, commercial, and institutional buildings through efficient energy management and conservation measures (Fernando & Hor, 2017; Vikhorev et al., 2013).

The presence of *a building*, *a heating system*, *a numerical model*, and *a performance assessment* highlights the importance of engineering and analytical approaches in evaluating energy systems. Research frequently employs simulation models, performance assessments, and building energy analyses to identify opportunities to reduce energy consumption and improve operational efficiency. These studies contribute to the development of sustainable building designs and energy-efficient technologies that support broader environmental and sustainability goals (Heydarian et al., 2020).

Overall, this cluster reflects the technological and operational dimension of energy research, emphasizing the role of energy management systems, building performance evaluation, and efficiency-enhancing strategies in achieving sustainable energy consumption and reducing environmental impacts.

3.3 Emerging Trends Characterize Contemporary Energy Literacy Research

The bibliometric and science mapping analyses reveal several emerging trends that characterize the contemporary development of Energy Literacy Research. First, the field is increasingly moving beyond traditional studies of energy knowledge and awareness toward a more comprehensive examination of energy-related behaviors and decision-making processes. The prominence of keywords such as *energy conservation*, *energy-saving behavior*, *theory of planned behavior*, and *household energy* indicates growing scholarly interest in understanding the psychological, social, and contextual factors that influence energy consumption practices (Ru et al., 2018; Wang et al., 2018).

Second, there is a notable expansion of research connecting energy literacy with sustainability and climate change education. The emergence of keywords such as *sustainability*, *climate change*, *energy education*, *public attitude*, and *energy literacy* demonstrates increasing recognition of energy literacy as a critical component of environmental education and sustainable development initiatives. Researchers are increasingly exploring how educational interventions can foster informed energy choices and support climate action (DeWaters & Powers, 2011; Jorgenson et al., 2019).

Third, the analysis highlights a growing emphasis on renewable energy transitions and low-carbon development. The strong presence of keywords such as *renewable energy*, *alternative energy*, *carbon emissions*, *sustainable development*, and *innovation* suggests that contemporary energy literacy research is increasingly aligned with global efforts to promote clean energy systems and achieve carbon-reduction

targets. This trend reflects the expanding role of energy literacy in supporting public acceptance and adoption of sustainable energy technologies (Sovacool, 2014).

Fourth, recent studies demonstrate increasing interest in building energy performance, energy management systems, and smart energy technologies. Keywords such as *energy efficiency*, *building*, *energy management*, *performance assessment*, and *numerical model* indicate that technological and engineering perspectives are becoming more integrated into energy literacy research. This shift reflects the growing importance of combining behavioral approaches with technological innovations to improve energy efficiency and sustainability outcomes (Fernando & Hor, 2017; Heydarian et al., 2020).

Finally, the co-word network reveals a trend toward greater interdisciplinary integration, linking behavioral science, environmental education, public policy, sustainability studies, and engineering research. The strong connectivity among keywords across all clusters suggests that contemporary energy literacy research is increasingly adopting holistic approaches to address complex energy challenges. As a result, the field is evolving into a multidisciplinary domain that supports sustainable energy transitions by integrating knowledge, behavior change, technological innovation, and policy development.

Table 5
Summary of Co-Word Analysis According to Cluster Labels and Keywords

Cluster No. (Color)	Cluster Label	Number of Keywords	Representative Keywords
Cluster 1 (Red)	Behavioral Determinants of Energy Conservation and Household Energy Use	14	energy conservation, energy-savings, energy-saving behavior, energy conservation behaviors, household, behavioral research, psychology, theory of planned behavior, surveys
Cluster 2 (Green)	Sustainable Energy Transition and Renewable Energy Development	13	sustainable development, renewable energy, alternative energy, carbon emission, energy resource, emission control, innovation, investments, energy behaviours
Cluster 3 (Blue)	Residential Energy Consumption and Energy Policy Decision-Making	13	energy policy, household energy, residential energy, housing, electricity, electricity generation, electricity supply, decision making, energy planning, environmental impact
Cluster 4 (Yellow)	Energy Literacy, Sustainability, and Environmental Education	12	energy literacy, energy education, sustainability, climate change, education, energy saving, public attitude, perception, knowledge, student
Cluster 5 (Purple)	Energy Efficiency and Building Energy Management	10	energy efficiency, energy utilization, energy use, building, energy management, energy consumption, heating, numerical model, performance assessment

4. STUDY IMPLICATIONS

4.1 Theoretical implications

This study contributes to the theoretical advancement of Energy Literacy Research by revealing its evolution from a knowledge-centered domain to a multidisciplinary field integrating behavioral science, sustainability education, energy policy, and technological innovation. The bibliographic coupling analysis identified five major thematic clusters that collectively demonstrate the interconnected nature of energy literacy, energy-saving behavior, renewable energy transitions, household energy consumption, sustainability education, and energy efficiency. These findings support the view that energy literacy extends beyond factual knowledge and encompasses attitudes, values, decision-making processes, and behavioral practices related to energy use.

Furthermore, the co-word analysis highlights the increasing conceptual integration of energy literacy with sustainability, climate change, renewable energy, and energy management. The prominence of behavioral and educational themes suggests that contemporary theoretical frameworks increasingly recognize the role of psychological, social, and contextual factors in shaping energy-related actions. Consequently, the study provides a comprehensive intellectual and conceptual map to guide future theory development and interdisciplinary research in the field of energy literacy.

4.2 Managerial Implications

The findings offer valuable insights for educators, policymakers, energy managers, and sustainability practitioners. The strong presence of themes related to energy conservation, energy-saving behavior, and household energy use indicates the importance of designing educational programs and public awareness campaigns that promote informed energy-related decision-making. Educational institutions can utilize the identified themes to strengthen energy literacy curricula and foster sustainable behaviors among students and communities.

For policymakers, the growing linkage between energy literacy, sustainability, and climate change underscores the need to integrate energy education into broader environmental and energy-transition strategies. Policies that combine knowledge dissemination with behavioral interventions may be more effective at encouraging energy conservation and supporting the adoption of renewable energy.

From an organizational perspective, the emergence of themes related to energy management, building performance, and energy efficiency suggests that businesses and institutions can enhance sustainability outcomes by investing in energy-awareness initiatives, smart energy technologies, and energy-efficient practices. Overall, the study provides evidence-based guidance for developing programs and policies that support sustainable energy consumption and advance global energy transition goals.

5. CONCLUSION

This study mapped the intellectual and conceptual development of Energy Literacy Research from 2000 to 2026 through bibliometric and science mapping analyses of 697 Scopus-indexed articles. Using bibliographic coupling and co-word analysis in VOSviewer, the study identified the main knowledge foundations, thematic structures, and emerging trends that have shaped the field.

The bibliographic coupling analysis revealed five major research clusters representing the core intellectual foundations of energy literacy research: (1) psychological and behavioral determinants of energy conservation, (2) sustainable energy transition and renewable energy development, (3) residential energy consumption and energy policy decision-making, (4) energy literacy and education for sustainable behavior, and (5) energy efficiency and energy management systems. These clusters show that energy literacy has evolved from a narrow focus on energy knowledge to a broader, more interdisciplinary field.

The co-word analysis further confirmed the field's conceptual cohesion. Keywords such as energy conservation, energy efficiency, energy utilization, energy use, energy policy, and household energy emerged as the most influential and interconnected concepts, indicating that contemporary energy literacy research is strongly oriented toward promoting sustainable energy behaviors and supporting energy transition goals.

The analysis also identified several emerging trends, including greater attention to behavioral and psychological determinants of energy use, the integration of energy literacy within sustainability and climate change education, increasing focus on renewable energy adoption and low-carbon transitions, and the incorporation of energy management technologies and building-performance research. These developments reflect the growing role of energy literacy in supporting informed decision-making and sustainable energy systems.

Overall, this study provides a concise overview of the evolution, current structure, and future directions of Energy Literacy Research. By identifying influential publications, dominant themes, and emerging research areas, the findings offer a useful foundation for future research, educational initiatives, policy development, and sustainability-oriented energy practices.

Declarations

Ethical approval

Not applicable. This study involved a bibliometric analysis of published literature and did not involve human participants or animals.

Consent to participate

Not applicable.

Consent to publish

Not applicable.

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Author Contribution

Joseph M. Salvador: Conceptualization, methodology, data curation, formal analysis, visualization, investigation, writing—original draft, writing—review and editing, and project administration. The author read and approved the final version of the manuscript and takes full responsibility for the work.

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Figures

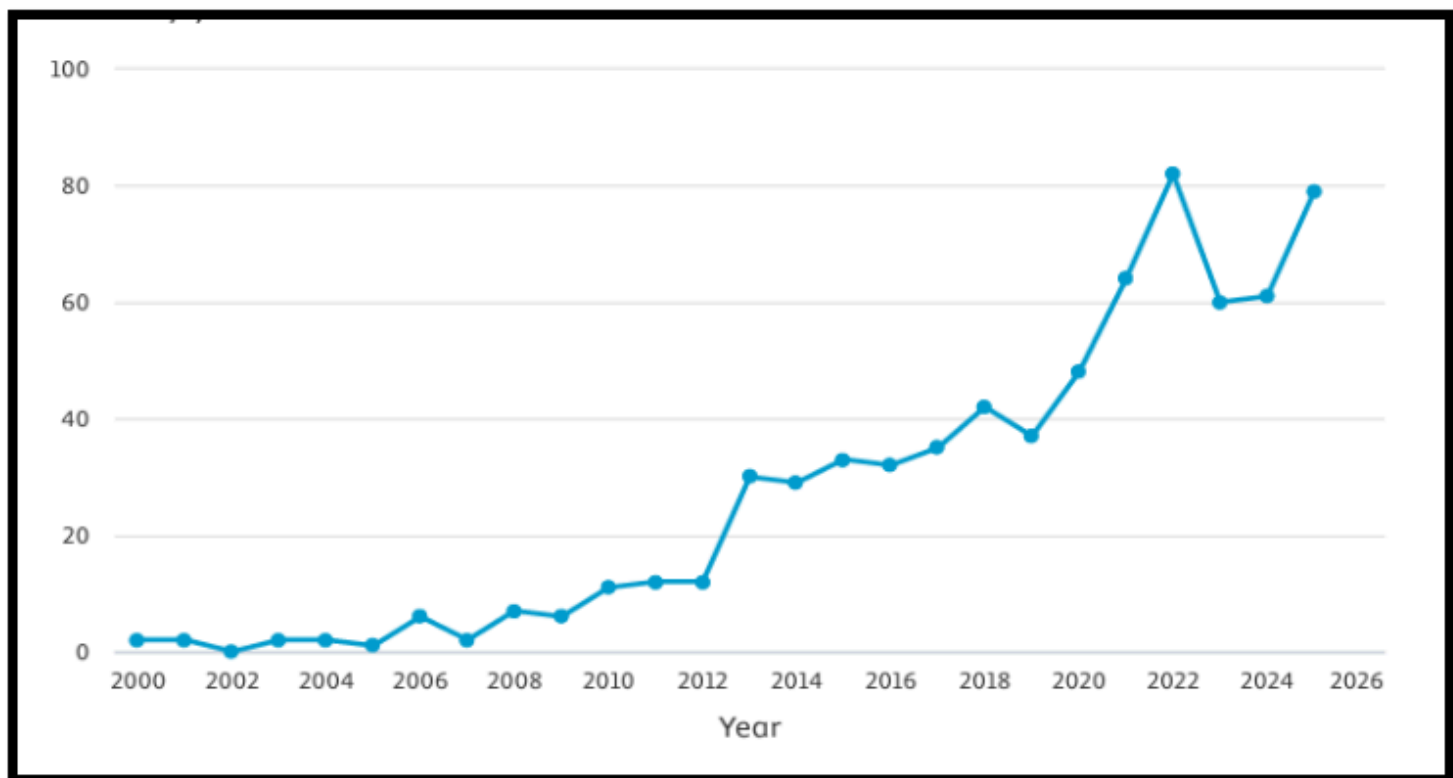


Figure 1

Annual Publication Trends in Energy Literacy Research Indexed in Scopus

(2000–2025) *Source: Scopus database*

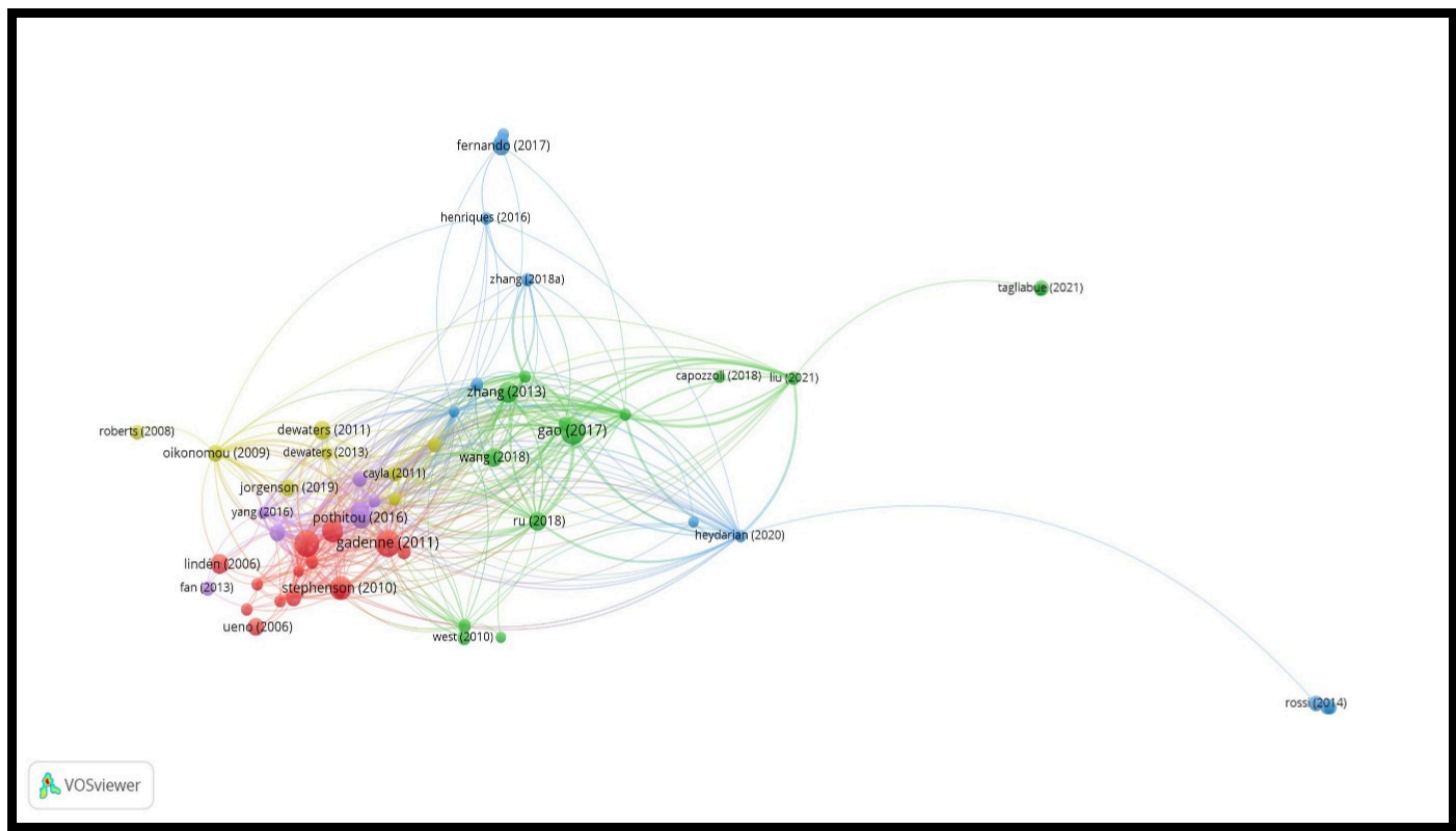


Figure 2

Network visualization of bibliographic coupling

Source: VOSviewer

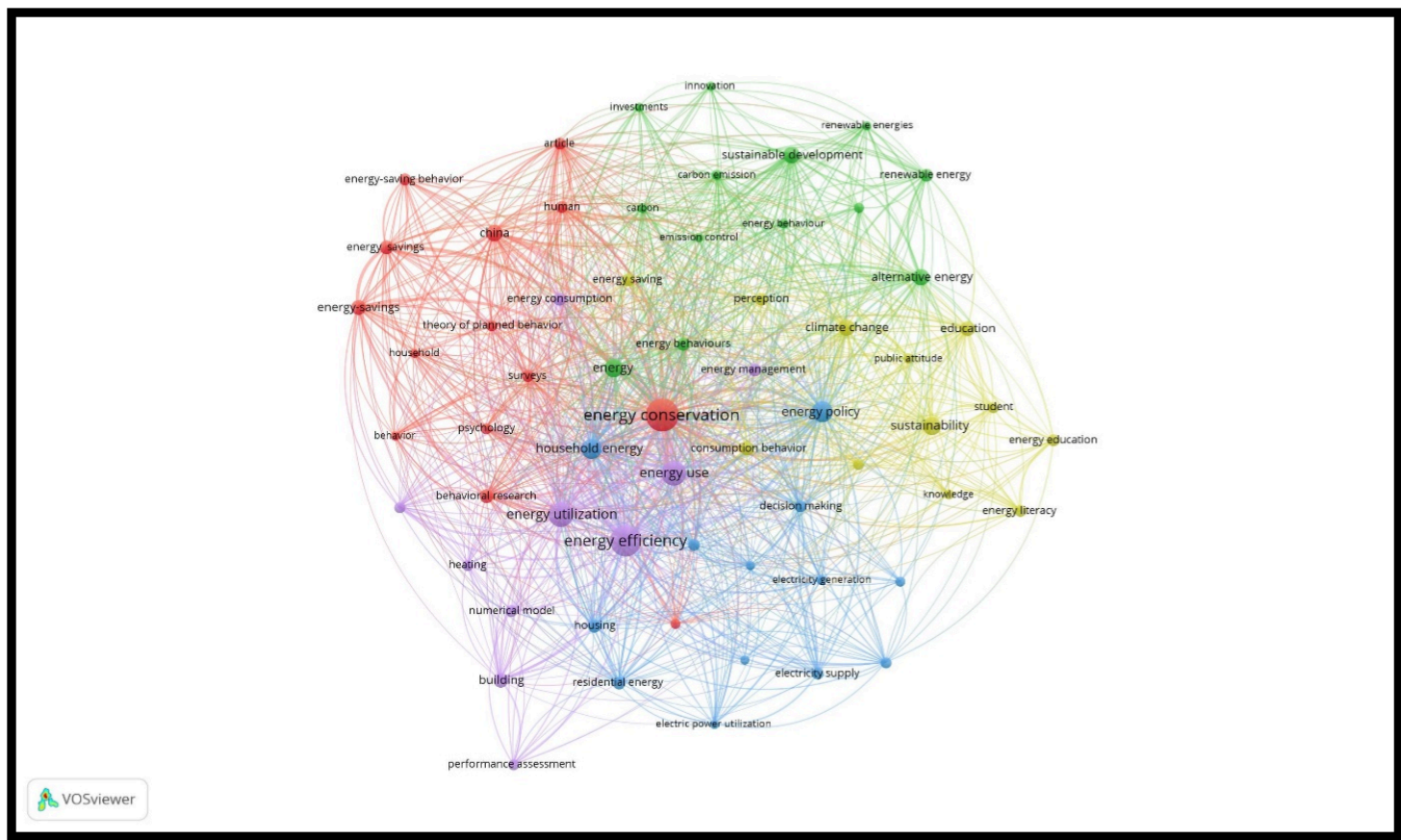


Figure 3

Network visualization of co-word analysis

Source: Vosviewer